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Pre-compound and Evaporation Model Code System for Calculation of Excitation Functions, Energy and Angular Distributions of Emitted Particles in Nuclear Reactions at Intermediate Energies

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ALICE/ASH – Pre-Compound und Verdampfungsmodell Code System zur Berechnung von Anregungsfunktionen und Energie- und Winkelverteilungen emittierter Teilchen aus Kernreaktionen bei mittleren Energien

Zusammenfassung

Der ALICE/ASH Code ist eine weiterentwickelte und modifizierte Version des ALICE Codes. Die Modifikationen betreffen die Implementierung von Modellen, die die Emission zusammengesetzter Teilchen aus dem Pre-Compound Zustand beschreiben, sowie die Emission schneller γ-Quanten. Außerdem wurden verschiedene Näherungen zur Berechnung der Kernniveau Dichte implementiert und das Modell zur Berechnung der Spaltprodukt Produktion.

Der ALICE/ASH Code kann angewendet werden für die Berechnung von Anregungsfunktionen und Energie- und Winkelverteilungen von Sekundärteilchen, die bei Kernreaktionen mit Nukleonen und Kernen mit einer Energie bis zu 300MeV entstehen.

Abstract

The ALICE/ASH code is an advanced and modified version of the ALICE code. The modifications concern the implementation in the code of models describing the pre-compound composite particle emission, fast γ-emission, different approaches for the nuclear level density calculation and the model for the fission fragment yield calculation.

The ALICE/ASH code can be applied for the calculation of excitation functions, energy and angular distribution of secondary particles in nuclear reactions induced by nucleons and nuclei with the energy up to 300 MeV.

CONTENTS

The ALICE/ASH code has been written to study the interaction of intermediate energy nucleons and nuclei with target nuclei.

The code calculates energy and angular distributions of particles emitted in nuclear reactions, residual nuclear yields, and total nonelastic cross-sections for nuclear reactions induced by particles and nuclei with energies up to 300 MeV.

1. Brief history of the code modifications starting from ALICE 87

The code ALICE was originated by Blann [1-3].

We have added additional physics, capabilities and corrections as follows:

(a) algorithms for the calculation of equilibrium γ-ray emission spectra and pre-compound γ-emission spectra using a phenomenological approach [4];

(b) the Kataria- Ramamurthy model for calculation of nuclear level densities [5];

(c) the superfluid nuclear model [6] has been made an option for level density calculation [5] using a subroutine by A.V.Ignatyuk;

(d) the exciton coalescence pick-up model and the knock-out model for the calculation of non-equilibrium α-particle emission spectra [7,8] (the parameters of models were obtained from the analysis of the experimental data for nucleon induced reactions below 200 MeV);

(e) algorithms for calculating pre-compound triton and ^{3}He emission spectra using the coalescence pick-up model [9,10];

(f) multiple non-equilibrium α-particle emission [10];

(g) several refinements and corrections to the algorithms of the code [11];

(h) a phenomenological model for the calculation of non-equilibrium deuteron emission spectra to estimate direct processes [12], (the main idea of the approach is to consider the nucleon pick-up from exciton states (1p,0h), (2p,1h) etc for n+2 states);

(i) an algorithm for the calculation of level densities in the Fermi gas model with an energy dependent level density parameter [13,14];

(j) corrections have been made to the GDH model for treatment of effects in peripheral nuclear regions [14];

(k) a model for the description of pre-compound γ-emission taking into account single particle radiative transitions according to Oblozinsky [51] and quasi-deuteron mechanism γ- production according to Ref.[15];

(l) parameters of a model for non-equilibrium α-particle emission have been specified to get agreement with experimental α-emission spectra at projectile energies up to 200 MeV [16];

and

(m) a new model for non-equilibrium deuteron emission has been developed [17], (problems of an earlier model [12] related to the deuteron formation mechanism and effective potential depth have been overcome).

Special versions of the code have been developed to treat the calculation of non-equilibrium emission spectra of light and heavy clusters [18] and fission product yields (A, Z distributions) [19].

The description of earlier modifications of the code are given in Refs.[11,14,20]. ALICE/ASH was mentioned as a distinct code for the first time in Ref.[21] .

2. Description of models implemented in the code

2.1 Pre-compound nucleon emission

The hybrid model [22] and the geometry dependent hybrid model (GDH) [23,24] can be used for the calculation of particle spectra. In the GDH model the pre-equilibrium spectrum of nucleons is calculated as follows:

$$\frac{d\sigma}{d\varepsilon_x} = \pi \mathbf{D}^2 \sum_{l=0}^{\infty} (2l+1) T_l \sum_{n=n_0}^{} {}_nX_x \frac{\omega(p-1,h,U)}{\omega(p,h,E)} \frac{\lambda_x^e}{\lambda_x^e + \lambda_x^+} g D_n, \quad (1)$$

where $\mathbf{D}$ is the reduced de Broglie wavelength of the incident particle; T_l is the transmission coefficient for *l*-th partial wave; ${}_nX_x$ is the number of nucleons of type "x" in the n-exciton state; ε_x is the channel energy of the nucleon; $\omega(p,h,E)$ is the density of exciton states with "p" particles and "h" holes (p+h=n) at the excitation energy E; U is the final excitation energy, $U=E-Q_x-\varepsilon_x$ and Q_x is the nucleon separation energy; D_n is the factor calculated according to Ref.[5], which takes into account the "depletion" of the n-exciton state due to the nucleon emission; n_0 is the initial exciton number.

The nucleon emission rate λ_x^e is calculated

$$\lambda_x^e = \frac{(2S_x+1)\mu_x \varepsilon_x \sigma_x^{inv}(\varepsilon_x)}{\pi^2 \mathbf{h}^3 g_x}, \quad (2)$$

where S_x and μ_x are the spin and reduced mass of the outgoing nucleon of type "x", σ_x^{inv} is the inverse reaction cross-section for particle "x", and the single particle density g_x is equal to Z/14 for protons and N/14 for neutrons.

The intranuclear transition rate λ_x^+ is defined as follows

$$\lambda_x^+ = V \sigma_0(\varepsilon_x) \rho_l, \quad (3)$$

where V is the velocity of a nucleon inside the nucleus, σ_0 is the nucleon-nucleon scattering cross-section corrected for the Pauli principle [24], ρ_l is the average nuclear matter density at the distance from $l\mathbf{D}$ to $(l+1)\mathbf{D}$.

The exciton state density is calculated according to the Strutinsky-Ericson formula [25,26]

$$\omega(p,h,E) = \frac{g(gE)^{n-1}}{p!h!(n-1)!} \quad (4)$$

For nucleon induced reactions the density of excited states with the number of excitons n=2 and 3 is calculated considering the finite depth of the nuclear potential well [27]

$$\omega(1,1,E) = \frac{g(gE_F)}{2}, \quad \text{if } E > E_F \tag{5}$$

$$\omega(1,1,E) = \frac{g(gE)}{2}, \quad \text{if } E \le E_F \tag{6}$$

$$\omega(2,1,E) = \frac{g^3[V(2E - E_F)]}{4}, \quad \text{if } E > E_F \tag{7}$$

$$\omega(2,1,E) = \frac{g^3 E^2}{4}, \quad \text{if } E \le E_F \tag{8}$$

where E_F is the Fermi energy, and the finite potential depth is equal to V + Q, and Q is the nucleon binding energy.

The number of nucleons of x-type in the n-exciton state ${}_nX_x$ for incident neutrons is calculated as

$${}_3X_n = 2\ \frac{(\sigma_{np}/\sigma_{nn})Z + 2N}{2(\sigma_{np}/\sigma_{nn})Z + 2N}, \tag{9}$$

$${}_3X_p = 2 - {}_3X_n, \tag{10}$$

and for incident proton

$${}_3X_p = 2\ \frac{(\sigma_{pn}/\sigma_{pp})N + 2\ Z}{2(\sigma_{pn}/\sigma_{pp})N + 2\ Z}, \tag{11}$$

$${}_3X_n = 2 - {}_3X_p, \tag{12}$$

where σ_{xy} is the nucleon - nucleon interaction cross-section in the nucleus.

The ratio of the nucleon-nucleon cross-sections calculated taking into account the Pauli principle and the nucleon motion is parameterized in the present work as

$$\sigma_{pn}/\sigma_{pp} = \sigma_{np}/\sigma_{nn} = 1.375\times10^{-5}\ T^2 - 8.734\times10^{-3}\ T + 2.776, \tag{13}$$

where T is the kinetic energy of the projectile outside the nucleus.

Multiple pre-compound emission is described by an approximation [24] in which only up to two precompound particles may be emitted. This approximation becomes increasingly poor as excitations exceed a few tens of MeV. The shortcoming was corrected in the Monte Carlo precompound decay model, in the code HMS ALICE [27]. Tables illustrating predictions of the newer formulation, the first precompound code to follow two body reactions through the cascade, and the two precompound limit of the hybrid/GDH model are presented in tables in Ref.[27].

A correction has been made for the high energy tails of (p,xn) and (n,xp) reaction spectra calculated by the GDH model [28]. Calculations with the original GDH model [24] overestimate nucleon spectra for (n,p) and (p,n) reactions (Fig.1), due to an overestimation of the contribution to nucleon spectra for partial cross-sections with *l* numbers corresponding to nuclear regions with low density. This resulted from a miss-match between the radii/densities in the original Fermi density distribution used to calculate nuclear densities, and the parameters of the nuclear optical model used to provide the partial reaction cross sections. An improvement for this problem had been made in ALICE by substituting the nuclear droplet model radius/density for the Fermi distribution. Also, one should note that for nuclear regions with low density the Thomas-Fermi approximation is inappropriate [29] and the definition of the potential and the Fermi energy according to the GDH model through relations: $E_F = (3\pi^2\rho_l)^{2/3}/(2m)$ and $U = -E_F - Q$, where ρ_l is nuclear density depending upon *l*, is incorrect. In this case a better definition of the E_F value corresponding to each partial *l*-wave is: $E_F = - U^{opt} - Q$, where U^{opt} is the real part of the optical model potential [29]. We introduced the limitation on the contribution of partial cross-sections with *l* numbers corresponding to unphysical E_F values, $E_F = - U^{opt} - Q < 0$ to the particle spectrum, which considerably improves the agreement between calculated emission spectra and experimental data. Examples are given in Fig.1 and Table 1.

Fig.1 shows excitation functions and nucleon spectra calculated by the GDH model, the hybrid model and the corrected GDH model. Table 1 contains the $\Sigma((\sigma^{calc}_i$-

$\sigma^{exp}_i)/\Delta\sigma^{exp}_i)^2$ values characterizing the deviation between calculated and experimental (n,p) reaction cross-sections at 14.5 MeV [30]. The calculations have been performed for 78 nuclei with $50 \le Z \le 83$ using the GDH model, the hybrid model and the corrected GDH model. It is seen that the best result corresponds to the corrected GDH model described above.

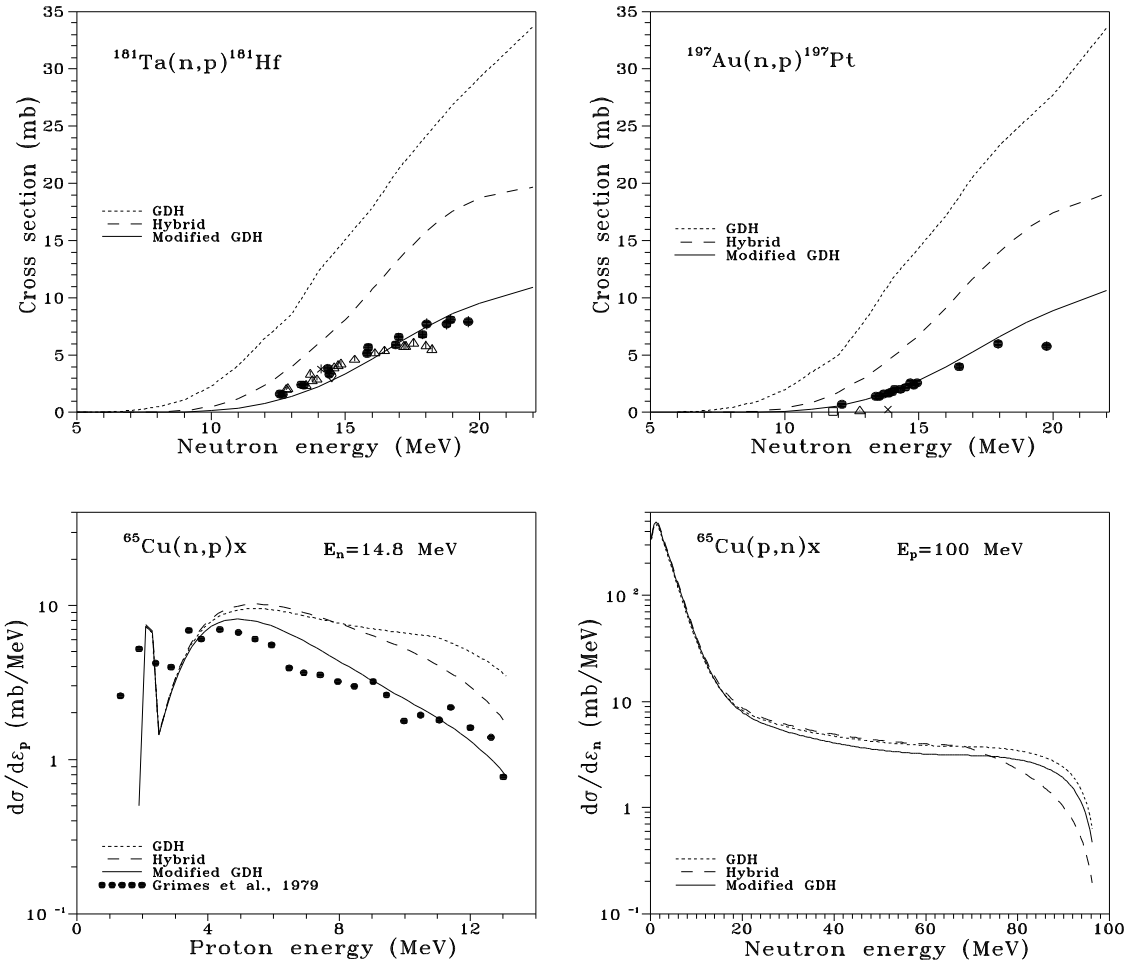

Fig.1 Upper figures: the (n,p) reaction cross-sections calculated using various pre-compound models. Lower figures: nucleon emission spectra predicted by GDH, the hybrid and corrected GDH models. The calculations using the hybrid model are performed with nucleon mean free path multiplied by two. Experimental data are taken from EXFOR.

Table 1

The $\Sigma((\sigma^{calc}_i-\sigma^{exp}_i)/\Delta\sigma^{exp}_i)^2$ value calculated for (n,p) reaction cross-sections at 14.5 MeV for 78 nuclei with Z ≥ 50. The calculation of σ^{calc}_i is performed using different pre-compound models and types of pairing corrections in the exciton level density. The"standard" and "back" shift for the excitation energy correspond to MP=1 and MP=3 ALICE code options (see Sect.2.7.3).

Type of pairing correction	GDH model	Hybrid model	Modified GDH model
"Standard" shift	22570.	530.	720.
"Back" shift	33380.	6060.	490.

2.2 Pre-compound α-particle emission

The pre-equilibrium α-particle emission spectrum for nucleon induced reaction is calculated as a sum of components corresponding to the mechanism of pick-up and knock-out

$$\frac{d\sigma}{d\varepsilon_\alpha} = \frac{d\sigma^{pick-up}}{d\varepsilon_\alpha} + \frac{d\sigma^{knock-out}}{d\varepsilon_\alpha} \qquad (14)$$

The contribution of the pick-up mechanism is calculated with the help of the coalescence pick-up model [7,9] combined with the hybrid exciton model [8]

$$\frac{d\sigma^{pick-up}}{d\varepsilon_\alpha} = \sigma_{non}(E_p) \sum_{n=n_0} \sum_{k+m=4} F_{k,m}(\varepsilon_\alpha) \frac{\omega(p-k,h,U)}{\omega(p,h,E)} \frac{\lambda^e_\alpha(\varepsilon_\alpha)}{\lambda^e_\alpha(\varepsilon_\alpha)+\lambda^+_x(\varepsilon_\alpha)} g_\alpha D_n, \qquad (15)$$

where σ_{non} is the nonelastic interaction cross-section of the primary particle with a nucleus at kinetic energy E_p, $F_{k,m}(\varepsilon_\alpha)$ is the α-formation factor [7] equal to the probability that the α-particle is composed of "k" particles above Fermi level and "m" particles below, the residual excitation energy U is equal to $E - Q_\alpha - \varepsilon_\alpha$; λ^e_α is the emission rate of the α-particle; λ^+_α is the intranuclear transition rate corresponding to the absorption of the α-particle in a nucleus; g_α is the intranuclear density of single particle states for the α-particle. The emission rate of α-particles is calculated as

$$\lambda^e_\alpha = \frac{(2S_\alpha+1)\mu_\alpha \varepsilon_\alpha \sigma^{inv}_\alpha(\varepsilon_\alpha)}{\pi^2 \mathbf{h}^3 g_\alpha}, \qquad (16)$$

where S_α and μ_α are the spin and reduced mass of the outgoing α-particle, and the inverse reaction cross-section for α-particles, $\sigma^{inv}_\alpha(\varepsilon_\alpha)$ is calculated by the optical model with the parameters described in Ref. [5]. The absorption rate of α-particles is defined as follows

$$\lambda^+_\alpha = 2W^{opt}_\alpha / \mathbf{h}, \qquad (17)$$

where W^{opt}_α is the imaginary part of the optical potential for α-particles.

The knock-out contribution to the α-particle spectrum [10] is calculated as

$$\frac{d\sigma^{knock-out}}{d\varepsilon_\alpha} = \sigma_{non}(E_p) \sum_{n=n_0} \varphi_\alpha \frac{g}{g_\alpha p} \frac{\omega(p-1,h,U)}{\omega(p,h,E)} \frac{\lambda^e_\alpha(\varepsilon_\alpha)}{\lambda^e_\alpha(\varepsilon_\alpha)+\lambda^+_x(\varepsilon_\alpha)} g_\alpha D_n, \qquad (18)$$

where the factor $g/(g_\alpha p)$ justifies the substitution of the level density $\omega(\pi,\tilde{\pi},\nu,\tilde{\nu},\alpha,\tilde{\alpha},E)$ for the three-component system (neutron, proton, α-particle) [31,10] by the one-component state density $\omega(p,h,E)$ in Eq.(18), and φ_α is the

probability of interaction of the incident particle with a "pre-formed" α-cluster resulting in its excitation in the nucleus [31].

Pre-compound α-emission after the pre-compound escape of neutrons and protons (multiple pre-equilibrium emission) is taken into account [10]. The formula for the calculation of the pre-compound emission spectrum of α-particles formed due to the nucleon pick-up process escaping after pre-equilibrium nucleon emission is written as follows

$$\frac{d\sigma_2}{d\varepsilon_\alpha} = \pi \lambda^2 \sum_{l=0}^{\infty} (2l+1) T_l \sum_{x=\pi,\nu}^{2} \int_{E_x^{min}}^{E_x^{max}} \sum_{n=n_0} {}_n X_x \frac{\omega(p-1,h,E-Q_x-\varepsilon_x)}{\omega(p,h,E)} \frac{\lambda_x^e(\varepsilon_x)}{\lambda_x^e(\varepsilon_x)+\lambda_x^+(\varepsilon_x)} g D_n$$

$$\times \sum_{n'=p+h-1} \sum_{k+m=4} F_{k,m}(\varepsilon_\alpha) \frac{\omega(p'-k,h',E-Q_x-\varepsilon_x-Q'_\alpha-\varepsilon_\alpha)}{\omega(p',h',E-Q_x-\varepsilon_x)} \frac{\lambda_\alpha^e(\varepsilon_\alpha)}{\lambda_\alpha^e(\varepsilon_\alpha)+\lambda_x^+(\varepsilon_\alpha)} g_\alpha D_{2n'} d\varepsilon_x \quad (19)$$

where "x" refers to proton and neutron, Q'_α is the separation energy for an α-particle in the nucleus formed after the emission of nucleon of x-type, and E_x^{min} and E_x^{max} define the energy range, where the emission of the x-particle occurs.

An analogous formula is written for the α-particle knock-out process following fast nucleon emission [10]. Successive emission of three and more pre-equilibrium particles is not considered.

The following parameters of the models are used for calculations: $\sum_{k+m=4} F_{k,m} = 0.3$ and $\varphi_\alpha = 0.012$. The imaginary part of the optical potential for α-particles is calculated as follows: $W_\alpha^{opt} = (\varepsilon_\alpha/\varepsilon_0)W'$ at $\varepsilon_\alpha \le \varepsilon_0$, $W_\alpha^{opt} = W'$ at $\varepsilon_0 < \varepsilon_\alpha < 72$ MeV, and $W_\alpha^{opt} = W' \cdot \exp(0.06\varepsilon_\alpha - 4.32)$ at $\varepsilon_\alpha \ge 72$ MeV, where $W' = \beta W_0$ and $\varepsilon_0 = 0.228A$, $\beta = 0.25$. The value of W_0 is taken from Refs.[32,33] $W_0 = 10 + 0.345(A-2Z)$ MeV. The values of the parameters listed above are from Refs.[14,20] except for the W_α^{opt} value calculation at energies ε_α above 72 MeV. The value adopted for the state density for α-particles, g_α is equal to A/13 (see discussion in Ref. [20]).

For many cases, inclusion of these models for pre-equilibrium complex particle emission results in noticeably improved agreement of calculated and experimental data (Fig.2).

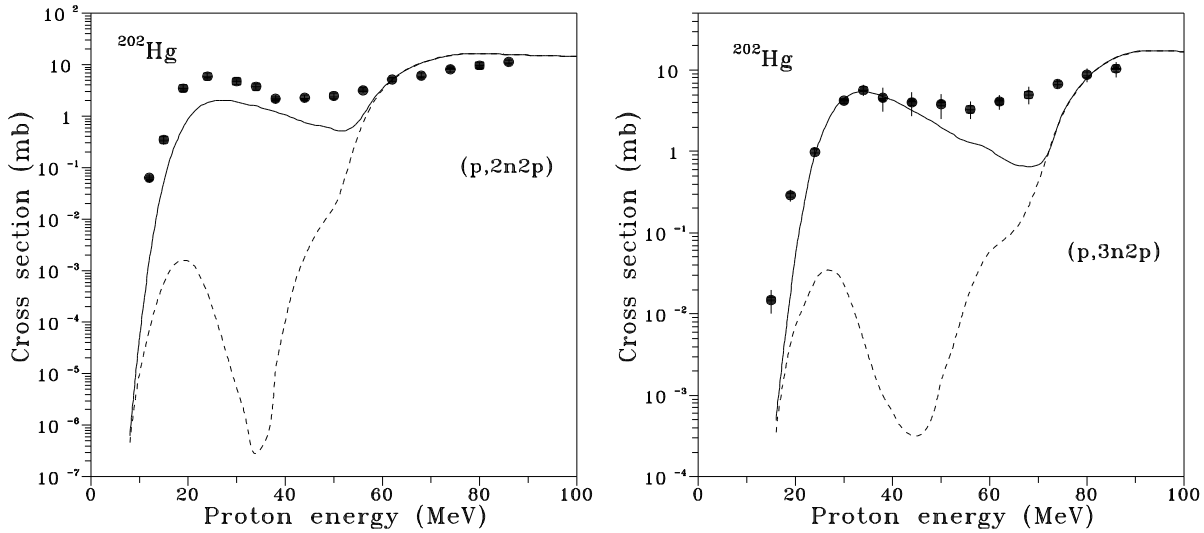

Fig.2 Excitation functions of (p,2n2p) and (p,3n2p) reactions for ^{202}Hg calculated with inclusion of pre-equilibrium α-emission (solid line) and without pre-compound α-emission (dashed line). The experimental data are from Ref.[34].

Figs.3,4 show the contribution of different processes in calculated α-particle emission spectra for ^{27}Al(p,α)x and ^{209}Bi(p,α)x reactions induced by 90 MeV protons.

Fig.5 shows examples of α-particle spectra calculated using the ALICE/ASH code at different projectile energies.

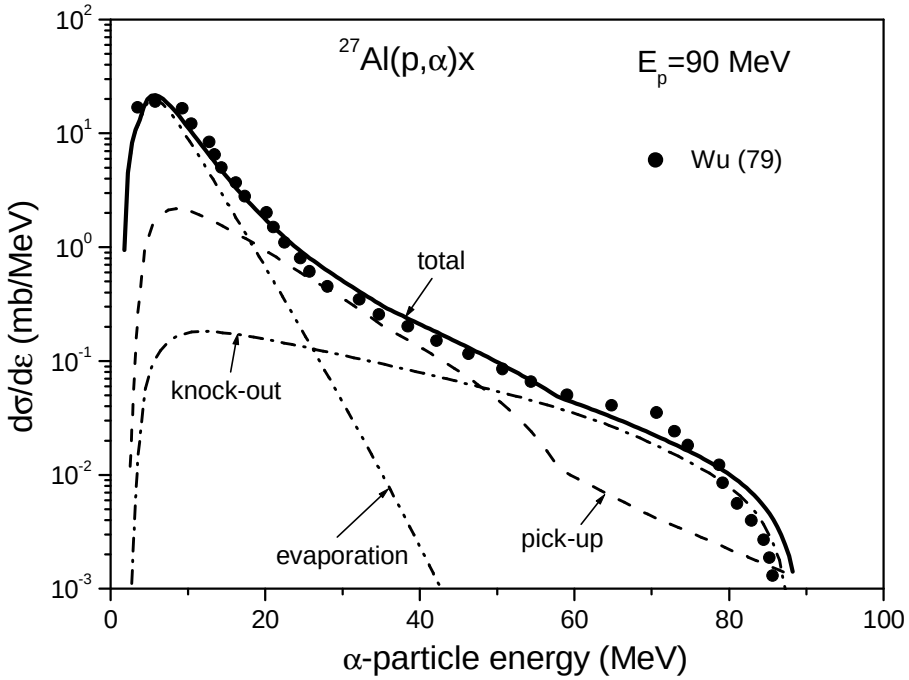

Fig.3 Calculated contributions of different processes in α-particle emission for the ^{27}Al(p,α)x reaction induced by 90 MeV protons. Experimental data are from Ref.[35].

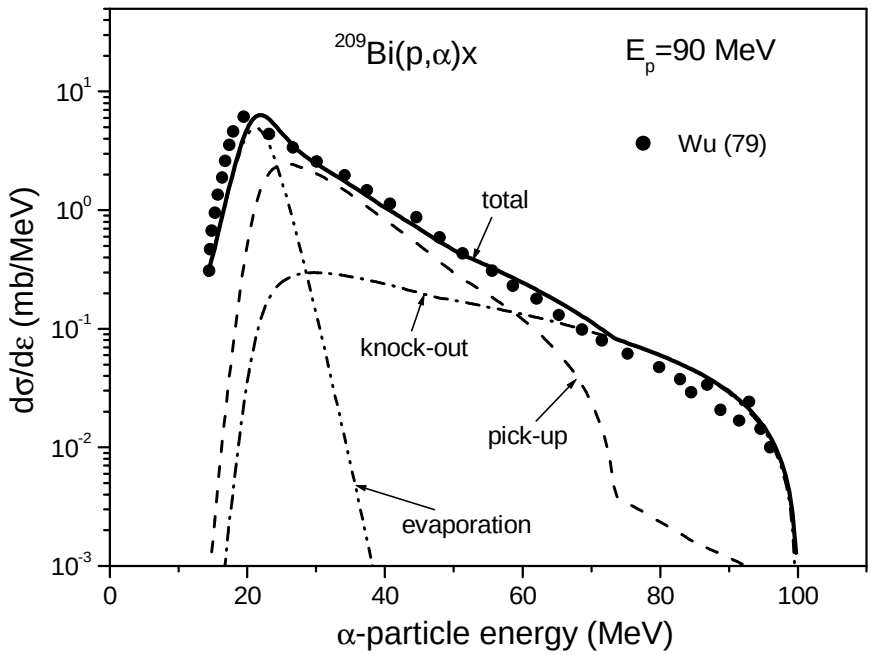

Fig.4 Calculated contributions of different processes in α-particle emission for the ^{209}Bi(p,α)x reaction induced by 90 MeV protons. Experimental data are from Ref.[35].

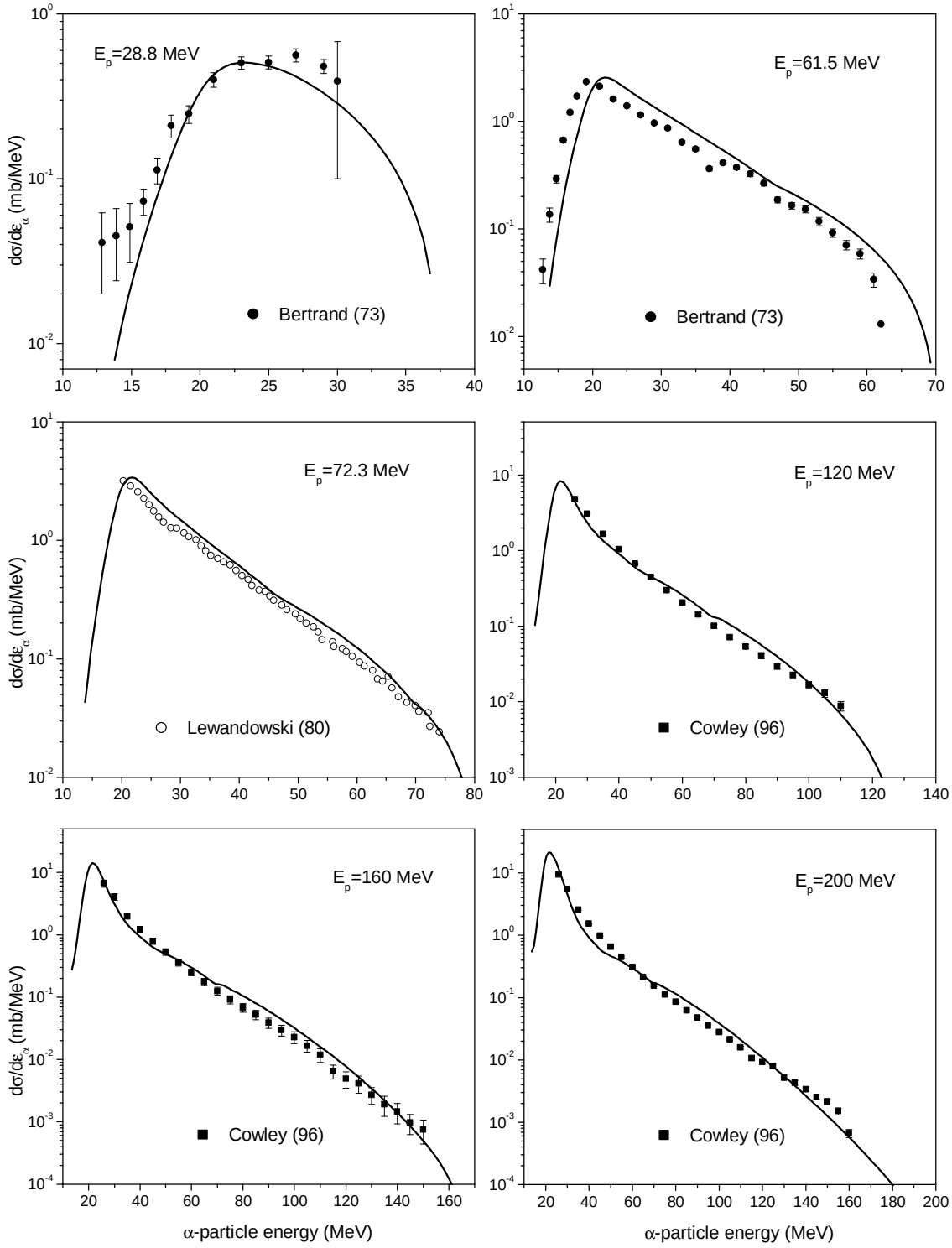

Fig.5 The α-particle emission spectra calculated for the p+^{197}Au reaction at primary proton energies from 28.8 to 200 MeV. The level density parameter for equilibrium states is A/13. The experimental data are from Refs.[36-38].

2.3 Pre-compound deuteron emission

It is expected that non-equilibrium deuteron emission in nucleon induced reactions results from: i) the pick-up of nucleons with energy below the Fermi energy after the formation of the (2p,1h) initial exciton state, ii) coalescence of two excited nucleons with energies above E_F, iii) knock-out of a "pre-formed" deuteron, and iv) a direct process resulting in deuteron formation and escape. The non-equilibrium deuteron spectrum is calculated as a sum of different components

$$\frac{d\sigma}{d\varepsilon_d} = \frac{d\sigma^{P-U,C}}{d\varepsilon_d} + \frac{d\sigma^{K-O}}{d\varepsilon_d} + \frac{d\sigma^{D}}{d\varepsilon_d} \quad , \tag{20}$$

where the first term relates to pick-up and coalescence after the formation of the (2p,1h) exciton state, the second component describes the contribution of the deuteron knock-out and the last term relates to the direct process.

The analytical expressions for each component of the deuteron emission spectrum were obtained in Ref.[17] using basic statements of the hybrid model [22].

The exciton level density is calculated following Běták, Dobeš [39] taking into account the finite depth of the nuclear potential well

$$\omega(p,h,E) = g^p \tilde{g}^h \sum_{k=0}^{h} {}_hC_k (-1)^k \ \Theta(E - k E_F) \frac{(E - k E_F)^{n-1}}{p!h!(n-1)!} \tag{21}$$

where E is the excitation energy, E_F is the Fermi energy, g and $\tilde{g}$ are the single particle level densities for particles and holes, respectively, $\Theta(x)$ is the Heaviside function, $\Theta = 0$ for $x < 0$ and $\Theta = 1$ for $x > 0$.

The single particle level densities for particles and holes are calculated according to Ref.[39]

$$g = A/14, \tag{22}$$

$$\tilde{g} = A / E_F \tag{23}$$

One should note that nuclear surface effects [40,41] influence the effective value of the Fermi energy E_F used for the calculation of pre-compound particle spectra. This point is discussed below.

The exciton coalescence pick-up model proposed in Ref.[9] is used for the calculation of the $d\sigma^{P\text{-}U,C}/d\varepsilon_d$ spectrum component [12]

$$\frac{d\sigma^{P-U,C}}{d\varepsilon_d} = \sigma_{non}(E_0) \sum_{n=n_0} \sum_{k+m=2} F_{k,m}(\varepsilon_d + Q_d) \frac{\omega(p-k,h,U)}{\omega(p,h,E)} \frac{\lambda_d^e(\varepsilon_d)}{\lambda_d^e(\varepsilon_d)+\lambda_d^+(\varepsilon_d)} g_d D_n, \quad (24)$$

where $F_{k,m}$ is the deuteron formation factor equal to the probability that the deuteron is composed of "k" particles above the Fermi level and "m" particles below; ε_d is the channel emission energy corresponding to the deuteron emission; λ_d^e is the deuteron emission rate; λ_d^+ is the intranuclear transition rate for the absorption of the deuteron in the nucleus; g_d is the density of single particle states for the deuteron.

The deuteron emission (λ_d^e) and absorption (λ_d^+) rates are calculated by formulas similar to Eqs.(16) and (17).

The form factors for deuteron formation, $F_{k,m}$ were calculated in Ref.[9] for the effective nuclear radius with a dR parameter value equal to 1 fm. The original values [9] are approximated and used in the code as follows

$$F_{1,1}(\varepsilon) = \begin{cases} -1.409\cdot10^{-2}\varepsilon + 0.6 & \text{for } \varepsilon \le 30\,\text{MeV} \\ 1.377\cdot10^{-4}\varepsilon^2 - 1.807\cdot10^{-2}\varepsilon + 0.5946 & \text{for } 30 < \varepsilon \le 65\,\text{MeV} \\ 0 & \text{for } \varepsilon > 65\,\text{MeV} \end{cases}, \quad (25)$$

$$F_{2,0}(\varepsilon) = 0.6 - F_{1,1}(\varepsilon) \quad (26)$$

As an illustration, Fig.6 shows the pick-up and coalescence contributions in the deuteron emission spectra for ^{54}Fe and ^{197}Au irradiated with 61.5 MeV protons.

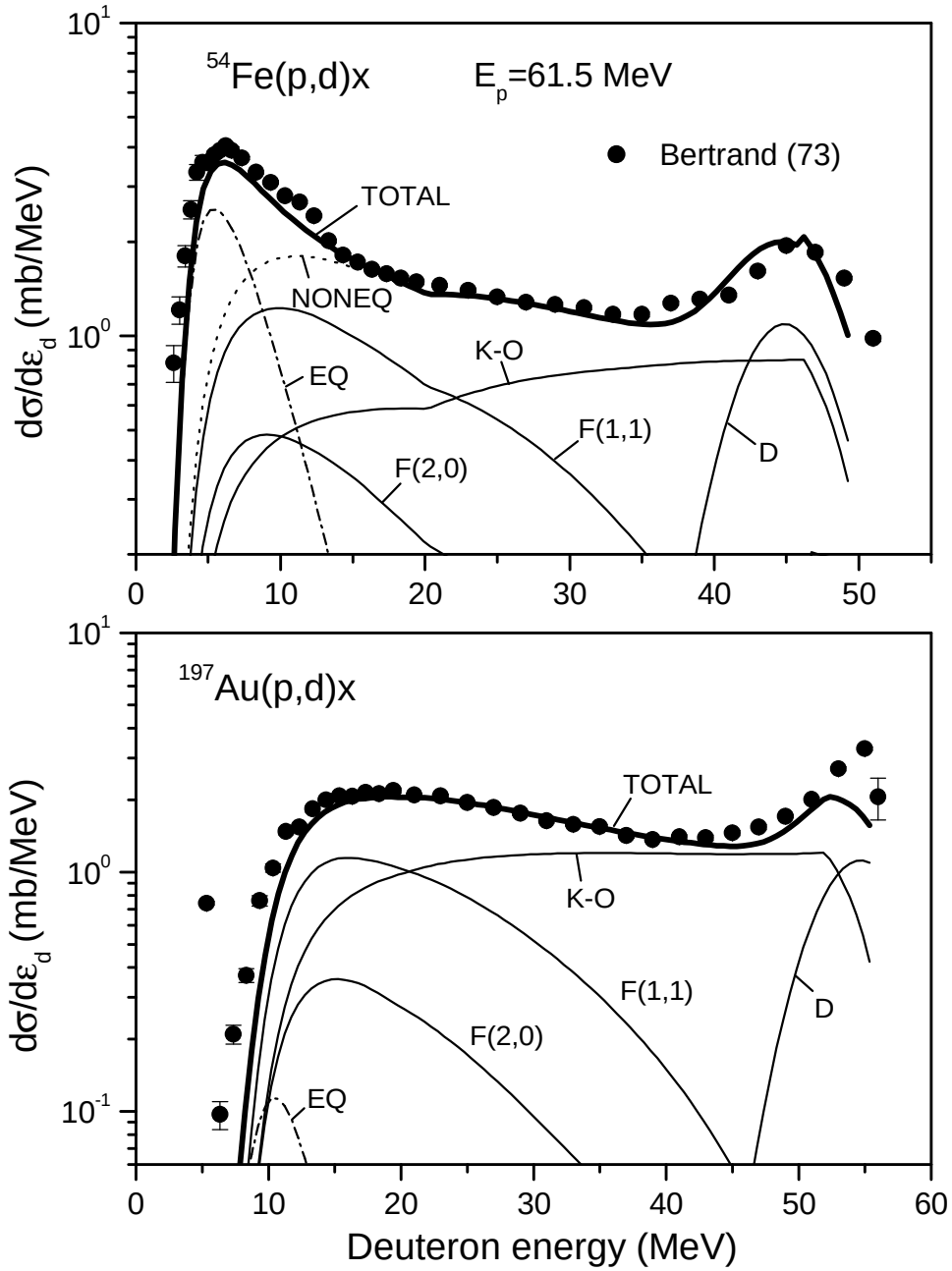

Fig.6 The contribution of different nuclear processes in deuteron emission in reactions p+^{54}Fe and p+^{197}Au induced by 61.5 MeV protons: equilibrium emission (EQ), pick-up of a nucleon from exciton states starting from (2p,1h) (F(1,1)), the coalescence of two excited nucleons (F(2,0)), and direct pick-up (D). The sum of all non-equilibrium components (NONEQ) and the total spectrum (TOTAL) are shown. The non-equilibrium deuteron spectrum for the p+^{197}Au reaction almost coincides with the total spectrum. Experimental data (black circles) are taken from Ref.[36]. The deuteron energy is shown in the laboratory coordinate system as in other figures.

In analogy with α-particle emission, (Eq.(18)) the knock-out component of the pre-compound deuteron emission spectrum is written as follows

$$\frac{d\sigma^{K-O}}{d\varepsilon_d}=\sigma_{non}(E_0)\sum_{n=n_0}\Phi_d(E_0)\ \frac{g}{g_d\,p}\ \frac{\omega(p-1,h,U)}{\omega(p,h,E)}\ \frac{\lambda_d^e(\varepsilon_d)}{\lambda_d^e(\varepsilon_d)+\lambda_d^+(\varepsilon_d)}\ g_d\ D(n), \qquad (27)$$

where the factor Φ_d describes the initial number of excited deuteron clusters in the nucleus

$$\Phi_d = 2\ F_d(E_0), \qquad (28)$$

where F_d is the probability of interaction of the incident particle with the "pre-formed" deuteron resulting in its excitation in the nucleus; and the factor of two reflects the normalization on the number of particles in the initial exciton state n_0.

The general expression for F_d [17] is

$$F_d = \frac{\varphi\sigma_{xd}(E_0)}{\frac{Z'}{A'}\sigma_{xp}(E_0)+\frac{(A'-Z')}{A'}\sigma_{xn}(E_0)+\varphi\sigma_{xd}(E_0)}, \qquad (29)$$

where "x" refers to the initial proton or neutron, σ_{xd}, σ_{xp} and σ_{xn} are the cross-sections of the elastic interaction of projectile with deuteron, proton and neutron, respectively, corrected for a Pauli principle, φ is the number of "pre-formed" deuterons in the nucleus, Z' and A' are the number of protons and nucleons in the nucleus corrected for a number of clustered deuterons.

Assuming that the number of pre-formed deuterons φ has a rather small value and Z'≈A'/2 one can make the approximation

$$F_d \cong \frac{2\ \varphi\sigma_{xd}}{\sigma_{xp}+\sigma_{xn}}. \qquad (30)$$

For the evaluation of the cross-section ratio in Eq.(30) the cross-section of the free elastic nucleon-deuteron scattering was taken from ENDF/B-VI at the energy up to 150 MeV and evaluated above 150 MeV using data from EXFOR. The free nucleon-nucleon interaction cross-sections were obtained from Ref.[42]. The σ_{xd}, σ_{xp}

and σ_{xn} cross-sections were calculated taking into account the limitation superimposed by the Pauli principle on the number of intranuclear interactions. It was assumed that the angular distribution of interacting particles is approximately isotropic in the center-of-mass system. The Fermi energy for deuterons was taken equal to $2E_F$.

Fig.7 shows the ratio of the cross-sections $\sigma_{xd}/(\sigma_{xp} + \sigma_{xn})$ at different kinetic energy of the incident nucleon calculated for a nuclear potential well with a Fermi energy equal to 32 MeV. The ratios for the free nucleon-deuteron and free nucleon-nucleon scattering cross-sections are also shown.

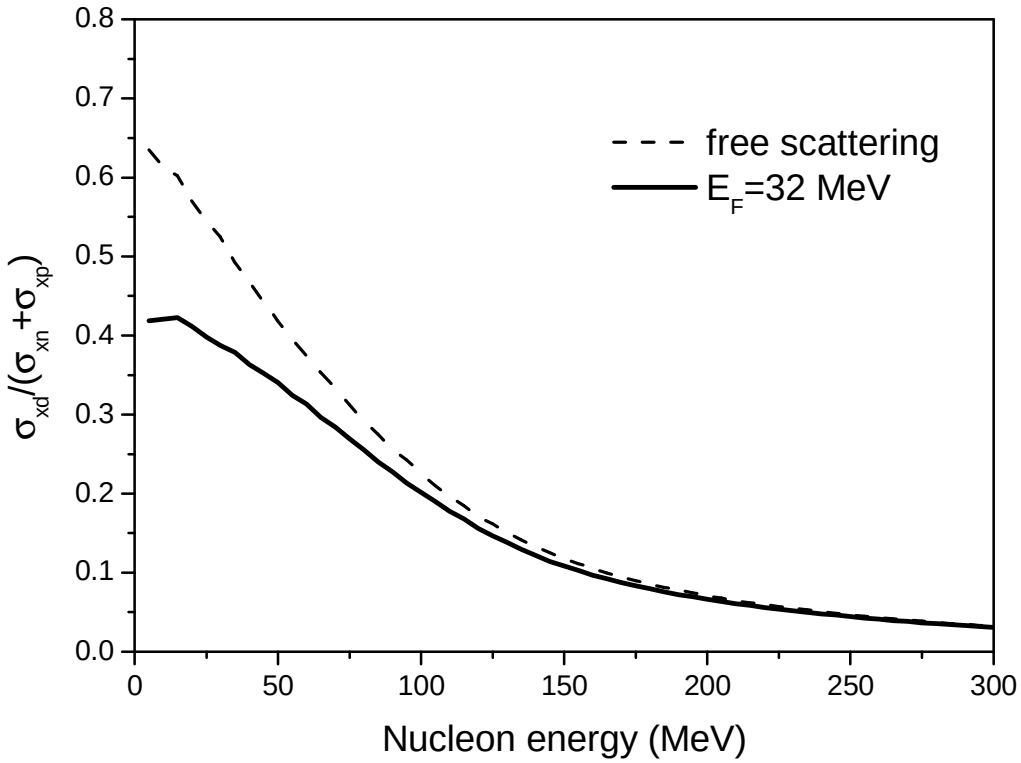

Fig.7 The ratio of the elastic nucleon-deuteron scattering cross-section to the sum of the elastic nucleon-nucleon cross-sections $\sigma_{xd}/(\sigma_{xp} + \sigma_{xn})$ calculated for a nuclear potential well with a Fermi energy of 32 MeV (solid line) and for free scattering (dashed line). The incident nucleon kinetic energy is referenced outside the nucleus, i.e. in the laboratory (abscissa).

The value obtained for $\sigma_{xd}/(\sigma_{xp}+\sigma_{xn})$ for the nuclear potential well (Fig.7) was approximated as follows

$$\frac{\sigma_{xd}}{\sigma_{xp}+\sigma_{xn}} = 0.512\,\exp(-9.81\cdot10^{-3}\,E_p)\,, \qquad (31)$$

where E_p is the kinetic energy of the projectile outside the nucleus in MeV.

Fig.6 shows the calculated contribution of the deuteron knock-out in the deuteron emission spectra for ^{54}Fe and ^{197}Au irradiated with 61.5 MeV protons. Parameters used for the calculation are discussed below.

Calculation of multiple pre-equilibrium deuteron emission spectra is described below. The pick-up and coalescence contributions for the spectrum of deuterons escaping after the pre-equilibrium emission of nucleons is calculated by the expression

$$\frac{d\sigma_2^{P-U,C}}{d\varepsilon_d} = \pi D^2 \sum_{l=0}^{\infty}(2l+1)\,T_l \sum_{x=\pi,\nu}^{2} \int_{E_x^{min}}^{E_x^{max}} \sum_{n=n_0} {}_n X_x \,\frac{\omega(p-1,h,E-Q_x-\varepsilon_x)}{\omega(p,h,E)}\,\frac{\lambda_x^e(\varepsilon_x)}{\lambda_x^e(\varepsilon_x)+\lambda_x^+(\varepsilon_x)}\; g\; D_n$$

$$\times \sum_{n'=p+h-1} \sum_{k+m=2} F_{k,m}(\varepsilon_d+Q_d')\,\frac{\omega(p'-k,h',E-Q_x-\varepsilon_x-Q'_d-\varepsilon_d)}{\omega(p',h',E-Q_x-\varepsilon_x)}\,\frac{\lambda_d^e(\varepsilon_d)}{\lambda_d^e(\varepsilon_d)+\lambda_d^+(\varepsilon_d)}\; g_d\; D_{2n'}\; d\varepsilon_x \qquad (32)$$

where Q_x is the separation energy of a nucleon in the composite nucleus, Q'_d is the separation energy for a deuteron in the nucleus formed after the emission of nucleon of x-type, E_x^{min} and E_x^{max} define the energy range where the emission of the x-particle occurs, and D_2 is the depletion factor relevant to escape of particles from an n'-exciton state.

An analogous formula is written for deuteron knock-out following fast nucleon emission. The successive emission of three or more pre-equilibrium particles is not considered.

Fig.8 shows the influence of multiple pre-equilibrium emission on the calculated deuteron spectrum.

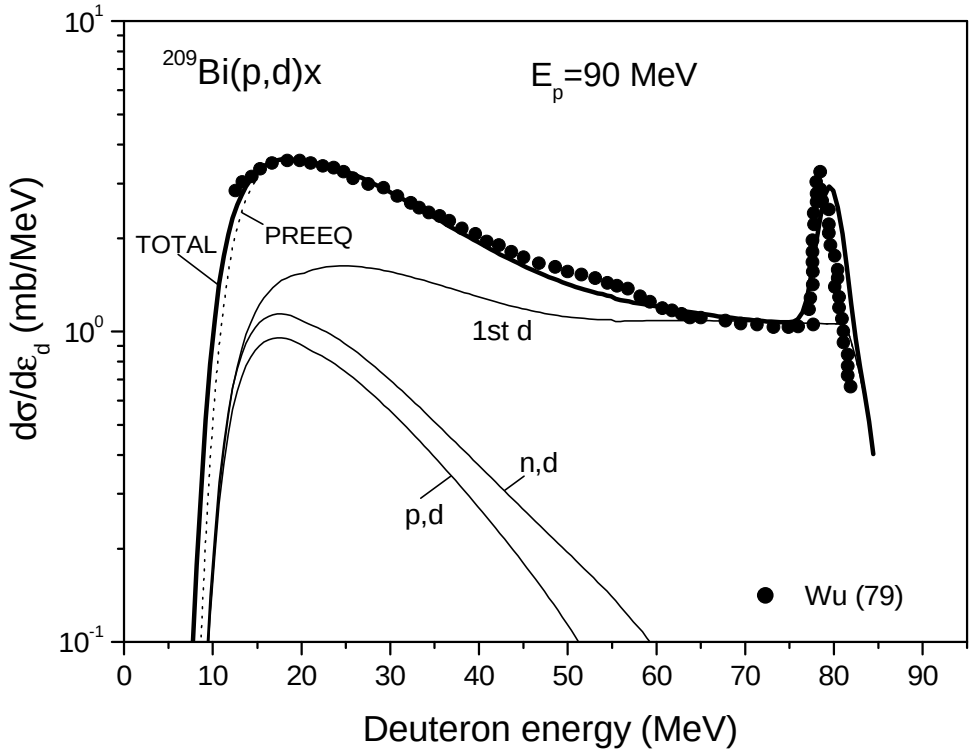

Fig.8 The contribution of deuterons formed in different pre-equilibrium stages for the reaction p+^{209}Bi induced by 90 MeV protons on the total deuteron emission spectrum: the emission of the first pre-compound deuteron ("1st d"), pre-compound deuteron emission after pre-equilibrium proton escape ("p,d"), pre-compound deuteron emission following pre-equilibrium neutron emission ("n,d"). The sum of all pre-equilibrium components ("1st d"+"p,d"+"n,d") (PREEQ) and the total spectrum (TOTAL) are shown. Experimental data (black circles) are taken from Ref.[35].

The direct pick-up process corresponds to the pick-up of a nucleon without formation of a (2p,1h) exciton configuration. The final state is (0p,1h). A rigorous description of this process can be done only outside of pre-equilibrium models. However, mathematical expressions obtained formally using the pre-compound exciton model [12,43] are used for the phenomenological and qualitative description of direct nucleon pick-up.

According to Ref.[12], the direct component of the deuteron spectrum is

$$\frac{d\sigma^D}{d\varepsilon_d} = \sigma_{non}\ \frac{\omega^*(U)}{\omega(1p,0h,E)}\ \frac{\lambda_d^e(\varepsilon_d)}{\lambda_d^e(\varepsilon_d)+\lambda_d^+(\varepsilon_d)}\ g_d\ , \qquad (33)$$

where the final level density $\omega^*(U)$ is approximated in Ref.[12] by $\omega(0p,1h,U)\cdot\gamma/g_d$ with the γ value equal to $2\cdot10^{-3}$ MeV^{-1} for all nuclei and excitation energies.

Formal consideration of the finite depth of the nuclear potential well shows that Eq.(33) can contribute only in the highest energy part of the deuteron emission spectrum, as has been mentioned above. In this case the calculated part of the spectrum is a rectangular step with width equal to E_F. To improve the agreement of calculations and the measured deuteron spectra, it is useful to write the direct component of the spectrum in the following form

$$\frac{d\sigma^D}{d\varepsilon_d} = \sigma_{non}\ \alpha_1\ \exp\left(-\frac{(E-\alpha_2 E_F)^2}{2(\alpha_3 E_F)^2}\right)\frac{\lambda_d^e(\varepsilon_d)}{\lambda_d^e(\varepsilon_d)+\lambda_d^+(\varepsilon_d)}\ g_d\ , \qquad (34)$$

where α_1, α_2 and α_3 are parameters and E_F is the effective value of the Fermi energy.

The values of α_i can be obtained from analysis of experimental deuteron spectra. The global parameterization of α_i parameters is hardly possible.

Fig.6 shows the $d\sigma^D/d\varepsilon_d$ component of the calculated deuteron spectrum for ^{54}Fe(p,d)x and ^{197}Au(p,d)x reactions induced by 61.5 MeV protons.

Model parameters were obtained from the comparison of calculations with experimental data [35,36,44-50]. The change in values of different parameters results to different energetic dependencies of calculated deuteron spectrum. In most cases such change cannot be represented by a simple redefinition of other model parameters.

The global normalization of the sum for the $F_{1,1}$ pick-up and the $F_{2,0}$ coalescence components adopted in Ref.[12] was kept unchanged

$$\sum_{k+m=2} F_{k,m} = 0.3 \qquad (35)$$

The single particle state density for deuteron g_d is taken equal to g/2. The φ parameter of the knock-out model obtained from the comparison of the experimental data and calculations for different nuclei is equal to 0.18 ± 0.03.

The effective value of the Fermi energy, E_F was found to be 5 MeV. This rather small value reflects the influence of surface nuclear effects on deuteron emission. A similar reduction of the effective Fermi energy was obtained from the analysis of nucleon pre-equilibrium spectra in Refs.[40,41]. Fig.9 shows the influence of the effective E_F value on the calculated deuteron energy distribution.

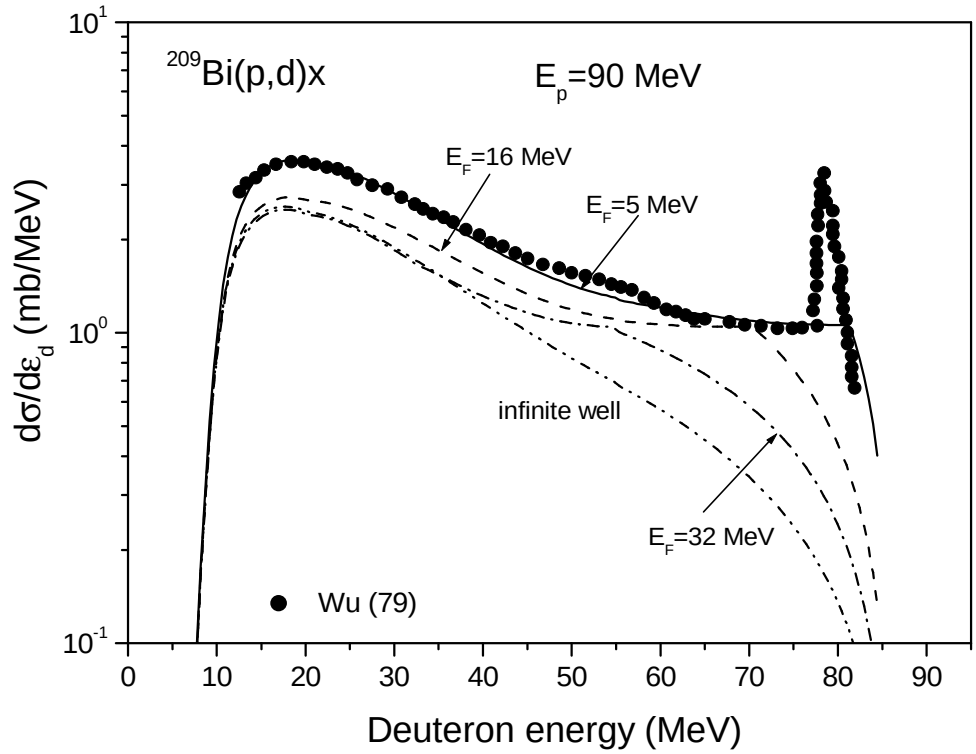

Fig.9 The deuteron emission spectrum for ^{209}Bi(p,d)x reaction induced by 90 MeV protons calculated using different values of the effective Fermi energy E_F. Experimental data (black circles) are taken from Ref.[35].

The imaginary part of the optical potential W_d^{opt} was parameterized as follows $W_d^{opt} = W_0$ at $\varepsilon_d < \varepsilon_1$ and $W_d^{opt} = W_0 \cdot \exp(\beta \cdot (\varepsilon_d - \varepsilon_1))$ at $\varepsilon_d \geq \varepsilon_1$; $W_0 = \gamma_1 \cdot (E_1 - E_p) + W_1$ at $E_p \leq E_1$, $W_0 = \gamma_2 \cdot (E_p - E_1) + W_1$ at $E_p > E_1$ and $W_0 = \gamma \cdot (E_2 - E_1) + W_1$ at $E_p > E_2$, where ε_1 = 20 MeV, $\beta = -0.1027 \cdot \exp(-11.45 \cdot (A - 2 \cdot Z)/A)$, E_1 = 62 MeV, E_2 = 90 MeV, $\gamma_1 = -1.37 \cdot 10^{-3} A - 0.213$, $\gamma_2 = -0.45$, W_1 = 32 MeV. This rather complex energy and A - dependence of W_d^{opt} results from the fitting of calculations to experimental deuteron spectra. Partly, it accumulates an uncertainty of different measurements and reflects the general approximate character of the model.

The parameters of Eq.(34) have been obtained from analysis of experimental data. For most nuclei the value of α_1 is equal to 1.5×10^{-3}. The α_2 parameter value is equal to 0.77 ± 0.54 and α_3 is equal to 0.52 ± 0.18. The value of E_F was taken to equal 5 MeV.

Fig.10 shows examples of deuteron emission spectra calculated for nuclear reactions induced by 61.5-61.9 MeV protons. The deuteron energy distributions obtained for reactions induced by 90 MeV protons and 96 MeV neutrons are shown in Fig.11.

Examples of deuteron emission spectra calculated for neutron induced reactions are shown in Fig.12.

2.4 Pre-compound triton and ^{3}He emission

The pre-equilibrium spectra for emission of tritons and ^{3}He nuclei is calculated using the coalescence pick-up exciton model [9]. The analytical expression for the spectra is similar to Eqs.(15) and (24).

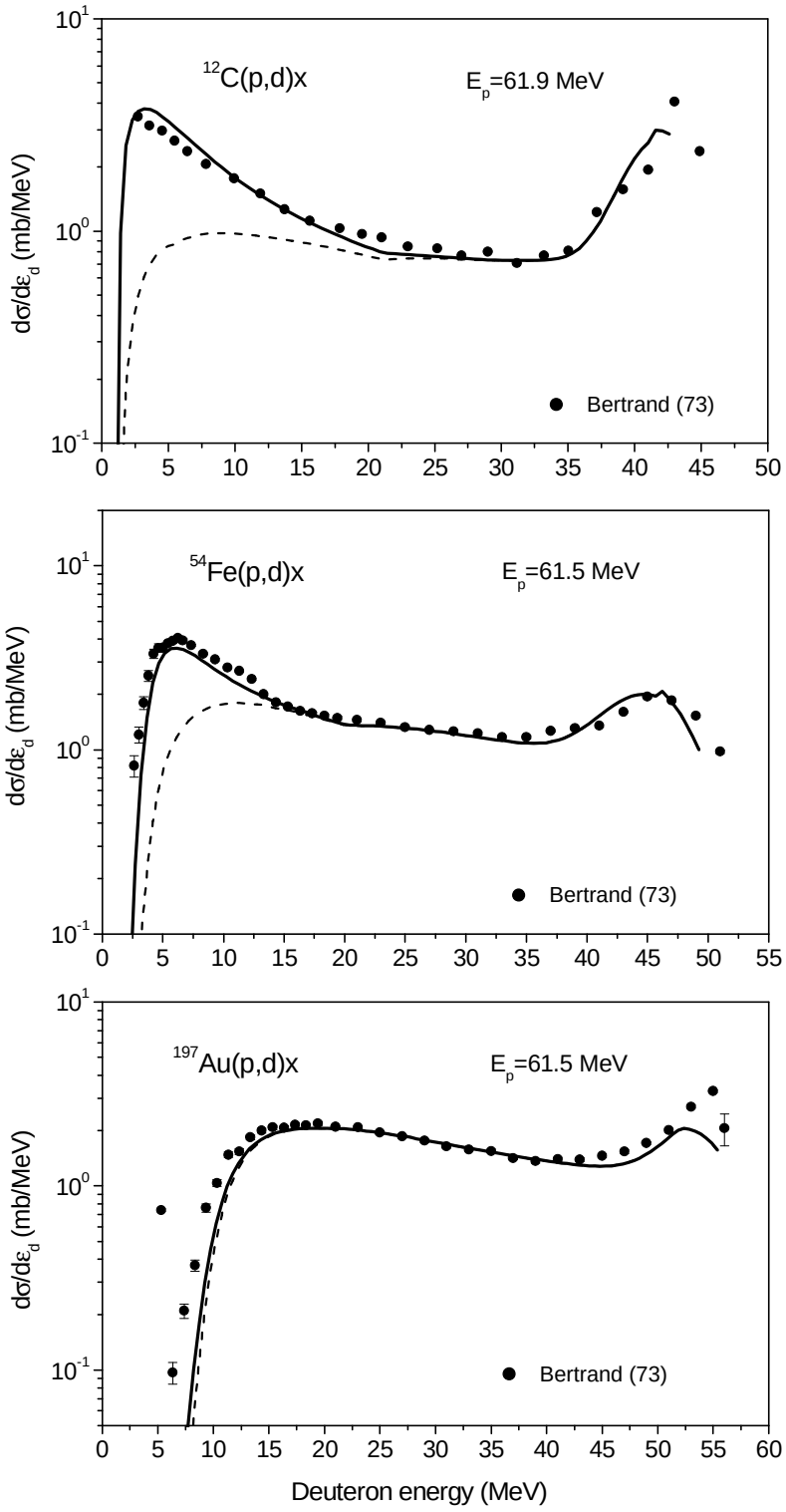

Fig.10 Calculated total deuteron emission spectrum (solid line) and non-equilibrium deuteron emission spectrum (dashed line) for a number of reactions induced by protons of energy about 62 MeV. Experimental data are from Ref.[36].

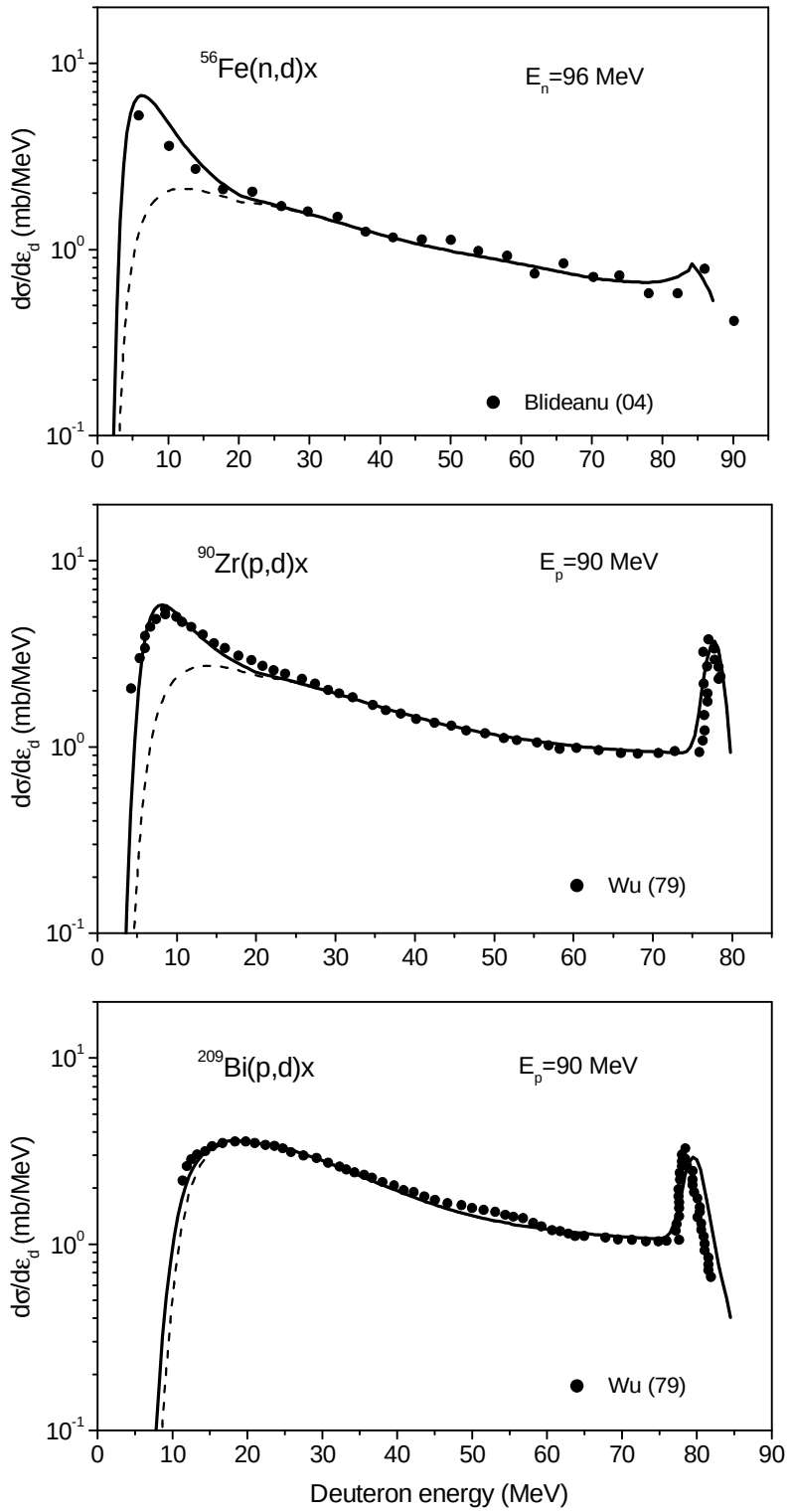

Fig.11 Calculated total deuteron emission spectrum (solid line) and non-equilibrium deuteron emission spectrum (dashed line) for a number of reactions induced by nucleons of energy 90 and 96 MeV. Experimental data are from Refs.[35,44].

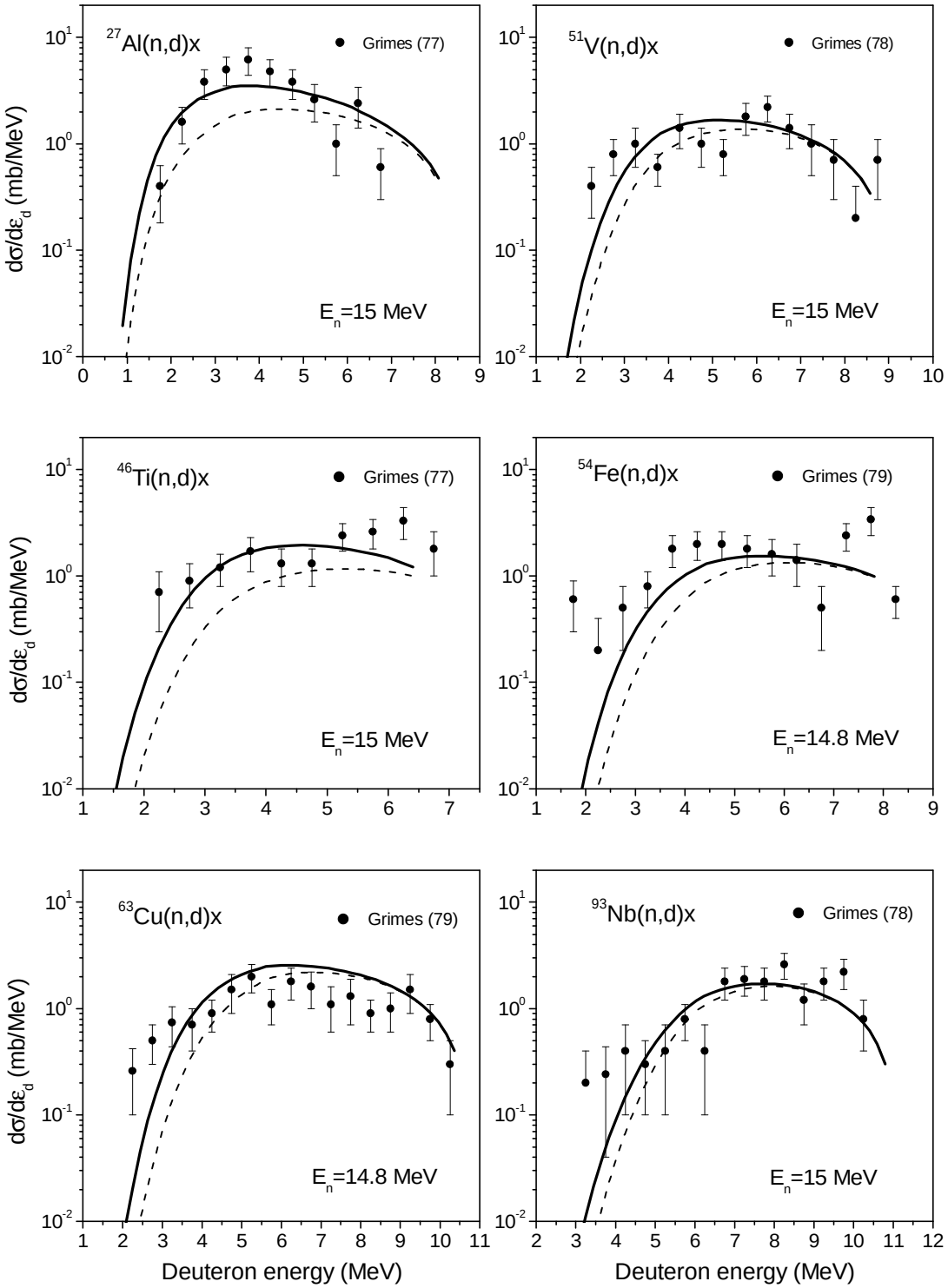

Fig.12 Calculated total deuteron emission spectrum (solid line) and non-equilibrium deuteron emission spectrum (dashed line) for a number of neutron induced reactions at the incident neutron energy 14.8 and 15 MeV. Experimental data are taken from Refs.[48-50].

2.5 Pre-compound g-**ray** *emission*

It is thought that single particle radiative transitions [51] and the n+p $\rightarrow$ d+γ reaction are the main origin of pre-compound γ-rays in nuclear reactions. The analytical expression for the γ-emission spectrum in nucleon induced reactions is written as follows:

$$\frac{d\sigma}{d\varepsilon_\gamma} = \sigma_{non}(E_p)\left\{\frac{\lambda_\gamma^{qd}(E_p,\varepsilon_\gamma)}{\lambda^+(E)} + \sum_{x=\nu,\pi}\sum_{n_0=3}\int_0^E{}_x X_n \frac{\omega(p-1,h,E-\varepsilon_x)}{\omega(p,h,E)}\right.$$

$$\left.\times\left(\frac{\lambda_\gamma(\varepsilon_x,\varepsilon_\gamma)}{\lambda_x^+(\varepsilon_x)+\lambda_x^e(\varepsilon_x')} + \frac{\lambda_\gamma^{qd}(\varepsilon_x',\varepsilon_\gamma)}{\lambda_x^+(\varepsilon_x)+\lambda_x^e(\varepsilon_x')}\right)D_n\, g\, d\varepsilon_x\right\}, \qquad (36)$$

where E_p is the kinetic energy of the incident nucleon, E is the energy of the excitation of the compound nucleus, $\lambda^+(E)$ is the absorption rate for the incident nucleon, λ_γ is the emission rate of γ-quanta due to single particle radiative transitions in $c^{-1}MeV^{-1}$ units [51], λ_γ^{qd} is the γ-emission rate relating to the "quasi-deuteron" formation, n+p $\rightarrow$ d+γ.

The first term in braces of Eq.(36) describes the probability of γ-ray emission in the first non-elastic interaction of the incident particle with the nucleus. Other terms describe photon emission from different exciton states. The $\lambda_\gamma(\varepsilon_x,\varepsilon_\gamma)$ value, which corresponds to the γ-quantum emission at the transition with the change of exciton states on $\Delta n = -2; 0$, is calculated according to Ref.[51]

for $\varepsilon_\gamma > \varepsilon_x$, ($\Delta n = -2$)

$$\lambda_\gamma(\varepsilon_x,\varepsilon_\gamma) = \lambda_\gamma^-(\varepsilon_x,\varepsilon_\gamma) =$$

$$\frac{\varepsilon_\gamma^2}{\pi^2\mathbf{h}^3c^2}\,\sigma_\gamma^{abs}(\varepsilon_\gamma)\,\frac{g}{g(n-2)+g^2\varepsilon_\gamma}\,\frac{\omega(p-1,h-1,E-\varepsilon_\gamma)}{\omega(p-1,h,E-\varepsilon_x)}, \qquad (37)$$

for $\varepsilon_\gamma < \varepsilon_x$, ($\Delta n=0$)

$$\lambda_\gamma(\varepsilon_x,\varepsilon_\gamma) = \lambda^0_\gamma(\varepsilon_x,\varepsilon_\gamma) = \frac{\varepsilon_\gamma^2}{\pi^2\mathbf{h}^3c^2}\,\sigma_\gamma^{abs}(\varepsilon_\gamma)\,\frac{g}{gn+g^2\varepsilon_\gamma}, \qquad (38)$$

where σ_γ^{abs} is the photon absorption cross-section.

The σ_γ^{abs} value is calculated by a formula describing the giant dipole resonance

$$\sigma_\gamma^{abs} = \sum_{R=1}^{2}\sigma_R\,\frac{\varepsilon_\gamma^2\Gamma_R^2}{(\varepsilon_\gamma^2-E_R^2)^2+\varepsilon_\gamma^2\Gamma_R^2}, \qquad (39)$$

where $E_1=E_0(1-\beta/3)^2$, $E_2=E_0(1-0.16\beta)$, $\sigma_1=0.0145A/E_1$ mb, $\sigma_2=0.0235A/E_2$ mb, $\Gamma_1=0.232E_1$, $\Gamma_2=0.275E_2$, $E_0=43.4A^{-0.215}$, and $\beta=0$ are taken from Ref.[4].

The γ-ray emission λ_γ^{qd} resulting from $n+p \rightarrow d+\gamma$ interactions is written as follows

$$\lambda_\gamma^{qd}(\varepsilon_x',\varepsilon_\gamma) = \rho v_x\,\frac{d\sigma^{qd}}{d\varepsilon_\gamma}, \qquad (40)$$

where ρ is the density of protons or neutrons in the nucleus depending upon the type of particle "x", v_x is the velocity of the x-particle: $v_x=(2T_x/m)^{-1/2}(1-0.75T_x/mc^2)$ and $T_x=\varepsilon_x'+\varepsilon_F+Q_x$, $d\sigma^{qd}/d\varepsilon_\gamma$ is the γ-ray spectrum in the $n+p \rightarrow d+\gamma$ reaction.

The expression for the calculation of $d\sigma^{qd}/d\varepsilon_\gamma$ is

$$\frac{d\sigma^{qd}}{d\varepsilon_\gamma} = \int\frac{v_{rel}}{v_x}\sigma_{p+n\rightarrow d+\gamma}(\mathbf{\vec{p}}_x,\mathbf{\vec{p}},\mathbf{\vec{p}}_d)N(\mathbf{\vec{p}})\delta(T_x+T-T_d-\varepsilon_\gamma)\,\delta(\mathbf{\vec{p}}_x+\mathbf{\vec{p}}-\mathbf{\vec{p}}_d-\mathbf{\vec{p}}_\gamma)\,G\,d\mathbf{\vec{p}}\,d\mathbf{\vec{p}}_d, \qquad (41)$$

where $\vec{p}$, $\vec{p}_d$, T and T_d are momenta and kinetic energies of the nucleon, which is a part of the nucleus, and the nucleon from which the "quasi-deuteron" is formed, $N(\vec{p})$ is the momentum distribution of intranuclear nucleons, σ is the cross-section of the $n+p\rightarrow d+\gamma$ reaction for free nucleons, proceeding with the formation of the quasi-deuteron with the momentum $\vec{p}_d$, G is a function describing the influence of nuclear matter on the process, v_{rel} is the relative speed of the incident nucleon with momentum $\vec{p}_x$ and the intranuclear nucleon.

It is assumed that the $n+p \rightarrow d+\gamma$ reaction results in the formation of a proton and neutron with the same momentum. The cross-section of the reaction considered for free nucleons in the energy region up to 300 MeV, practically, is constant (see Ref.[52]). It is taken to be equal to 7.5 μb.

The calculation of $d\sigma^{qd}/d\varepsilon_\gamma$ has been performed for a square potential well. The G value in Eq.(41) was calculated taking into account the limitation on the number of interactions superimposed by the Pauli principle and limitation on orbital momenta [29,53]. The limitation on orbital momenta makes it possible to reject the false potential resonances appearing in the square well and which are absent in a realistic potential. According to Refs.[29,53] only interactions with final states having a nucleon in the continuous spectrum with orbital momenta less than $p \cdot R$ is considered, where "p" is the momentum of a nucleon outside the nucleus, and R is the radius of the potential well.

To take into account the final size of the nucleus, $d\sigma^{qd}/d\varepsilon_\gamma$, Eq.(41) has been calculated for different trajectories of the nucleon inside the nucleus. The result was averaged for different trajectories. The refraction of the momentum of the incident nucleon is considered on the boundary of the well. The motion was described using relativistic kinematics. The calculation was done by the Monte Carlo method.

Fig.13 shows the $d\sigma^{qd}/d\varepsilon_\gamma$ value calculated both taking into account the limitation on the orbital momenta for intranuclear nucleon-nucleon interactions [29,53] and without such limitation. In both cases the Pauli principle was considered. The calculations were performed for incident proton energies of 50, 140 and 300 MeV. One should note, that the $d\sigma^{qd}/d\varepsilon_\gamma$ value does not depend strongly upon the nucleus size.

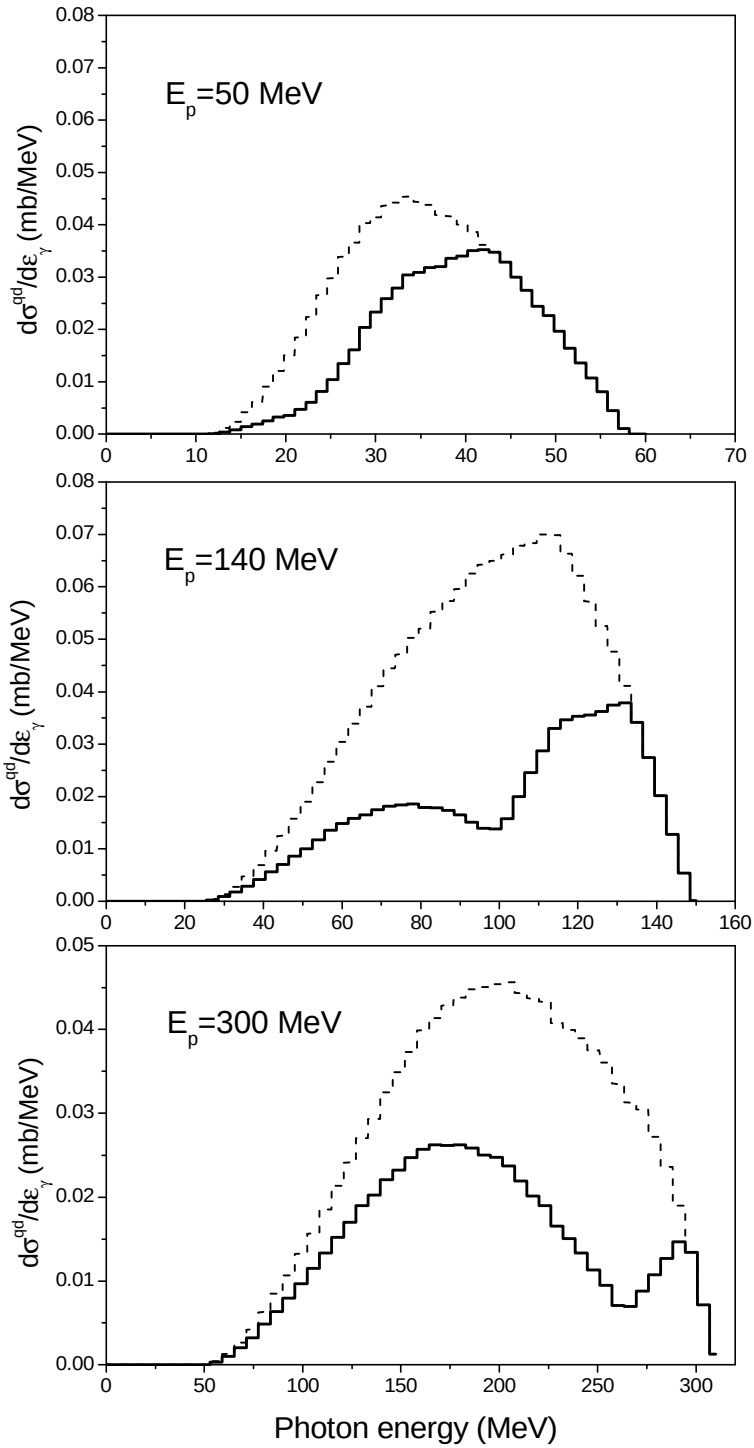

Fig.13 The $d\sigma^{qd}/d\varepsilon_\gamma$ value calculated taking into account the limitation on orbital momenta of nucleons after an intranuclear interaction (solid histogram) and neglecting this limitation (dashed histogram) for incident protons with the energy 50, 140 and 300 MeV. Proton energy is shown in the laboratory coordinate system.

The $d\sigma^{qd}/d\varepsilon_\gamma$ distribution obtained taking into account the limitation on the orbital momenta has two maxima. The part of the spectrum corresponding to the region of the first maximum is formed mainly due to interactions, where in the final state two nucleons are in the continuous spectrum. For such processes the limitation on orbital momenta [29,53] is actual, which reduces the total number of reactions considered. The region of the second maximum corresponds principally to interactions with the creation of nucleons with energy $\varepsilon_F < \varepsilon_x < \varepsilon_F + Q_x$, where the limitation [29,53] is not valid.

Fig.14 illustrates the dependence of the calculated hard γ-ray spectrum upon the method of calculation of $d\sigma^{qd}/d\varepsilon_\gamma$. Fig.14 shows the γ-ray spectra for the ^{27}Al(p,γ)x reaction induced by 140 MeV protons, obtained with different descriptions of the influence of nuclear matter. It is seen that the consideration of the Pauli exclusion principle and the limitation on the orbital momenta after intranuclear interaction [29,53] results in better agreement with experimental data [54].

Calculated contributions of different processes in photon emission in nuclear reactions induced by nucleons of different energy are shown in Figs.15-17 for the example of nucleon interactions with ^{27}Al. The experimental data are from Refs.[54,55]. The equilibrium γ-ray spectrum for the ^{27}Al(n,γ) reaction induced by 14.1 MeV neutrons has been calculated using the STAPRE code [56]. The pre-compound particle and γ-spectra have been obtained using the global set of input parameters. The Pauli exclusion principle and the limitation on orbital momenta discussed above were considered in the calculation of $d\sigma^{qd}/d\varepsilon_\gamma$. Figs.15-17 show that at relatively low incident particle energy the single particle radiative transitions [51] define the hardest part of the γ-ray spectrum. The role of the “quasi-deuteron” mechanism in the formation of non-equilibrium γ-spectrum increases with projectile energy.

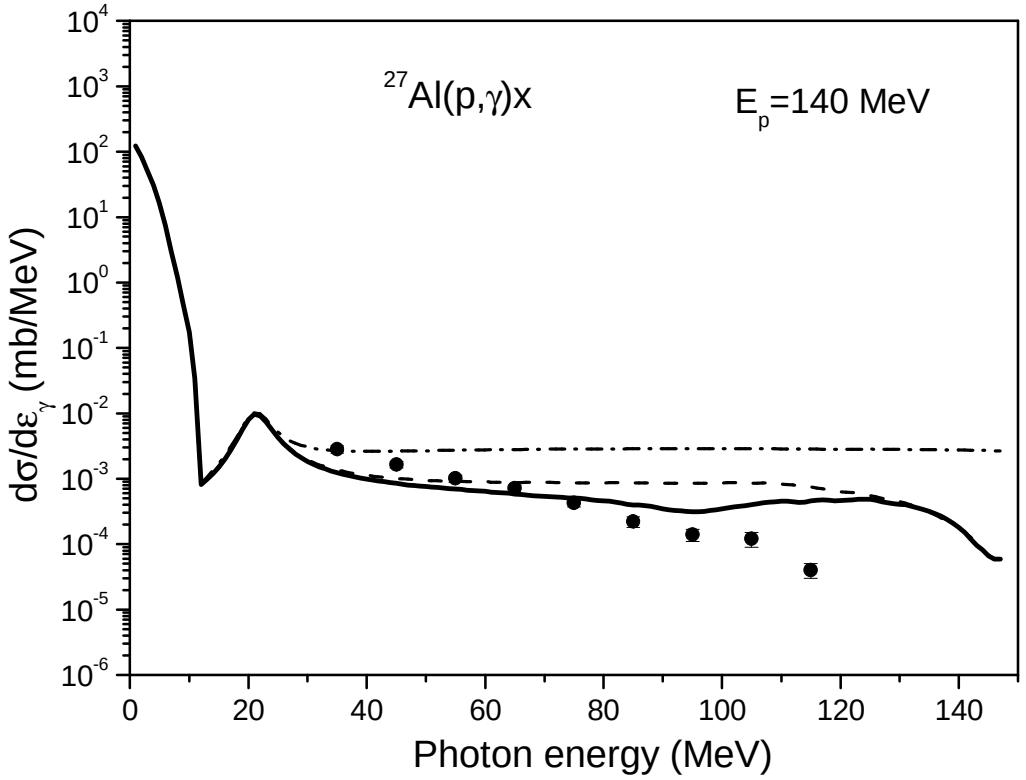

Fig.14 Energy distribution of γ-rays from the ^{27}Al(p,γ)x reaction induced by 140 MeV protons obtained i) taking into account the Pauli exclusion principle and the limitation on the orbital momenta of nucleons after an intranuclear interaction in the calculation of $d\sigma^{qd}/d\varepsilon_\gamma$ (solid line), ii) considering only the Pauli exclusion principle (dashed line), iii) neglecting both the Pauli principle and the limitation on the orbital momenta [29,53] (dashed-dotted line). Experimental data (circle) are taken from Ref.[54].

Fig.18 shows the γ-ray emission spectrum, obtained by different authors for the ^{208}Pb(p,γ)x reaction at an incident proton energy of 140 MeV. The non-equilibrium γ-spectrum was calculated in Ref.[52] using the intranuclear cascade model and analytically for a number of reaction characteristics. Data from ENDF/HE-6.4 [57] were obtained using the approximate approach of Ref.[4].

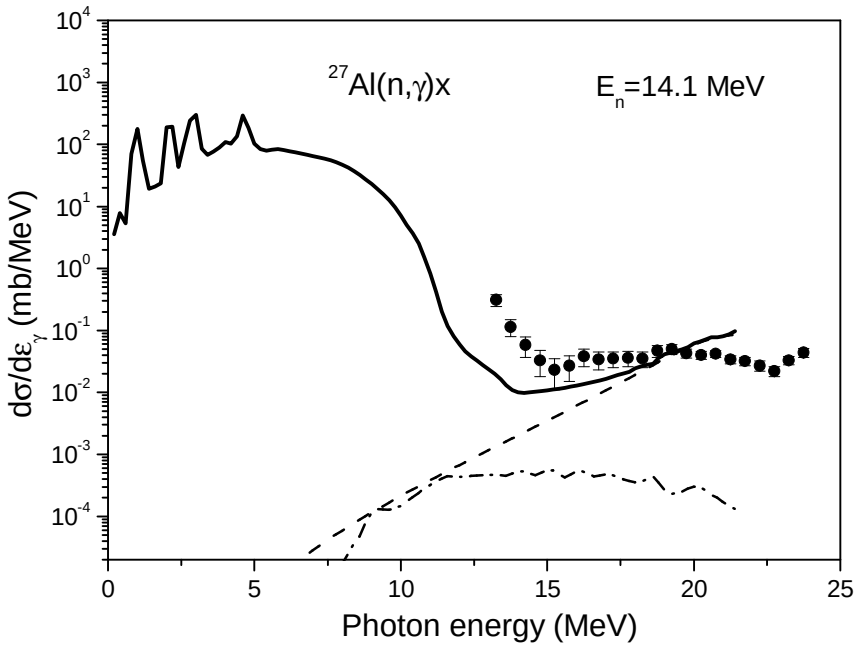

Fig.15 Energy distribution of γ-rays from the ^{27}Al(n,γ)x induced by 14.1 MeV neutrons: total spectrum (solid line), the contribution of single radiative transitions (dashed line), the contribution of the "quasi-deuteron" mechanism (dashed-dotted line). Experimental data are from Ref.[55].

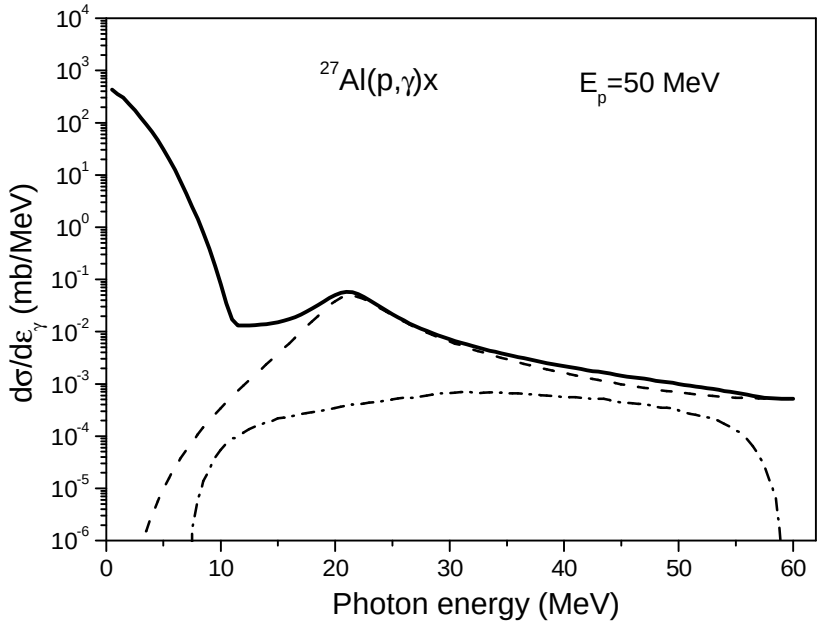

Fig.16 Energy distribution of γ-rays from the ^{27}Al(p,γ)x induced by 50 MeV protons. Captions as in Fig.15.

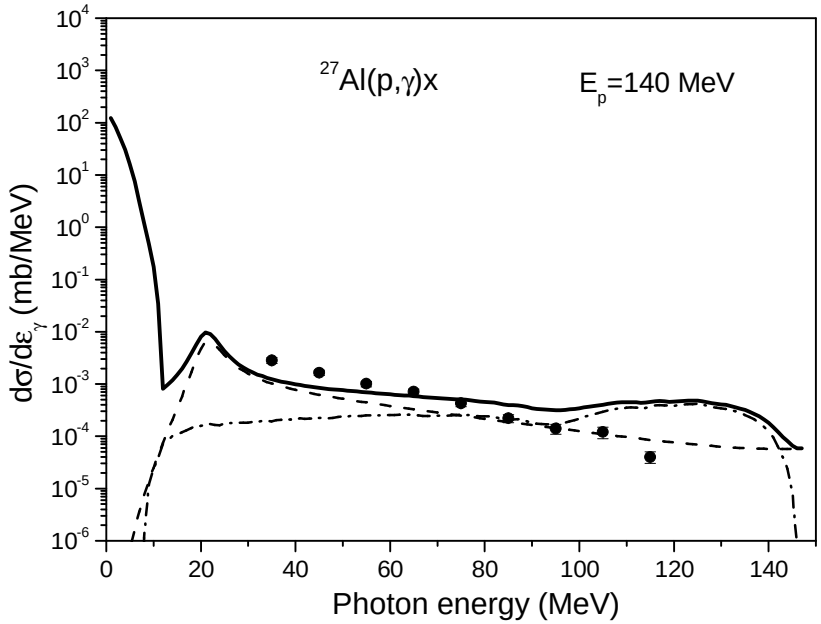

Fig.17 Energy distribution of γ-rays from the ^{27}Al(p,γ)x induced by 140 MeV protons. Captions as in Fig.15. Experimental data are from Ref.[54].

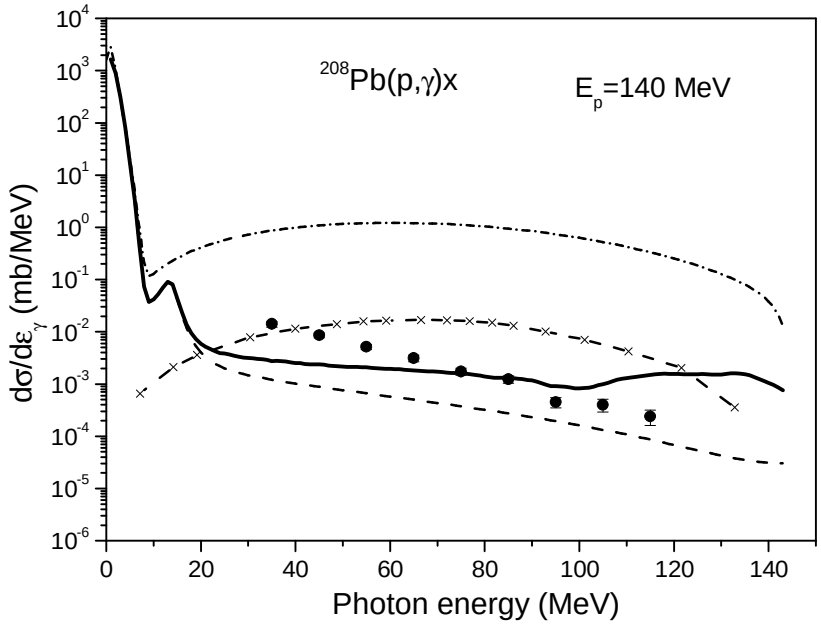

Fig.18 Energy distribution of γ-rays from the ^{208}Pb(p,γ)x reaction induced by 140 MeV protons: result of the calculation using the ALICE/ASH code (solid line), the sum of the equilibrium photon spectrum and the part of the pre-compound spectrum corresponding to the single particle radiative transitions (dashed line), the calculations performed in Ref.[52] (dashed crossed line) and the ENDF/HE-6.4 data (dashed dotted line). Experimental data are from Ref.[54].

2.6 Angular distribution of pre-compound particles

Nucleon angular distribution are evaluated using the Kalbach systematics [59] and different approaches from Ref.[58].

The α-particle angular distributions are estimated using systematics due to Kalbach.

2.7 Equilibrium particle emission

2.7.1 Nucleons and light clusters

The equilibrium emission of particles is described using the Weisskopf-Ewing model [60]. The probability of the evaporation is given by

$$W_x(\varepsilon_x) \propto (2S_x+1)\mu_x \varepsilon_x \sigma_x^{inv}(\varepsilon_x) \frac{\rho(Z',A',U)}{\rho(Z,A,E)}, \qquad (42)$$

where S_x, μ_x and ε_x are respectively spin, reduced mass and energy of the emitted particle, σ_x^{inv} is the inverse reaction cross-section, ρ(Z',A',U) is the nuclear level density of the residual nucleus with excitation energy U, ρ(Z,A,E) is the level density of the nucleus emitting the x-particle, E is the excitation energy of the emitting nucleus.

2.7.2 Photons

The probability of photon emission is defined as follows:

$$W_\gamma(\varepsilon_\gamma) \propto \varepsilon_\gamma^2 \sigma_\gamma^{abs}(U) \frac{\rho(Z,A,U)}{\rho(Z,A,E)}, \qquad (43)$$

where σ_γ^{abs} is calculated by Eq.(39).

2.7.3 Nuclear level density

The level density for equilibrium states is calculated using one of the following approaches.

1. Fermi gas model with an energy independent level density parameter. The nuclear level density is taken in the form

$$\rho(U) \propto (U-\delta)^{-5/4} \exp(2\sqrt{a(U-\delta)}) \qquad (44)$$

and the level density parameter is equal to

$$a=A/y \qquad (45)$$

where "y" is a constant. The pairing correction, δ can be evaluated using different schemes depending upon the input parameter MP:

"standard" shift (MP=3)

$\delta = 11/A^{1/2}$ for even-even nuclei,

$\delta = 0$ for nuclei with odd A,

$\delta = -11/A^{1/2}$ for odd-odd nuclei

"backshift" (MP=1)

$\delta = 0$ for even-even nuclei,

$\delta = -11/A^{1/2}$ for nuclei with odd A,

$\delta = -22/A^{1/2}$ for odd-odd nuclei.

At excitation energies below 2 MeV, the level density is calculated by the "constant" temperature model.

2. Kataria-Ramamurthy Fermi gas model. The model is described in Ref.[61].

3. Fermi gas model of Ignatyuk, Smirenkin, Tishin with an energy dependent level density parameter. The nuclear level density is defined by the expression

$$\rho(U) \propto a^{-1/4}(U-\delta)^{-5/4} \exp(2\sqrt{a(U-\delta)}) \qquad (46)$$

The nuclear level density parameter is calculated as follows [13]

$$a(U) = \tilde{a}(1 + f(U)\delta W / U), \qquad (47)$$

where δW is the shell correction, $f(U) = 1 - \exp(-\gamma U)$, $\tilde{a} = A(\alpha + \beta A)$, $\alpha = 0.154$, $\beta = -6.3 \times 10^{-5}$, $\gamma = 0.054$ MeV^{-1}.

The pairing correction is

$\delta = 24/A^{1/2}$ for even-even nuclei

$\delta = 12/A^{1/2}$ for nuclei with odd A

$\delta = 0$ for odd-odd nuclei

At excitation energies < 2 MeV the level density is calculated using the "constant" temperature approach.

4. Superfluid nuclear model. The nuclear level density is calculated according to the generalized superfluid model [6]

$$\rho(U) = \rho_{qp}(U') K_{vib}(U') K_{rot}(U'), \qquad (48)$$

where $\rho_{qp}(U')$ is the density of quasi-particle nuclear excitation, $K_{vib}(U')$ and $K_{rot}(U')$ are the vibrational and rotational enhancement factors at the effective energy of excitation U' calculated according to Refs. [62,63].

The nuclear level density parameters are calculated according to the expression [6]

$$a(U) = \begin{cases} \tilde{a}\left(1 + \delta W \varphi(U' - E_{cond})/(U' - E_{cond}\right), & U' > U_{cr} \\ a(U_{cr}), & U' \le U_{cr}, \end{cases} \qquad (49)$$

where δW is the shell correction to the mass formula equal to the difference between experimental mass defect and one calculated from the liquid drop model [64], $\varphi(U) = 1 - \exp(-\gamma U)$, $\gamma = 0.4/A^{1/3}$ MeV^{-1}. The asymptotic value of nuclear level parameter is equal to

$$\tilde{a} = A(0.073 + 0.115A^{-1/3}) \qquad (50)$$

The effective energy of excitation U', the critical energy of the phase transition U_{cr} and the condensation energy E_{cond} are calculated as follows

$$U' = U - n\Delta_0, \quad (51)$$

$$U_{cr} = 0{,}472\, a(U_{cr})\Delta_0^2 - n\Delta_0, \quad (52)$$

$$E_{cond} = 0{,}152\, a(U_{cr})\Delta_0^2 - n\Delta_0, \quad (53)$$

The correlation function Δ_0 is equal to

$$\Delta_0 = 12A^{-1/2} \quad (54)$$

where n=0 for even-even nuclei, n=1 for nuclei with odd A value, n=2 for odd-odd nuclei.

The comparison of the different approaches for level density calculations is presented in Table 2. This Table contains the values describing the deviation of calculated cross-sections for 60 proton induced reactions (p,xnypzα) and experimental data. Calculations have been performed using various models for nuclear level density for reactions with the number of emitted particles ≥ 3, on target nuclei from ^{27}Al to ^{209}Bi irradiated with protons of energy up to 100 MeV. The pre-compound emission was described using the GDH model. The bibliography of the experimental data used for the comparison is given in Refs.[65,66].

The last row of Table 2 shows results for the F - criterion [67-69], which is the most appropriate for the comparative analyses of calculations and experimental data, taking into account that the measured yields are known only for a limited number of residual nuclei [70]. The use of other criteria is of secondary importance [70].

The data show that the superfluid model [6] is the best approach describing the experimental data.

2.8 Fission

The Bohr-Wheeler approach [71] is used for the calculation of the fission probability. The angular momentum is taken into account approximately as described in Ref.[1].

The special ALICE/ASH code version allows one to perform calculations using experimental energy independent ratios of neutron to fission widths Γ_n/Γ_f at low excitation energy [72]. At high energy of excitation the realistic energy dependence of the Γ_n/Γ_f ratio is assumed. The example of fission cross-sections for ^{238}U calculated for nucleon induced reactions in Ref.[19] is shown in Figs.19,20.

Table 2

The values describing the deviation of calculated and measured cross-sections for 60 nuclear reactions with the number of emitted particles ≥ 3 for nuclei from ^{27}Al to ^{209}Bi irradiated with protons of energies up to 100 MeV. Total number of experimental points (N) is equal to 635. The best results are underlined

Value	Fermi-gas model with a=A/9	Kataria-Ramamurthy Fermi-gas model [61]	Fermi-gas model with a(U) [13]	Generalized superfluid nuclear model [6][1]
$\left(\frac{1}{N}\sum_{i=1}^{N}\left(\frac{\sigma_i^{exp}-\sigma_i^{calc}}{\Delta\sigma_i^{exp}}\right)^2\right)^{1/2}$	6.22	5.60	<u>5.26</u>	5.29
$\frac{1}{N}\sum_{i=1}^{N}\left\|\frac{\sigma_i^{exp}-\sigma_i^{calc}}{\sigma_i^{exp}}\right\|$	0.516	0.470	<u>0.459</u>	0.478
$\frac{1}{N}\sum_{i=1}^{N}\frac{\sigma_i^{calc}}{\sigma_i^{exp}}$	1.07	1.07	1.08	<u>1.02</u>
$\left(\frac{1}{N}\sum_{i=1}^{N}\lg^2\left(\frac{\sigma_i^{calc}}{\sigma_i^{exp}}\right)\right)^{1/2}$	0.350	0.339	0.346	<u>0.313</u>

[1] Calculations were performed in Ref.[66]

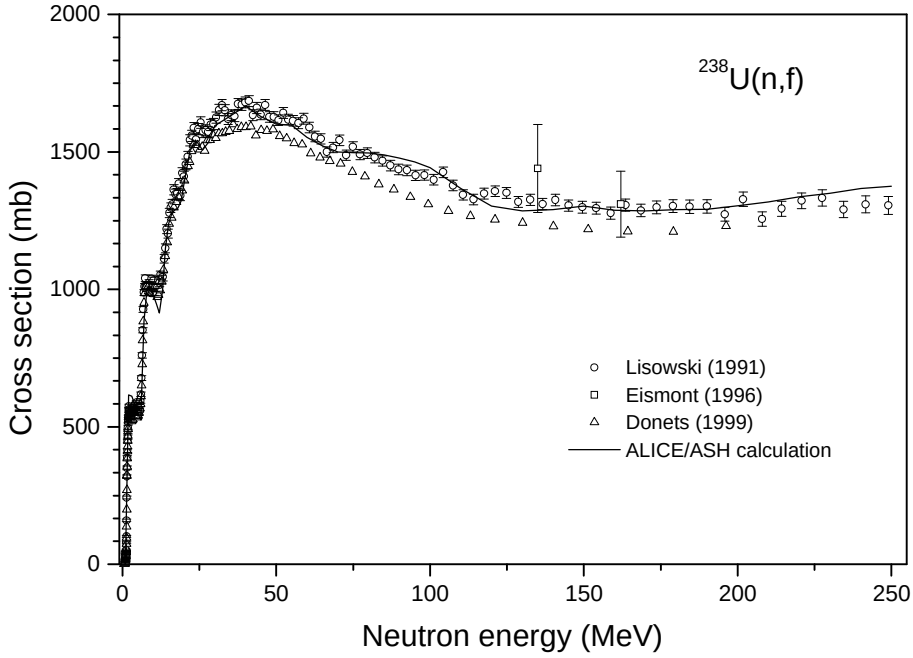

Fig.19 Fission cross-section for ^{238}U irradiated with neutrons calculated by the ALICE/ASH code in Ref.[19]. See bibliography of experimental works in Ref.[19].

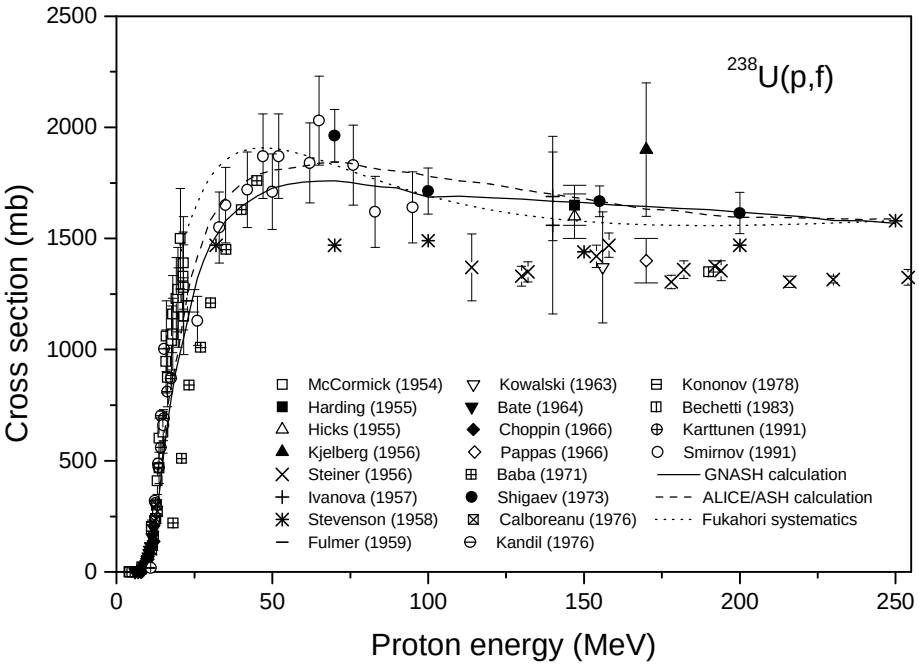

Fig.20 Fission cross-section for ^{238}U irradiated with protons calculated using the ALICE/ASH code (dashed line), the GNASH code (solid line) and evaluated by the Fukahori systematics. See details and the bibliography of measurements in Ref.[19].

2.9 Calculation of inverse and reaction cross-sections

The reaction cross-sections are calculated for nucleon and deuteron projectiles according to the optical model [1-3,11,24]. For other incident particles the parabolic optical model is applied.

3. Optimum energy range for code use

Some of the factors which limit use of the code are the non-relativistic description of nuclear processes, neglect of inelastic nucleon-nucleon interactions (e.g. delta formation), and the approximate character of the approach describing multiple pre-compound emission. Taking these factors into account, the best range for code application is expected to be at energies of incident nucleons up to 150 MeV.

The neglect of multiple precompound emission is corrected for in the Monte Carlo HMS precompound model, where there is no limit to the number of precompound nucleons emitted [27]. The HMS ALICE code has successfully treated the precompound plus evaporation decay of stopped pion capture. Thus it will require the addition of delta resonance formation and decay to extend its energy range beyond a practical pion physics limit of around 250 MeV (due to lack of the delta physics).

Formally, the ALICE/ASH code can be used for calculations at energies up to 300 MeV; newer versions work at higher energies, but use is not advised above 250 MeV due to failure to include delta resonances.

4. Computer compatibility

The ALICE/ASH code is written in FORTRAN. Certain attempts have been made to make the code independent from compiler versions. Certain optimization options give

suspicious results, so before using optimized compiler options the user should check optimized compiles against non- optimized results. Preliminary use of bounds check options is also recommended.

5. Input data file

Card 1. NAMRD, (IWR(i),i=1,4). Format(A8,4I1)

NAMRD is the name of output files: "NAMRD.XXX". (See structure of output files in Section 8.)

NAMRD.FUL: full listing with detailed information

NAMRD.CRS: short listing with information about the yields of residuals.

NAMRD.GAS: listing with the information about the gas production. It is created, if IKE=4 (see below).

IWR(1) = 1 creates the file with calculated neutron emission spectra. IKE=4 is supposed; IWR(1) = 0 no file with neutron spectra.

IWR(2) the same as for IWR(1), but for proton spectra

IWR(3) is the same as for IWR(1), but for α-particle spectra

IWR(4) is the same as for IWR(1), but for deuteron, triton or ^{3}He spectra depending upon the M3 parameter value (see below)

Card 2. AP, AT, ZP, ZT, QVAL, CLD, IFIS, BARFAC, ISOT, NA, NZ, MC, MP, LDOPT, INVER, ED, IKE, IPCH, PLD, KPLT, CORL, M3

Format(6F5.1, I1, F4.1, I1, I4, 3I5, I1, I4, F4.1, I1, I5, F5.1, I1, A1, I3)

AP (F5.1) is the projectile mass number

AT (F5.1) is the target mass number (AT = 0 means end of calculations)

ZP (F5.1) is the projectile atomic number

ZT (F5.1) is the target atomic number

QVAL (F5.1) is the separation energy of the projectile in MeV: $AP+AT-A_{compound}$. If QVAL=0, the separation energy is calculated from the mass table or by the Myers, Swiatecki, Lysekil (MSL) mass formula [1-3,5] depending upon the MC value (see below). Recommended: QVAL=0.

CLD (F5.1) is the multiplication factor for the level density parameter for a fission channel $a_f=CLD\times A_{compound}/y$. It is close to a_f/a_n ratio. If CLD=0 the ratio equal to 1.0 is used for calculations. Recommended: CLD=0.

IFIS (I1) = 0 use rotating finite range fission barriers due to A.J.Sierk [5]. If IFIS is greater than 0 rotating liquid drop barriers will be used.

BARFAC (F4.1) scales liquid drop or finite range fission barriers. If BARFAC = 0 the default value equal to 1 is used (recommended). (Typically, below the actinide nuclei, values of 0.7 give better results).

ISOT (I1) is not used in the present version of the code. Zero value must be introduced.

NA (I4) number of nuclides of each Z to be included in calculation. The maximal value is 22. If NA = 0 the default value is equal to 11.

NZ (I5) number of Z to be calculated in the emission process. The maximal value is 9. If NZ = 0 the default value is equal to 9.

MC (I5) is the mass option, for separation energies and level density ground state shifts (LDGS) (together with MP). MC=0 means MSL masses including shell corrections; MC=1: MSL masses without shell correction term (used with MP=0 only); MC=2: MSL masses including. shell corrections, but separation energies and/or LDGS at least partly provided by user (see below). If MC increased by

10, the code will substitute the table masses for MSL masses where available and (if so selected by MC=11 or MP=0) subtract pairing or shell correction from the binding energies (BE).

Recommended value: MC=10

MP (I5) is the pairing option. MP=0 means no pairing term in masses; MP=1: pairing term in masses, LDGS calculated from the MSL formula and applied back-shifted. MP=2, as MP=1, but shell corrections are also included in LDGS. MP=3 normal pairing shift, zero for odd-even nuclei, delta added to excitation for odd-odd nuclei (See Section 2.7.3).

Recommended values: MP=3 or MP=1

LDOPT (I1) if zero: the Fermi gas level density with a=A/y (Section 2.7.3 Part 1);

if LDOPT=1: Kataria, Ramamurthy formula with shell correction due to difference of experimental mass and liquid drop correction. See subroutines LDLOAD and LDCALC. (Section 2.7.3 Part 2);

if LDOPT=2: the level density is calculated according to the superfluid nuclear model for all residual nuclei included in calculations (Section 2.7.3 Part 4). The obtained values are stored in a special file.

(The MAXOBN variable in the MAIN code routine restricts the maximal energy of excitation for which level density calculations are performed with LDOPT=2. Use small MAXOBN value reduces the CPU time substantially. MAXOBN must not be lower than [projectile energy + 20 MeV]×10).

if LDOPT=3: the level density calculated in the preceding code run with the same input variables for *Card 2* and LDOPT=2 are taken from the computer file (not recommended).

if LDOPT=4: the level density is calculated according to the Fermi gas model with level density parameter depending upon the excitation energy. (Section 2.7.3 Part 3)

Note, if LDOPT=1 or =4 is selected, the fission width calculation in the code is not consistent with the level density calculation for particle channels. To avoid errors do not use this options for fissile nuclei.

Recommended: for non-fissile nuclei, LDOPT=0 or 2 or 4; for fissile nuclei, LDOPT =0 or 2.

INVER (I4) defines the method of the inverse cross-section calculation. INVER=0: the optical model is used for the inverse reaction calculation. The calculations are performed for the first residuals formed after neutron, proton, α-particle and deuteron, triton or ^{3}He emission. For other residuals the same results are used. INVER=1: user supplied inverse reaction cross-section. INVER=2: inverse reaction cross-sections are evaluated using the sharp cutoff formulas for each residual formed during particle emission.

Note, if INVER=0 the results of inverse reaction cross-sections calculations are recorded in the computer file ALICE92.INV. If INVER is set to 1 the inverse cross-sections are taken from the same file.

Recommended: INVER=0

ED (F4.1) is the energy bin mesh size used for the integration of particle spectra in MeV. The ED value is defined according to the rule: the sum of the incident particle energy in MeV and the separation energy for projectile divided on the ED value must not exceed 300, (EQ+QVAL)/ED < 300.

IKE (I1) if zero, no particle spectra will be printed;

if IKE=1: equilibrium spectra for each residual nuclide will be printed;

if IKE=2: only pre-compound spectra printed;

if IKE=3: as 1+2;

If IKE=4: pre-compound spectra will be printed along with the total particle spectra (pre-compound and equilibrium). The particle production cross-sections are printed;

If IKE=5: γ-spectra will be printed.

Recommended: IKE=4 or 5

IPCH (I5) is the fission barriers reading option. If IPCH =1 or =2, fission barriers may be read in after *Card 2* as (IA,IZ) array, one card for each Z. Format is (11F5.1). Barriers are independent of angular momentum for IPCH=1, and are scaled as rotating liquid drop model (RLDM) barriers [73] for IPCH=2. This option should be used with care as abuses are not disallowed. Recommended: IPCH=0

PLD (F5.1) defines the level density parameter "a" as: a=A/PLD. If PLD is zero the default value equal to 9. is used.

The PLD value is not important, if LDOPT = 2 (superfluid model calculation) is selected for all nuclei or LDOPT= 4 (Ignatyuk, Smirenkin, Tishin model) is selected for non-fissile nuclei.

KPLT (I1) is the cross-section printing option. If KPLT is 1 and the last energy input line is followed by −1. in columns 1-5, excitation functions will be plotted on standard output (NAMRD.FUL). In addition, the cross-section for each residual nuclide will be printed in separate file.

CORL (A1) defines the laboratory or CMS system for the particle spectra printing. If CORL is empty or equal to "C" or "c", the particle

spectra prepared by PLOTSP subroutine will be printed in the CMS system. The printing is controlled by the IWR() array (see *Card 1*) . If CORL=”L” or “l”, the laboratory system is used. CORL makes no influence on the printing of spectra in other subroutines, i.e. for main output listing NAMRD.FUL

M3 (I3) defines number and type of particles to be emitted from each nuclide.

M3 = 1 for neutrons only,

M3 = 2 for neutrons and protons,

M3 = 3 for neutrons, protons, and α-particles,

M3 = 4 for neutrons, protons, α-particles, and deuterons,

M3 = 5 for neutrons, protons, α-particles, and tritons,

M3 = 6 for neutrons, protons, α-particles, and ^{3}He.

Recommended: M3 = 4, 5 or 6 depending upon the task.

Card 3. CNFNCS, TITLE. Format(20A4)

The card allows to read the nonelastic cross-section for incident particle from an external file.

If the first symbol on the *Card 3* begins from “C”, “c”, “*”, “+”, or “–“ the line is considered as a title line. In that case the title (TITLE) of length 80 is printed in the main output file NAMRD.FUL. In this case the nonelastic cross-section will be calculated by the code using the optical model with internal parameters.

If the first symbol on the *Card 3* does not start from “C”, “c”, “*”, “+”, and “–“ the first 12 symbols on this *Card* are considered to be the name of external file (CNFNCS) with the nonelastic cross-section written in two columns format (energy, cross-section). The energy unit is MeV and cross-section is in mb. The first line in the file with cross-section shows ZP, AP, ZT and AT. All formats in CNFNCS file are

free. Data from CNFNCS are used for the total renormalization of the results of calculations.

In the continued calculations with the composite input and with different *Cards 2* (see above) and *Cards 3* the nonelastic cross-sections will be taken from files indicated on each *Card 3*. The absence of the name CNFNCS in the consequent calculations[2] supposes the use of the nonelastic cross-sections taken from the last *Card 2*. (For details see Subroutine READD and RENCS).

Recommended: provide the data for nonelastic cross-section, if necessary, and at the projectile energies above 150 MeV.

Card 4. EQ, RCSS, IADST, IRFR, I3D, JCAL, DLT, JFRAC, JUPPER, JANG, TD, EX1, EX2, TMX, AV, GAV, COST, GDO, IJ, IALP91

Format(2F5.1,3I1,I2,F3.0,I2,2I5,8F5.1,I5,I5)

Card 4 is the energy/options card. This card is repeated for each energy for a given target + projectile (defined by *Card 2*). The maximum number of *Cards 4* with energies EQ, not equal to 0. or −1., must not exceed 20. (The Monte Carlo code version allows up to 100 energies per problem, but does not have many of the added physics listed in Sect.2.)

EQ (F5.1) is the projectile kinetic energy in the laboratory system (MeV).
If EQ = 0., a new problem will start at *Card 2*.
If EQ = −1., previously calculated excitation functions will be plotted. Use of EQ= −1. requires KPLT = 1 and the code run with different EQ values in ascending order.
If EQ = 0. on two successive cards, a normal end of calculations will occur.

[2] i.e. the first symbol on the *Card 3* begins from “C”, “c”, “*”, “+”, or “–“

RCSS (F5.1) is the reaction cross section. If left blank, the reaction cross section will be internally generated by the optical model subroutine for incident neutrons, protons or deuterons and by the parabolic model routine for all other projectiles.

If RCSS is read in, this value entered for RCSS will be used. If a geometry dependent hybrid model and/or fission calculation is selected, and if one wishes to enter transmission coefficients for entrance channel, then the negative of the no. of T(l) to be read must be entered for RCSS. The T(l) will then be read on *Card(s) 5*.

Recommended: set RCSS =0 and provide the external file with nonelastic cross-section, if necessary (*Card 3*)

IADST (I1) If zero: no angular distribution printed , if = 1: yes for neutrons; = 2: yes for protons; =3 for neutrons using Kalbach systematics; = 4 for protons using Kalbach systematics; = 5 for α-particles using Kalbach systematics

Recommended: IADST = 3, 4 or 5 for practical applications.

IRFR (I1) defines a choice for refraction with angular distributions (except Kalbach systematics).

If IRFR=0, no refraction,

If IRFR =1 or 2, entrance channel refraction,

If IRFR =3, Heisenberg entrance and exit refraction,

If IRFR =2, entrance refraction and Heisenberg exit channel.

See discussion in Ref.[58]. For practical applications IRFR=0 is recommended along with IADST =3,4 or 5

I3D (I1) If zero: three dimensional folding for angular distribution, else two dimensional.

JCAL (I2) is the type of calculation option.

JCAL =1, Weisskopf-Ewing evaporation calculation,

JCAL =2, s-wave approximation, liquid drop moment of inertia,

JCAL =3, s-wave approximation, rigid body moment of inertia, (only if entrance channel cross sections calculated by PARAP subroutine, i.e. ZP > 1. and RCSS=0.)

JCAL =0, evaporation-fission competition, partial wave by partial wave. If fission is to be calculated using zero barrier for all J > JCRIT, increase JCAL by 10

Recommended: for non-fissile nuclei JCAL=1, for fissile nuclei JCAL=0

DLT (F3.0) the energy increment for calculating angular distributions (MeV). To avoid errors, i) choose DLT value < 1 only with ED=DLT; ii) do not use fractional number of DLT; iii) use the DLT and ED combination with the DLT/ED value equal to a whole number (e.g. ED=0.5, DLT=1.) In any case, check the printed sum for double-differential cross-section for given ejectile energy and printed value of the particle spectrum.

JFRAC (I2) if a fission calculation is to be only in a specified angular momentum range, this is the lower limit. Recommended: JFRAC=0

JUPPER (I5) is the upper limit of angular momentum, if the range is to be restricted. Recommended: JUPPER=0

JANG (I5) is the option of emitted particles decreasing angular momentum. If = 1, yes; =0, no. If JANG is greater than 100 (less than 200) loop over angular momenta will be for increments of JANG-100 and “no” option on removal of angular momentum holds. If JANG is greater than 200, delta L “yes” option holds, and loop is incremented by jang-200. Use JANG > 100 with JCAL=0 and TD = 0. only. Recommended: JANG = 0

All additional parameters on the *Card 4* are for pre-compound option. User leaves remaining columns blank, if no pre-compound calculation selected.

If TD is positive and EX1 and EX2 are blank, default parameters will be selected. The GDO option may still be selected. For default pre-compound hybrid model, use TD =1., remaining other variables on this *Card* equal to zero. In this case the mean free path will be multiplied by coefficient equal to 2.0 and the additional change of the COST variable will not be effective.

For geometry dependent hybrid model (GDH) calculation, enter TD=1., TMX = 1., and leave all other variables after TD blank. In this case the COST value actually defines the coefficient for the GDH mean free path calculation. Default values means GDO = 1 (see below). Also the IALP91 parameter defines if the multiple pre-compound emission is taken into account for complex particles. See example below in Table 3.

TD (F5.1) is the initial exciton number = p+h.

EX1 (F5.1) is the initial excited neutron number,

EX2 (F5.1) is the initial excited proton number, EX1+EX2=p

If EX1 and EX2 are left blank, the initial neutron and proton numbers are calculated taking into account the ratio of elementary n-p (p-n) and n-n (p-p) cross-sections corrected for the Pauli principle and the Fermi motion, Eqs.(9)-(13).

If EX1= –1 and/or EX2 = –1 the old algorithm [24] is used.

TMX (F5.1) If zero, the hybrid model is selected. If TMX=1, GDH.

AV (F5.1) If AV=0, optical model transition rates; these values should not be used above 55 MeV. If AV=1 nucleon-nucleon mean free paths are used.

Note, if AV=0 and TD=1 (default values choice) the nucleon-nucleon mean free paths will be used.

GAV (F5.1) The parameter is not important for hybrid model calculations; If =0 the standard GDH model will be used; if =1 corrections for (n,p)x or (p,n)x spectra will be performed.

COST (F5.1) The multiplication factor for nucleon free path. The mean free paths are multiplied by COST+1.

GDO (F5.1) If =1, GDH calculation (if any) restricted to initial exciton number, hybrid calc. for higher exciton numbers.

Note, if default parameters are not used for GDH calculations (see page 49: “For geometry dependent hybrid model (GDH) calculation..."), GDO=0 is incorrect.

Recommended: Use TD=1., TMX = 1., and leave all other variables after TD blank for nucleon induced reactions below 62 MeV. Increase COST value for other energies.

IJ (I5) If IJ=1, isospin pre-compound option is selected. (See the text of the code).

Recommended: IJ=0

IALP91 (I5) If = 0 pre-compound α-particle spectra are calculated for nucleon induced reactions. Pre-compound calculations for the emission of other complex particles will be carried out according to the M3 option;

If = 1 no complex particles pre-compound spectra will be calculated;

If = 2, or = 3 the non-equilibrium α-spectra will be calculated for the first pre-compound α-particle and for α-particles emitted after the non-equilibrium emission of neutrons and protons. Pre-compound calculations for other complex particles will be carried out according to the M3 parameter value without consideration of multiple pre-compound emission.

Note, (1) the choice IALP91= 2 or 3 improves the calculation of non-equilibrium α-particle spectra, but not the yields of residuals. (2) Pre-compound α-particle followed by α-emission is not yet included.

If = 4 the same as = 2 (or 3), but for multiple pre-compound deuteron emission. It requires M3 = 4 on *Card 2*.

Recommended: IALP91=0 for the incident nucleon energy below 62 MeV

Card 5. Entrance channel transmission coefficients T(l), needed only, if RCSS < 0., The code will try to read as many T(l) as indicated by the absolute value of RCSS (i.e. it may expect several cards here). Format(10F5.3)

Example of the ALICE/ASH input file

Table 3 shows an example of the code input. The task is the study of the p+^{27}Al reaction at two proton incident energies equal to 62 and 90 MeV.

The calculations are performed for nine chemical elements produced in the nuclear reactions. Eleven isotopes for each element are considered. The inverse reaction cross-sections are calculated using the optical model. The Fermi gas model with a=A/7 is used to calculate nuclear level density. The emission of neutrons, protons, α-particles and tritons is simulated.

The GDH model is used for pre-compound particle spectra calculation for an initial number of excitons (n=3). For other exciton configurations the hybrid model is applied. The mean free path in the GDH model is multiplied by unity for the incident energy 62 MeV and by two for the energy 90 MeV. The pre-compound α-particle emission spectrum is calculated taking into account the multiple pre-compound

emission. The energy histogram step for integration of particle spectra is equal to 0.5 MeV. The spectra will be printed in separate files in laboratory coordinate system. The output file name is P_AL27.

Table 3

```
P_AL27B 1111
  1.0 27.0  1.0 13.0  0.0  0.00 0.00  11    9   10    10   00.504    0  7.00L  5
ABS_AL7.DAT     Proton induced reaction for Al-27
 61.7  0.0000 1 0. 0    0    0  1.0  0.0  0.0  1.0  0.0  0.0  .00  0.0    0    2
 90.0  0.0000 1 0. 0    0    0  1.0  0.0  0.0  1.0  0.0  0.0 1.00  0.0    0    2
0.
0.
```

6. Output data files

The results of calculations are written in several output files. The name of files is defined by the character input variable NAMRD (Sect. 5). A brief description of output files is given below.

NAMRD.FUL is the main output file of the code, which contains detail information about calculations performed.

Printed:
- calculation options;
- binding energies;
- inverse reaction cross-sections (mb)
- reaction cross-section (mb) and partial reaction cross-sections;

- pre-compound particle spectra from the initial exciton state calculated by the GDH model (mb/MeV) and total pre-compound particle spectra;
- production cross-section for residuals (mb). Values are printed in the line starting from "E"=" symbols.
- total particle emission spectra (mb/MeV) and particle production cross-sections (mb), if IKE=4 is selected. If IKE=5 the γ-spectra are printed (mb/MeV), first column: γ-ray energy; second and third column: equilibrium spectrum; 4^{th}: total spectrum (sum of equilibrium and pre-compound) (recommended values); 5^{th}: contribution of the single particle radiative transitions in the pre-compound spectrum according to Ref.[51]; 6^{th}: contribution of the quasi-deuteron model in the pre-compound spectrum according to Ref.[15]; 7^{th}: total spectrum divided on 4π; 8^{th}: sum of the equilibrium spectrum and the pre-compound spectrum evaluated by the approximate approach from Ref.[4]; 9^{th}: sum of the equilibrium spectrum and the pre-compound spectrum evaluated by the approximate approach (see subroutine GAMMA).

NAMRD.CRS includes information about production cross-sections for residuals (mb). Values are printed in line starting from "ER XSECT S(J)=" symbols.

NAMRD.GAS contains calculated particle production cross-sections. First column: the kinetic energy of the incident particle (MeV); 2^{nd}: total α-particle production cross-section; 3^{rd}: pre-compound component of the α-particle production cross-section; 4^{th}: total production cross-section for deuteron, triton or ^{3}He depending from the input M3 parameter; 5^{th}: pre-compound contribution for the last cross-section; 6^{th}: total

proton production cross-section; 7th: total nonelastic cross-section. The cross-sections are printed in mb.

NAMRD.NNN, NAMRD.PPP and NAMRD.TTT contain neutron, proton and triton emission spectra. First column: the energy of the ejectile (MeV) in the LC or CM system depending from the CORL parameter; second column: equilibrium spectrum; third column: pre-compound spectrum; fourth column: total spectrum; fifth column (exists, if CORL="L"): the ratio of the particle energy in the laboratory coordinate system to the channel energy. The spectra are in mb/MeV

NAMRD.DDD and NAMRD.AAA include deuteron and α-particle emission spectra. If multiple pre-compound emission is not considered (IALP91=0 in the input file) the format of the data is the same as for NAMRD.NNN, *.PPP and *.TTT files. In the case the multiple pre-compound option is turned on, the file contains the detailed information about deuterons and α-particles emitted after the pre-compound neutron and proton emission, first column: the particle energy in the LC or CM system; 2nd: equilibrium spectrum; 3rd: spectrum for the first pre-compound particle (deuteron or α-particle); 4th: the pre-compound spectrum for the particle emitted after the pre-compound neutron emission; 5th: the same as 4th, but after proton emission; 6th: not used yet and reserved for the deuteron-deuteron or α-α multiple emission; 7th: total pre-compound spectrum; 8th: total particle emission spectrum. Spectra are written in mb/MeV.

7. Publications relating to the ALICE/ASH code

The ALICE/ASH code has been used for

1 the calculation of residual nuclei yields in Refs.[21,66,67,76,90,96]

2 the calculation of the energy and angular distribution of nucleons and composite particles in nuclear reactions [8,10,12,16,17,28,74]

3 the calculation of the photon spectra in nuclear reactions induced by nucleons of intermediate energy [15,83]

4 prediction of the heavy cluster (^{7}Be) yield in nucleon induced reactions including the pre-equilibrium emission [18]

5 recoil spectra and damage cross-sections calculations [83]

6 the calculation of helium production cross-sections [16,75,89,100,101]

7 the calculation of the fission cross-section, fission product yields and particle production cross-sections and spectra for heavy nuclei [19,77,78-81,85,95,98]

8 formation evaluated data files for incident neutrons and protons at intermediate energies [11,28,65,79-88,91-94,97,99].

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The text of the ALICE/ASH code

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* ALICE/ASH code
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* Last changes 03/2005
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      IMPLICIT REAL*8 (A-H,O-Z)
      Character*12 Namful,Namsho,Namgas, CNFNCS
      Character*8  Namrd,Partix(3)
      Character CORL*1
      COMMON/GIANI/PRE, SIGT(500),SIGAM(500),SIGPRE(500),GSP(500),
     # EQGAM(500),IGAM /QQ/GOW(3000)
      COMMON/Q/ Q(300),SP(300),SIFIS(300),GAMFT(300),T(300),PAIRX(4)
     #,SCALE(22,9),RD(4) /CS/CRSUM
      COMMON/PAR3/EQ,SIGML(300),ACRS(300) /LAB10/POW(4,3000),GAM(3000)
      DOUBLE PRECISION POW,GAM,SQ11
      COMMON/SF6/AOZ,ZOZ,EN(4,300)
      COMMON/SHFT/QVAL,AP,AT,ZP,ZT,CLD,MC,MP,INVER,IKE,IPCH,BARFAC
      COMMON/UG/IZ,IA /NHY2/GDO,BISP /PL2/SUM(22,9,20)
      COMMON/S1/JFRAC,JUPPER /SF/M3,KPLT
      COMMON/SFT9/K5,PLD,JMAX,C(4),DELT,ALT /PAR2/CNCSS
      COMMON/PL8/JAMMA(10,24),NULIM(10,24) /PL1/ECM(70)
      COMMON/NAME/K2 /HJK/RCSS,JANG /SS/SOR,RR
      COMMON/NR34/NR3,NR4,KE5,TEM(36),I3D,IRTST,I3T2,IJKL
      COMMON/PARFS/DELRR(300),K6
      COMMON/SHFT2/K3,FS(22),DSP(22),BRR(22),DER(22),ER(22),FISS,SUMIZ
     #,CX(22),BILSUM,JCAL,XMISS
      COMMON/SHFT3/CORG(30) /PL4/CRS(22,9)
      COMMON/NHY/TD,EX1,EX2,TMX,AV,GAV,IJ,COST,JL,JI,JJ,B(3)
      COMMON/PARO/PQ,CROSS /HYB2/PP(3,22,300) /SFT5/EXC(10,24),XMAX
      COMMON/PL3/EB(70),RCSP(70),ZEE,AMASS,PLEX,NEPR
      CHARACTER*4 SYMB,SYMBP,SYMBS
      COMMON/LYM1/BE(11,24,4),SYMB(11,24),PAIR(11,24),SYMBP(11,24),
     #SYMBS(11,24),XMAS(11,24),DELSHL(11,24),AMAS(11,24)
      COMMON/PL7/MAS /LAB3/SIG(4,300) /PL5/TITLE(20),NA,NZ
      COMMON/SCR/K9 /WILD/BEXP(22,9) /ISO/QPN(3),QPNC /INCR/ED
      COMMON/TST/TEST /SEND/IRFR,DLT,IADST
      COMMON/GAM/PPGAM(300),GMSPEC(300),LA,BETA,AMS
      COMMON/IST/ISOT,FRACTS,FRACT,CCRS(32,9,20)
      COMMON/IST1/EEN(4,300,20),IIKL, ENGBUF(20),KNZ,EXD,IDELM
      COMMON/CSHEL/SHEL(11,24,2) /GR/RINT(500) /GRL/AGA,AXSG
      COMMON/IALPH/IALPHA /RATMP/RATMP1,SUMAPR,SUMDER
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      COMMON/OBN2/MAXOBN /ADDPC1/IWR(4),NAMRD /HOT/KPG,MPG
      COMMON/LCSCMS/LCS
C
C----------------------Output files-----------------------------------
      Open(1,file='ALICE92.INV')
      Open(2,file='ALICE92.INV')
      Open(5,file='ALICE.DAT')
                Read(5,111)Namrd,(IWR(i),i=1,4)
111             Format(a8,4i1)
                Namsho=Namrd//'.crs'
                Namful=Namrd//'.ful'
                Namgas=Namrd//'.gas'
      Open(7,file=Namful)
      Open(8,file=Namsho)
      Open(9,file='density.lev',form='unformatted')
C Gas production cross-section printing (See Subr. PLOTSP)
      Open(10,file=Namgas)
C Files for (x,2n) (e.g.(n,2n) and other selected reactions
      Open(21,file='X2N.0')
      Open(22,file='XP.0')
      Open(23,file='XA.0')
      Open(24,file='XNA.0')
      Open(25,file='XNP.0')
C-----------------------------------------------------------------------
      DATA PARTIX/8HDEUTERON,8HTRITON  ,8HHE-3    /
      Write(7,660)

* MAXOBN
      MAXOBN=3000
      CHANGEXS=0
      ISOT=0
      JSOT=0
      FRACT=0.D0
      NEPR=1
      SELMAX=0.D0
      GO TO 10000
10008 Write(7,10009)
10009 FORMAT('ISOTOPICALLY WEIGHTED CROSS SECTIONS AND SPECTRA FOLLOW')
      JSOT=0
      K3=5
      CALL SHAFT
10000 FRACTS=0.D0
      DO 10001 I=1,9
      DO 10002 J=1,32
      DO 10002 K=1,20
      ENGBUF(K)=0.D0
      CCRS(J,I,K)=0.D0
10002 CONTINUE
10001 CONTINUE
      DO 10003 I=1,4
      DO 10004 J=1,300
      DO 10004 K=1,20
      EEN(I,J,K)=0.D0
10004 CONTINUE
10003 CONTINUE
      FRACTS=0.D0
      KSOT=0
      IAREF=0
      IDELM=0
```

```
C
    5 READ(5,655)AP,AT,ZP,ZT,QVAL,CLD,IFIS,BARFAC,ISOT,NA,NZ,MC,MP,LDOPT
     1,INVER,ED,IKE,IPCH,PLD,KPLT,CORL,M3
      WRITE(*,5604)ZT,AT
5604  FORMAT('                Nucleus ',f5.1,f6.1)
C
                                                              LCS=0
                              If(CORL.eq.'l'.or.CORL.eq.'L') LCS=1

                 KPG= 0
      IF(M3.eq.5) KPG= 1
      IF(M3.eq.6) KPG= 2
      IF(M3.gt.4) M3 = 4
C
            AGA =1.00000
            AXSG=1.00001
                    LDEX =-1
      IF(LDOPT.EQ.3)LDEX = 0
      IF(LDOPT.EQ.3)LDOPT= 2
C
      IGAM=0
      IF(IKE.GT.4)IGAM=1
      IF(IKE.GT.4)IKE=IKE-5
      PRE=0.D0
      IF(AP.NE.0.D0)IECOUN=0
      IF(ED.EQ.0.D0)ED=1.D0
      AMS=AP+AT
      IF(ISOT.GT.0)FRACT=CLD
      IF(ISOT.GT.0)CLD=0.D0
      IF(ISOT.GT.0)KSOT=KSOT+1
      IF(ISOT.GT.0.AND.KSOT.EQ.1)IAREF=AP+AT
      IF(ISOT.GT.0)EF=ED/FRACT
      IF(ISOT.EQ.0)EF=ED
       IF(ISOT.GT.0)FRACTS=FRACTS+FRACT
      IF(ISOT.GT.0)KNZ=NZ
      IF(ISOT.GT.0)EXD=ED
      IF(ISOT.GT.0.AND.KSOT.GT.1)IDELM=IAREF-AP-AT
       IPARM=0
      IPARM=MC+MP+NA+NZ
      IF(IPARM.GT.0)GO TO 80001
      MC=10
      MP=3
      INVER=2
      IKE=4
      IF(AP.NE.0.D0)Write(7,80002)
80002 FORMAT(//,10X,  ' PARAMETERS SELECTED INTERNALLY UNDER DEFAULT OPT
     1ION: MC=10,MP=3,INVER=2,ED=1.,IKE=4')
80001 CONTINUE
      IF(AP.EQ.0.D0.AND.JSOT.GT.0)GO TO 10008
      JSOT=ISOT
      IF(ISOT.GT.0)Write(7,77777)FRACT
77777 FORMAT(//,' WEIGHTING OPTION SELECTED;ABUNDANCE THIS ISOTOPE = ',
     1F10.5)
      IIKL=0
      AMS=AP+AT
      IF(ED.EQ.0.D0)ED=1.D0
      PQ=0.D0
      IF(NA.EQ.0)NA=11
      IF(NZ.EQ.0)NZ=9
```

```
      K5=0
      K9=0
      IF(INVER.EQ.2)K9=1
      IF(AT)10,10,15
   10 If(CHANGEXS.ne.0.0) then
                         Write(7,2685)CNFNCS
                         Write(8,2685)CNFNCS
                         endif
      Write(7,690)
      MX=0
      STOP
   15 PLEX=DFLOAT(NZ)
      K6=0
      GIM=0.D0
      IF(KPLT.GT.0)K2=1
      IF(KPLT.GT.0)CALL PLT
      NEPR = 0
      K3=0
      IF(IPCH.EQ.0)GO TO 18
      IF(IPCH.EQ.2)Write(7,9877)
      IF(IPCH.EQ.1)Write(7,9878)
9877  FORMAT(' FISSION BARRIERS USER SUPPLIED AND SCALED PRO
     1PORTIONALLY WITH RLDM VS. J')
9878  FORMAT(' FISSION BARRIERS USER SUPPLIED AND ARE NOT J DEPENDENT')
      DO 16 IZ=1,NZ
      READ(5,9876)(BEXP(IA,IZ),IA=1,NA)
   16 Write(7,9876)(BEXP(IA,IZ),IA=1,NA)
C
   18 READ(5,7005) TITLE
      Write(7,7475)TITLE
C
      CALL READD(CHANGEXS,CNFNCS)
C
      IF(BARFAC.EQ.0.D0)BARFAC=1.D0
      IF(NZ.GT.9)Write(7,7010)
      IF(NA.GT.22)Write(7,7015)
      IF(NZ.GT.9)NZ=9
      IF(NA.GT.22)NA=22
      IF(M3.GT.4)M3=3
      IF(M3.EQ.0)M3=3
      IF(PLD.EQ.0.D0)PLD=9.D0
      AMASS=AP+AT
      ZEE=ZP+ZT
C------- PARAMETER FOR LEVEL DENSITY  RR
      RR=AMASS/PLD
      QJMAX=DFLOAT(90)/ED
      JMAX=IDINT(QJMAX)
      IF(JMAX.GT.300)JMAX=300
      TENED=10.D0*ED
      Write(7,7465)QVAL,AP,AT,ZP,ZT,CLD,NA,NZ,MC,MP,INVER,IKE,IPCH,
     1 PLD,KPLT,M3
      WRITE(8,7465)QVAL,AP,AT,ZP,ZT,CLD,NA,NZ,MC,MP,INVER,IKE,IPCH,
     1 PLD,KPLT,M3
      Write(7,7466)LDOPT
      WRITE(8,7466)LDOPT
C
      IF(NA.GT.0.AND.NZ.GT.0)GO TO 7025
 7020 NZ=5
      PLEX=DFLOAT(NZ)
```

```
      NA=10
 7025 IF(CLD)7030,7030,7035
 7030 CLD=1.D0
 7035 CONTINUE
C
      IF(LDOPT.EQ.1)MP=1
C
 1000 FORMAT(' QVAL=0. ; Q VALUE WILL BE CALCULATED INTERNALLY')
 1001 FORMAT(' PROJECTILE MASS NO = ',F5.1,
     1'  PROJECTILE ATOMIC NO =',F5.1,/,
     2' TARGET MASS NO =      ',F5.1,
     3' TARGET ATOMIC NO =     ',F5.1/)
 1002 FORMAT(' CLD =',F5.1,'   RATIO OF NUCLEON TO FISSION LEVEL DENSITY
     3 PARAMETERS')
 1003 FORMAT(' CLD =',F5.3,'   ISOTOPIC ABUNDANCE OF THIS ISOTOPE')
 1004 FORMAT(' NA = ',I5,'   CALCULATE UP TO NA-1 NEUTRONS OUT')
 1005 FORMAT(' NZ = ',I5,'   CALCULATE UP TO NZ-1 CHARGES OUT')
 1006 FORMAT(' MC=0   MYERS SWIATECKI LYSEKIL (MSL) MASSES INCL.',
     1' SHELL CORR.')
 1007 FORMAT(' MC=1   MSL MASSES WITHOUT SHELL CORR., BUT SEPARATION',
     1' ENERGIES',/,
     2'       AND/OR LDGS AT LEAST PARTLY PROVIDED BY USER (SEE BELOW)')
 1008 FORMAT(' MC = ',I5,'   EXPERIMENTAL MASSES USED WHERE AVAILABLE (S
     2EE COMMENT CARDS IN MAIN FOR DESCRIPTION OF MC, MP OPTIONS)')
 1009 FORMAT(' MP =     0   NO PAIRING TERM IN MASSES')
 1010 FORMAT(' MP =     1   PAIRING TERM IN MASSES, LDGS CALCULATED FROM
     1 MSL FORMULA AND APPLIED BACKSHIFTED')
 1011 FORMAT(' MP =     2    PAIRING TERM IN MASSES, LDGS CALCULATED FRO
     1M MSL FORMULA WITH SHELL CORRECTION AND BACKSHIFTED')
 1012 FORMAT(' MP =     3   NORMAL PAIRING SHIFT, ZERO FOR ODD-EVEN NUCL
     1EI, DELTA ADDED TO EXCITATION FOR ODD-ODD NUCLEI, ETC.')
 1013 FORMAT(' INVER =  0   OPTICAL MODEL USED TO CALCULATE INVERSE CROS
     1S SECTIONS')
 1014 FORMAT(' INVER =  1   USER SUPPLIED INVERSE CROSS SECTIONS')
 1015 FORMAT(' INVER =  2   SHARP CUTOFF METHOD USED TO CALCULATE',
     1'INVERSE CROSS SECTIONS')
 1016 FORMAT(' PLD =',F5.1,'   LEVEL DENSITY PARAMETER = ACN /',F4.1)
 1017 FORMAT(' IKE =    0   NO PARTICLE SPECTRA WILL BE PRINTED')
 1018 FORMAT(' IKE =    1   EQUILIBRIUM SPECTRA FOR EACH NUCLIDE WILL BE
     1 PRINTED')
 1019 FORMAT(' IKE =    2   ONLY PRECOMPOUND SPECTRA PRINTED')
 1020 FORMAT(' IKE =    3   EQUILIBRIUM SPECTRA FOR EACH NUCLIDE AND PRE
     1COMPOUND SPECTRA WILL BE PRINTED')
 1021 FORMAT(' IKE =    4   PRECOMPOUND SPECTRA WILL BE PRINTED AS WELL
     1AS THE SUM',/,'(OVER ALL EMITTING NUCLIDES AND ALL PARTIAL WAVES)
     2OF PRECOMPOUND PLUS EQUILIBRIUM SPECTRA')
 1022 FORMAT(' M3 =     1   NEUTRON EMISSION ONLY')
 1023 FORMAT(' M3 =     2   NEUTRON AND PROTON EMISSION')
 1024 FORMAT(' M3 =     3   NEUTRON, PROTON AND ALPHA EMISSION')
 1025 FORMAT(' M3 =     4   NEUTRON, PROTON, ALPHA AND DEUTERON EMISSION
     3')
10251 FORMAT(' M3 =     4   NEUTRON, PROTON, ALPHA AND TRITON EMISSION')
10252 FORMAT(' M3 =     4   NEUTRON, PROTON, ALPHA AND HE-3 EMISSION')
 1027 FORMAT(' LDOPT =  0   FERMI GAS LEVEL DENSITY')
 1028 FORMAT(' LDOPT =  1   KATARIA RAMAMURTHY LEVEL DENSITY OPTION SELE
     1CTED - MP SET TO 1, BACKSHIFTED PAIRING REQUIRED')
 1029 FORMAT(' LDOPT =  2   IGNATYUK LEVEL DENSITY')
10294 FORMAT(' LDOPT =  4   FERMI-GAS: IGNATYUK,SMIRENKIN,TISHIN')
 1030 FORMAT(//,' *** INPUT OPTIONS SELECTED ***',//)
```

```
 1031 FORMAT(' IFIS =   0   ROTATING FINITE RANGE BARRIERS OF A.J. SIERK
     1 USED')
 1032 FORMAT(' IFIS =',I5,'  ROTATING LIQUID DROP BARRIERS OF C-P-S USED
     1')
 1033 FORMAT(' BARFAC=',F5.1,' MULTIPLIER OF FISSION BARRIER')
 1034 FORMAT(' ED = ',F5.2,'   ENERGY BIN MESH SIZE IN MEV')
 1035 FORMAT(' IPCH =   1  FISSION BARRIERS READ IN AFTER CARD #1 AND AR
     1E INDEPENDENT OF ANG. MOMENTUM')
 1036 FORMAT(' IPCH =   2  FISSION BARRIERS READ IN AFTER CARD #1 AND AR
     1E SCALED AS ROTATING LIQUID DROP MODEL BARRIERS')
 1037 FORMAT(' KPLT =   1   EXCITATION FUNCTIONS WILL BE PLOTTED ON STAN
     1DARD OUTPUT IF LAST ENERGY INPUT LINE IS FOLLOWED BY -1., COL 1-5'
     1)
 1038 FORMAT('              GAMMA SPECTRA WILL BE PRINTED')
C
      Write(7,1030)
      IF(QVAL.EQ.0.D0)Write(7,1000)
      Write(7,1001)AP,ZP,AT,ZT
      IF(ISOT.EQ.0)Write(7,1002)CLD
      IF(IFIS.EQ.0)Write(7,1031)
      IF(IFIS.GT.0)Write(7,1032)IFIS
      Write(7,1033)BARFAC
      IF(ISOT.GT.0)Write(7,1003)FRACT
      Write(7,1004)NA
      Write(7,1005)NZ
      IF(MC.EQ.0)Write(7,1006)
      IF(MC.EQ.1)Write(7,1007)
      IF(MC.GE.10)Write(7,1008)MC
      IF(MP.EQ.0)Write(7,1009)
      IF(MP.EQ.1)Write(7,1010)
      IF(MP.EQ.2)Write(7,1011)
      IF(MP.EQ.3)Write(7,1012)
      IF(LDOPT.EQ.0)Write(7,1027)
      IF(LDOPT.EQ.1)Write(7,1028)
      IF(LDOPT.EQ.2)Write(7,1029)
      IF(LDOPT.EQ.4)Write(7,10294)
      IF(INVER.EQ.0)Write(7,1013)
      IF(INVER.EQ.1)Write(7,1014)
      IF(INVER.EQ.2)Write(7,1015)
      Write(7,1034)ED
      IF(IKE.EQ.0)Write(7,1017)
      IF(IKE.EQ.1)Write(7,1018)
      IF(IKE.EQ.2)Write(7,1019)
      IF(IKE.EQ.3)Write(7,1020)
      IF(IKE.EQ.4)Write(7,1021)
      IF(IGAM.EQ.1)Write(7,1038)
      IF(IPCH.EQ.1)Write(7,1035)
      IF(IPCH.EQ.2)Write(7,1036)
      Write(7,1016)PLD,PLD
      IF(KPLT.EQ.1)Write(7,1037)
      IF(M3.EQ.1)Write(7,1022)
      IF(M3.EQ.2)Write(7,1023)
      IF(M3.EQ.3)Write(7,1024)
      IF(M3.EQ.4.AND.KPG.EQ.0)Write(7,1025)
      IF(M3.EQ.4.AND.KPG.EQ.1)Write(7,10251)
      IF(M3.EQ.4.AND.KPG.EQ.2)Write(7,10252)
C
      DO 7040 KK=1,10
      DO 7040 JJ=1,24
```

```
 7040 EXC(KK,JJ)=0.D0
 7045 SOR=DSQRT(RR*100.D0)
C  LEVEL DENSITY PARAMETER FOR FISSION CHANNEL  RF
      RF=AMASS*CLD/PLD
C     LEVEL DENSITY PARAMETERS FOR  PARTICLES CHANNELS POW(I)
      RD(1)=(AMASS-1.D0)/PLD
      RD(2)=(AMASS-1.D0)/PLD
      RD(3)=(AMASS-4.D0)/PLD
      IF(KPG.EQ.0) RD(4)=(AMASS-2.D0)/PLD
      IF(KPG.EQ.1) RD(4)=(AMASS-3.D0)/PLD
      IF(KPG.EQ.2) RD(4)=(AMASS-3.D0)/PLD
C CHANGE 25 - SEPTEMBER - 1993        FOR GAMMA CHANEL
      RDD=RD(1)
C -------------------------------
C     LEVEL DENSITY  FOR  PARTICLES CHANNELS POW(I)
      DO 7050 L=1,M3
      DO 7050 IB=1,3000
      BJ=DFLOAT(IB)/10.D0-.05D0
      SQ=2.D0*DSQRT(RD(L)*BJ)-SOR
      SQ11=SQ
 7050 POW(L,IB)=(1.D0/(1.D0+BJ**1.25))*DEXP(SQ11)
C----- LEVEL DENSITY FOR GAMMA CHANNEL  GOW(I)
      DO 7051 IB=1,3000
      BJ=DFLOAT(IB)/10.D0-.05D0
      SQ=2.D0*DSQRT(RDD*BJ)-SOR
      SQ11=SQ
 7051 GOW(IB)=(1.D0/(1.D0+BJ**1.25))*DEXP(SQ11)
C 7051 GOW(IB)= .5*(1.D0/(1.D0+BJ**1.25))*DEXP(SQ11)
      CONST=33.0D0
C----- LEVEL DENSITY FOR FISSION CHANNEL  GAM(I)
      RF=CLD*RR
      DO 7055 IB=1,3000
      BJ=DFLOAT(IB)*0.10D0-0.05D0
      SR=2.D0*DSQRT(RF*BJ)-SOR
      SQ11=SR
 7055 GAM(IB)=CONST*(1.D0/(1.D0+BJ**1.25))*DEXP(SQ11)
C     GET SEPARATION ENERGIES AND LEVEL DENSITY GROUND STATE SHIFTS
      CALL LYMASS(ZEE,AMASS,NZ,NA,MC,MP,AP,AT,ZP,ZT,QVAL,LDOPT)
C
      NIA=IDINT(AMASS)
      IIP=IDINT(ZEE)
      EX=2.D0
      TEN=10.D0*EX+0.05D0
      IT=IDINT(TEN)
      IF=IT-1
      TEMP=DSQRT(EX/RF)
      D=DEXP(EX/TEMP)
      CQ1=GAM(IT)/D
      DO 17055 IB=1,IF
      E=DFLOAT(IB)*0.1D0-0.05D0
17055 GAM(IB)=CQ1*DEXP(E/TEMP)
      Write(7,12221)
12221 FORMAT(1X,'FULL LEVEL DENSITY FOR TEMPERATURE GOW CALCULATED')
      DO 17056 IB=2,3000
17056 GAM(IB)=GAM(IB)+GAM(IB-1)
C
      TEMP=DSQRT(EX/RDD)
      D=DEXP((EX)/TEMP)
      CQ1=GOW(IT)/D
```

```
      DO 27048 IB=1,IF
      E=0.10D0*DFLOAT(IB)-0.05D0
      GOW(IB)=CQ1*DEXP((E)/TEMP)
27048  CONTINUE
      DO 7047 L=1,M3
      TEMP=DSQRT(EX/RD(L))
      D=DEXP((EX)/TEMP)
      CQ1=POW(L,IT)/D
      DO 7048 IB=1,IF
      E=0.10D0*DFLOAT(IB)-0.05D0
      POW(L,IB)=CQ1*DEXP((E)/TEMP)
7048  CONTINUE
7047  CONTINUE
C-----------------23 - SEPTEMBER - 1993
C     CHANGE TO AVOID FISSION COMPETITION PRINTING
      GAM(1)=0.D0
C
      DO 7150 I=1,300
      EQGAM(I)=0.D0
      SIGT(I)=0.D0
      GMSPEC(I)=0.D0
      SIGAM(I)=0.D0
      SIGPRE(I)=0.D0
 7150 CONTINUE
      DO 71580 I=1,500
71580  RINT(I)=0.D0
      Write(7,12121)
12121 FORMAT(/'LEVEL DENSITY FOR GAMMA CALCULATED RO WITH A/9.')
      PRE=1.D0
      CALL GAMMA
      PRE=0.D0
      KX=IDINT(40.D0/ED)
C     KX=IDINT(80.D0/ED)
      IF(KX.GT.500)KX=500

      RINT(1)=1.D-10
C      RINT(1)=0.D0
      DO 6144 IT=2,KX
      DO 6143 IF=2,IT
      JF=IF-1
      EG=DFLOAT(JF)*ED
      AIB=(DFLOAT(IT)*ED-EG)*10.D0+0.05D0
      IB=IDINT(AIB)
      RTEM=SIGT(JF)*GOW(IB)
C     RTEM=SIGT(JF)*POW(1,IB)
      RINT(IT)=RINT(IT)+RTEM
 6143 CONTINUE
C   NOTE THAT SIGT(I) IS E*E*SIG(E) FROM SUBROUTINE GAMMA
 6144 CONTINUE
      DO 6145 IT=2,KX
C
C-----------(2*SG+1)/4./(M1*C**2)=2./4./931.5016MEV = 5.366E-4
      RINT(IT)=5.36766D-4*RINT(IT)*ED
 6145 CONTINUE
      NIA=IDINT(AMASS)
      IIP=IDINT(ZEE)
C
C     GET INVERSE CROSS SECTIONS, SEE CALL SIGI ALSO
      IF(INVER.EQ.0)WRITE(2,6550)AP,AT,ZP,ZT,ED,M3
```

```
      IF(INVER.EQ.0)GO TO 35
      IF(INVER.EQ.1)GO TO 25
      IF(INVER.EQ.2)GO TO 44
   25 Write(7,680)
      READ(1,6550)AP8,AT8,ZP8,ZT8,ED8,M38
      IF(AP.NE.AP8 .OR. AT.NE.AT8 .OR. ZP.NE.ZP8 .OR. ZT.NE.ZT8. OR.
     $   ED.NE.ED8 .OR. M3.GT.M38) GOTO 65500
      EDJMAX=DFLOAT(JMAX) * ED
      DO 30 K = 1,M3
      READ(1,625)(SIG(K,JE),JE=1,JMAX)
      GO TO (895,805,815,825),K
  895 Write(7,800)
  800 FORMAT(/,38X,'USER PROVIDED NEUTRON INVERSE CROSS SECTIONS'/)
      GO TO 835
  805 Write(7,810)
  810 FORMAT(//38X,'USER PROVIDED PROTON INVERSE CROSS SECTIONS'/)
      GO TO 835
  815 Write(7,820)
  820 FORMAT(//39X,'USER PROVIDED ALPHA INVERSE CROSS SECTIONS'/)
      GO TO 835
  825 Write(7,830)PARTIX(KPG+1)
  830 FORMAT(//37X,'USER PROVIDED ',A8,' INVERSE CROSS SECTIONS'/)
  835 Write(7,840) EDJMAX
  840 FORMAT('0INVERSE REACTION CROSS SECT. FOR E = 1 TO ',F7.2,' MEV')
      Write(7,845) (SIG(K,JE),JE=1,JMAX)
  845 FORMAT ( 1H ,10F7.0)
   30 CONTINUE
C
      GO TO 40
   35 CONTINUE
      WRITE(*,5602)
5602  FORMAT(/1X,'Calculation of INVERSE CROSS-SECTIONs via OPTICAL ',
     $'MODEL...')
      CALL OVER
C
   40  K3=3
C
      CALL SHAFT
C
   44 CONTINUE
C
C IALP91 = 0   alpha precompound calculation will be performed for single
C              nonequilibrium alpha-particle. Precompound calculations
C              for other complex particle are carried out according to
C              M3 parameter
C IALP91 = 1   no complex particles precompound calculations
C IALP91 = 2,3 alpha precompound calculation will be performed for first
C              and secondary alpha particle emitted in the nonequlibrium
C              process. Precompound calculations for other complex
C              particle are carried out according to M3 parameter without
C              secondary precompound emission taken into account.
C IALP91 = 4   the same as IALP91=2, but for multiple deuteron pre-
C              compound emission. It requires M3=4
C
   50 READ(5,630)EQ,RCSS,IADST,IRFR,I3D,JCAL,DLT,JFRAC,JUPPER,JANG,TD,EX
     11,EX2,TMX,AV,GAV,COST,GDO,IJ,IALP91
C
      If(EQ.ne.0.0)WRITE(*,5603)EQ
5603  FORMAT(' Energy =',f7.2)
```

```
C
                                    MPG = 0
      IF(IALP91.eq.2.or.IALP91.eq.3) then
                                    MPG = 1
                                    IALP91 = 0
                                    endif
      IF(IALP91.eq.4) then
                      MPG = 2
                      IALP91 = 0
                      endif
      IALPHA=0
      IF(IALP91.EQ.0.AND.EQ.NE.0.0)IALPHA=1
C
      IF(IALPHA.EQ.1) then
                      Write(7,6783)PARTIX(KPG+1)
                      WRITE(8,6783)PARTIX(KPG+1)
                      endif
      IF(MPG.EQ.1) then
                   WRITE(7,67831)
                   WRITE(8,67831)
                   endif
      IF(MPG.EQ.2) then
                   if(KPG.ne.0.or.M3.ne.4) then
                                           write(7,67833)
                                           write(8,67833)
                                           stop
                                           else
                   WRITE(7,67832)
                   WRITE(8,67832)
                                           endif
                   endif
6783  FORMAT(1X,' ++++',28X,'ALPHA    PRECOMPOUND CALCULATION INCLUDED',
     +      /1X,' ++++',28X,A8,' PRECOMPOUND CALCULATION INCLUDED')
67831 FORMAT(/1X,' ++++',28X,'MULTIPLE PRECOMPOUND ALPHA-PARTICLE',
     +      ' EMISSION SIMULATED')
67832 FORMAT(/1X,' ++++',28X,'MULTIPLE PRECOMPOUND DEUTERON EMISSION',
     c      ' SIMULATED')
67833 FORMAT(/1X,120('ERROR. (see below)'/)//' Deuteron multiple preco',
     c'mpound option is turned ON, but  M3 option (CARD1) is INCORRECT')
      IF(LDOPT.GT.1.AND.  LDOPT.ne.4 .and.
     #(EQ+20.).GT.DFLOAT(MAXOBN/10))  GOTO 76543
C
      DO 7152 I=1,300
      EQGAM(I)=0.D0
      GMSPEC(I)=0.D0
      SIGAM(I)=0.D0
      SIGPRE(I)=0.D0
7152  CONTINUE
      LDEX=LDEX+1
      IF(LDOPT.EQ.2.AND.LDEX.GT.0)REWIND 9
C
      IF(IPARM.EQ.0)JCAL=1
      IF(IPARM.EQ.0)TD=1.
      IF(IPARM.EQ.0.AND.AP.EQ.1.D0)TMX=1.
C
      DIF=0.D0
      IIKL=IIKL+1
      IF(ISOT.GT.0.AND.FRACTS.GT.FRACT)DIF=EQ-ENGBUF(IIKL)
      IF(DIF.NE.0.D0)Write(7,10006)
```

```
      IF(DIF.NE.0.D0)STOP
      ENGBUF(IIKL)=EQ
10006 FORMAT('  ENERGIES OF DIFFERENT ISOTOPES DO NOT MATCH;ABORT')
6781  FORMAT(//,10X,'FISSION BARRIERS AND ROTATING GROUND STATE ENERGIES
     1 CALCULATED VIA ROTATING FINITE RANGE MODEL OF SIERK'//)
6782  FORMAT(//,10X,'FISSION BARRIERS AND ROTATING GROUND STATE ENERGIES
     1 CALCULATED FROM ROTATING LIQUID DROP MODEL'//)
C
C   ADD READ FOR ISOSPIN QCD VALUES IF IJ EQ 1
C
      QPN(1)=0.D0
      QPN(2)=0.D0
      QPNC=0.D0
      IF(IJ.EQ.1)READ(5,6789)QPN(1),QPN(2),QPNC
6789  FORMAT(3F10.2)
C
      IF (EQ) 620,5,80
C
C
C     CALC MAX. EXCITATION EACH NUCLIDE, EVALUATE AND PRINT OPTIONS
   80 JDELT=1
      IECOUN=IECOUN+1
C      ECOUN(IECOUN)=EQ
      IF (JANG.GT.300) JDELT=JANG-300
      IF (JANG.GT.300) JANG=1
      IF (JANG.GT.100) JDELT=JANG-100
      IF (JANG.GT.100) JANG=0
      JSW=0
      IF (JCAL.GE.9) JSW=1
      IF (JCAL.GE.9) JCAL=JCAL-10
C
      IF(TD.GT.0.D0.AND.JCAL.GT.1)Write(7,82)
      IF(TD.GT.0.D0.AND.JCAL.GT.1)JCAL=0
C
      IF(DLT.EQ.0.D0)DLT=5.D0
      IF (TD.EQ.0.D0.OR.JCAL.NE.-1) GO TO 81
      Write(7,82)
   82 FORMAT (1H ,80('*')/' PRECOMPOUND CALCULATION INCOMPA',
     1 'TIBLE WITH 1 MEV BIN ROTATION GRID, JCAL RESET TO 0.'/
     2 1H ,80('*'))
      JCAL=0
   81 DO 55 M=1,300
      DELRR(M)=0.D0
      T(M)=0.D0
   55 SIGML(M)=0.D0
      DO 60 N=1,300
      DO 60 M=1,4
   60 EN(M,N)=0.D0
      IF(JCAL.NE.1)K6=1
   62 CONTINUE
C
      IF(JCAL.NE.1)CALL FISROT(A,Z,AN,AL,DELR,DELSP,ERO,BARFAC)
C
      PQ=EQ*AT/AMASS
      BAR=300.D0
      AFIS=0.D0
      NEPR=NEPR+1

      XMAX=PQ+QVAL
```

```
         XLIM2=XMAX/ED
       IF(XMAX.LE.0.D0)GO TO 50
       IF(XMAX.GT.300.D0)Write(7,56)
56     FORMAT(' COMPOUND NUCLEUS EXCITATION EXCEEDS 300 MEV LI
      1MIT. NEXT BOMBARDING ENERGY WILL BE ATTEMPTED.')
       IF(XMAX.GT.300.D0)GO TO 50
          IF(XLIM2.GT.300.D0)Write(7,5601)
5601   FORMAT(///'+++++ DIMENSION OF ARRAYS HAS BEEN EXCEEDED...',
      1' NEXT BOMBARDING ENERGY WILL BE ATTEMPTED.'///)
          IF(XLIM2.GT.300.D0)GOTO 50
       K3=2
C
       CALL SHAFT
C
       IF(NEPR.LT.21)ECM(NEPR) = XMAX
       IF(NEPR.LT.21)EB(NEPR)=EQ
       DELR=0.D0
       DELSP=0.D0
       IF(XMAX.GT.300.D0)GO TO 50
C
C      ENTRANCE CHANNEL CROSS SECTIONS
       IF(RCSS.GE.0.D0)GO TO 75
       JKL=IDINT(-RCSS)
       RCSS=0.D0
C
       READ(5,65)(T(L),L=1,JKL)
C
    65 FORMAT(10F5.3)
       CON=660.D0*AMASS/(PQ*AP*AT)
       DO 70 L=1,300
       TL=DFLOAT(L-1)
       SIGML(L)=(TL+TL+1.D0)*T(L)*CON
       RCSS=RCSS+SIGML(L)
    70 CONTINUE
    75 IF(RCSS.NE.0.D0)Write(7,305) RCSS
   305 FORMAT (36X,'COMPOUND NUCLEUS CROSS SECTION PROVIDED BY USER ='
      1  ,F8.2,' MB')
       IF(RCSS.LE.0.D0) GO TO 85
       CNCSS = RCSS
       GO TO 100
    85 IF(ZP.LT.2.D0)GO TO 90
C
       CALL PARAP(MX,JCAL)
C
       GO TO 95
    90 I3=M3
       IF(ZP.EQ.0.D0)M3=1
       IF(ZP.EQ.1.D0.AND.AP.EQ.1.D0)M3=2
       IF(ZP.EQ.1.D0.AND.AP.EQ.2.D0)M3=4
C
       CALL OVER
C
       If(CHANGEXS.ne.0.d0) then
       CALL RENCS(EQ,CROSS1)
       DO 91 L=1,300
91     SIGML(L)=SIGML(L)*CROSS1/CROSS
       CROSS=CROSS1
                          endif
C
```

```
      M3=I3
      CNCSS=CROSS
   95 CONTINUE
  100 DO 105 I=1,300
      JJ=I-1
      IF(SIGML(I).LT..001D0)GO TO 110
  105 CONTINUE
  110 CONTINUE
      IF(JJ.LE.0)JJ=1
      RCSS=CNCSS
      IF (TMX.EQ.1.D0) TMX=DFLOAT(JJ)
      JJJ=JJ
      IF(JFRAC)120,120,125
  120 JI=1
      GO TO 130
  125 JI=JFRAC + 1
  130 IF(JUPPER.NE.0) JJ = JUPPER + 1
      IF (JCAL.GT.0) GO TO 131
      IF (JFRAC.LE.0.AND.JUPPER.LE.0) GO TO 131
      BUFF=0.D0
      DO 132 LIN=1,300
      IF (LIN.LT.JI) SIGML(LIN)=0.D0
      IF (LIN.GT.JJ) SIGML(LIN)=0.D0
  132 BUFF=BUFF+SIGML(LIN)
      RCSS=BUFF
      CNCSS=BUFF
  131 IF(JCAL)140,140,135
  135 JI=1
      JJ=1
  140 IF(NEPR.LT.21)RCSP(NEPR) = RCSS
C
      CRSUM=0.D0
      BISP=0.D0
      TOTFIS=0.D0
      FISS=0.D0
      SUMIZ =0.D0
C
C     BEGIN CALC ON PARTIAL CROSS SECTION ON J
C     1111111111111111111111111111111111111111111111111111111111111111
      IF(JJ.GT.100)Write(7,9610)
      IF(JJ.GT.100)JJ=100
9610  FORMAT(//,20X,'PARTIAL WAVE UPPER LIMIT REDUCED TO 100 H-BAR ')
      DO 610 JL=JI,JJ,JDELT
      CRSUM=CRSUM+SIGML(JL)
      AJL=DFLOAT(JL)
      TEST=DFLOAT(5*(JL/5))-AJL
      IF(JL.LE.2) TEST=0.D0
      DO 145 MK=1,22
      DO 145 ML=1,3
      DO 145 MM=1,300
  145 PP(ML,MK,MM)=0.D0
      DO 146 MK=1,300
      PPGAM(MK)=0.D0
  146 CONTINUE
      LMX=1
      LMN=1
      AL=DFLOAT(JL-1)
      JLL=IDINT(AL)
      IF(JCAL.LT.0.AND.TD.GT.0.D0)GO TO 165
```

```
      IF(JCAL)155,165,165
  155 IF(ACRS(JL))610,610,160
  160 PP(1,1,1)=ACRS(JL)
      GO TO 170
  165 PP(1,1,1)=SIGML(JL)
  170 NIA=IDINT(AMASS)
      IIP=IDINT(ZEE)
      IF(JCAL.GE.1)PP(1,1,1)=RCSS
      IF(JCAL.EQ.0.AND.SIGML(JL).LE.0.D0)GO TO 610
      TEST2=PP(1,1,1)/RCSP(NEPR)
      IF(TEST2.LE.0.001D0)TEST=0.D0
      IF(TEST.NE.0.D0)GO TO 171
C
      Write(7,640)
      Write(7,645)IIP,NIA
      IF(CHANGEXS.eq.0.0) then
                          Write(7,685) RCSP(NEPR)
                          WRITE(8,685) RCSP(NEPR)
                          else
                          Write(7,1685) RCSP(NEPR),CNFNCS
                          WRITE(8,1685) RCSP(NEPR),CNFNCS
                          endif
      RATMP1=RCSP(NEPR)
      Write(7,635)XMAX,JLL
      WRITE(8,635)XMAX,JLL
      Write(7,701)PP(1,1,1)
      WRITE(8,701)PP(1,1,1)
C
C
  171 IZ=1
      IF(INVER.EQ.2)CALL SIGI
      SWC=0.D0
      EAAMAX=DFLOAT(20)/ED
      MAX=IDINT(EAAMAX)
      IF(TD.EQ.0.D0)GO TO 185
      B(1)=BE(1,1,1)
      B(2)=BE(1,1,2)
C
      CALL HYBRID
C
      IF (JCAL.LE.0) PP(1,1,1)=SIGML(JL)
      IF(TEST.NE.0.D0)GO TO 172
C
      IF (JCAL.LE.0) Write(7,186)PP(1,1,1)
  186 FORMAT (20X,'COMPOUND NUCLEUS (EQUILIBRIUM) CROSS SECTION',
     1 ' THIS PARTIAL WAVE =',E10.3,' MB')
  172 IF (JCAL.EQ.1) PP(1,1,1)=CNCSS
      IF (JCAL.EQ.1) Write(7,650) PP(1,1,1)
  185 IF (JCAL.LE.1) GO TO 205
      Write(7,187)
  187 FORMAT (/' PARTIAL COMPOUND NUCLEUS (EQUILIBRIUM) CROSS ',
     1 'SECTIONS FOR S-WAVE APPROXIMATION'/1H )
      Write(7,188) (SIGML(J),J=1,JJJ)
  188 FORMAT (1H ,10E10.3)
      PP(1,1,1)=0.D0
      LMX=IDINT(XMAX/ED+1.D0)
      LMN=1
      DO 200 IX=1,JJJ
      IU=IDINT((XMAX-DELRR(IX))/ED+1.D0)
```

```
      IF(IU.LT.1)IU=1
  200 PP(1,1,IU)=PP(1,1,IU)+SIGML(IX)
      IF(MX.EQ.0)LMN=1
  205 CONTINUE
C     BEGIN CALC ON Z
C
C     22222222222222222222222222222222222222222222222222222222222
C
      DO 605 IZ=1,NZ
C
      IZN=IZ
      IF(IZN.GT.3)IZN=3
      IF(IZ.NE.1.AND.INVER.EQ.2)CALL SIGI
C
      IIIZ=IZ
      DO 210 IA=1,22
      FS(IA)=0.D0
      DSP(IA)=0.D0
      BRR(IA)=0.D0
      DER(IA)=0.D0
  210 ER(IA)=0.D0
      IIZ=IIP-IZ+1
C     BEGIN CALC ON A
C     33333333333333333333333333333333333333333333333333333333333
C
      AEJMAX=DFLOAT(50)/ED
      JMAX=IDINT(AEJMAX)
      IF(JMAX.GT.300)JMAX=300
             DO 212 IA=1,22
  212        CORG(IA)=0.0
      DO 560 IA=1,NA
      DELCN=PAIR(IZ,IA)
      PAIRX(1)=PAIR(IZ,IA+1)
      PAIRX(2)=PAIR(IZ+1,IA)
      PAIRX(3)=PAIR(IZ+2,IA+2)
      IF(KPG.eq.0) PAIRX(4)=PAIR(IZ+1,IA+1)
      IF(KPG.eq.1) PAIRX(4)=PAIR(IZ+1,IA+2)
      IF(KPG.eq.2) PAIRX(4)=PAIR(IZ+2,IA+1)
C
      IF(LDOPT.EQ.0)GO TO 211
      DELCN=0.D0
      PAIRX(1)=0.D0
      PAIRX(2)=0.D0
      PAIRX(3)=0.D0
      PAIRX(4)=0.D0
  211 IIIA=IA
      AOZ=DFLOAT(NIA-IZ-IA+2)
      ZOZ=DFLOAT(IIP-IZ+1)
      DO 225 IPJ=1,22
  225 CX(IPJ)=0.D0
      IF(IKE.EQ.4)GO TO 235
      DO 230 IM=1,4
      DO 230 IL=1,300
  230 EN(IM,IL)=0.D0

  235 DO 240 IND=1,300
  240 SP(IND)=0.D0
      IF(JCAL)250,250,245
  245 NULIM(IZ,IA)=JAMMA(IZ,IA)
```

```
      GO TO 310
  250 IF(JANG)265,265,255
  255 AL=DFLOAT(JL-IA-IZ+1)
      IF(AL)260,260,265
  260 AL=0.D0
  265 AFIS=0.D0
      DO 275 JM=1,300
      SIFIS(JM)=0.D0
  275 GAMFT(JM)=0.D0
C     CALC CORR TO EXC SADDLE
      IAI=NIA-IA-IZ+2
      A=DFLOAT(IAI)
      NEUT=IAI-IIZ
      AN=DFLOAT(NEUT)
      Z=DFLOAT(IIZ)
      IL=IDINT(AL)
      IF(IFIS.EQ.0)CALL ASIERK(IIZ,IAI,IL,BARFS,DELR,SELMAX)
      IF(AL.GT.SELMAX.AND.IFIS.EQ.0)BARFS=DELR
      IF(IFIS.EQ.0)DELSP=DELR+BARFS
      IF(IFIS.EQ.0)ERO=DELR
      IF(IFIS.GT.0)CALL FISROT(A,Z,AN,AL,DELR,DELSP,ERO,BARFAC)
      IF(DELSP.LT.DELR)DELSP=DELR
      IF(JL.EQ.1)SCALE(IA,IZ)=DELSP+0.000001D0
      IF(IPCH.EQ.2)BRDEC=((DELSP-DELR)/SCALE(IA,IZ))*BEXP
     1(IA,IZ)+DELR
      IF(IPCH.EQ.2)DELSP=BRDEC
      IF(IPCH.EQ.1)DELSP=BEXP(IA,IZ)+DELR
      NUL=IDINT((DELSP-DELR)/ED+1.D0)
      DSP(IA)=DELSP
      DER(IA)=DELR
      ER(IA)=ERO
      IF(NUL-JAMMA(IZ,IA))280,280,285
  280 NULIM(IZ,IA)=NUL
      GO TO 290
  285 NULIM(IZ,IA)=JAMMA(IZ,IA)
  290 CONTINUE
      JKL=IDINT(EXC(IZ,IA)/ED+1.D0)
      IF(JKL.LE.0)JKL=1
      PFIS=0.D0
      BAR=DELSP-DELR
      IF(BAR.LT.0.D0)BAR=0.D0
      BRR(IA)=BAR
      IF (BAR.GT.0.D0.OR.JSW.EQ.1) GO TO 310
      DO 300 I=1,JKL
  300 PFIS=PFIS+PP(1,IA,I)
      FS(IA)=PFIS
      FISS=FISS+FS(IA)
      GO TO 560
  310 DO 315 IJJ=1,300
  315 Q(IJJ)=0.0D0
      EXCZA=EXC(IZ,IA)-DELR
      IF(SWC)335,335,320
  320 LMX=IDINT(EXCZA/ED+1.D0)
      IF(LMX-300)330,330,325
  325 LMN=LMX-300
      GO TO 335
  330 LMN=1
  335 SWC=1.D0
C
```

```
      IF(LDOPT.NE.2)GO TO 319
*+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
      IF(LDEX.GT.0)READ(9)((POW(J,I),J=1,4),I=1,MAXOBN)
      IF(LDEX.GT.0)READ(9) (GOW(I),I=1,MAXOBN)
      IF(LDEX.GT.0)GO TO 318
      CALL OBNINS(IZ,IA)
      IF(LDEX.EQ.0)WRITE(9)((POW(J,I),J=1,4),I=1,MAXOBN)
      IF(LDEX.EQ.0)WRITE(9) (GOW(I),I=1,MAXOBN)
*+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
318    DO 71581 II3=1,500
71581  RINT(II3)=0.D0
       KX3=IDINT(40.D0/ED)
       IF(KX3.GT.500)KX3=500
       RINT(1)=1.D-10
C      RINT(1)=0.D0
       DO 61441 IT3=2,KX3
       DO 61431 IF3=2,IT3
       JF3=IF3-1
       EG3=DFLOAT(JF3)*ED
       AIB3=(DFLOAT(IT3)*ED-EG3)*10.D0+0.05D0
       IB3=IDINT(AIB3)
       RTEM3=SIGT(JF3)*GOW(IB3)
       RINT(IT3)=RINT(IT3)+RTEM3
61431  CONTINUE
C   NOTE THAT SIGT(I) IS E*E*SIG(E) FROM SUBROUTINE GAMMA
61441 CONTINUE
      DO 61451 IT3=2,KX3
C
C--------------(2*SG+1)/4./(M1*C**2)=2./4./931.5016MEV = 5.366E-4
      RINT(IT3)=5.36766D-4*RINT(IT3)*ED
61451 CONTINUE
C
C
C
  319 IF(LMX)560,560,340
C
C     BEGIN CALC ON PARTICLE TYPE
C     4444444444444444444444444444444444444444444444444444444444444444
C
  340 DO 515 K=1,M3
      GO TO(350,355,360,365),K
  350 JZ=1
      KZ=IZ
      JA=IA+1
      GO TO 370
  355 JZ=2
      KZ=IZ+1
      JA=IA
      GO TO 370
  360 JZ=3
      KZ=IZ+2
      JA=IA+2
      GO TO 370
  365 IF(KPG.eq.0)  JZ=2
      IF(KPG.eq.0)  KZ=IZ+1
      IF(KPG.eq.0)  JA=IA+1
            IF(KPG.eq.1)  JZ=2
            IF(KPG.eq.1)  KZ=IZ+1
            IF(KPG.eq.1)  JA=IA+2
```

```
      IF(KPG.eq.2)  JZ=3
      IF(KPG.eq.2)  KZ=IZ+2
      IF(KPG.eq.2)  JA=IA+1
  370 BB=ED/2.D0
      IJJ=NULIM(IZ,IA)
C
      IF(LDOPT.EQ.1.AND.K.EQ.1)CALL LDLOAD
      IF(LDOPT.EQ.4.AND.K.EQ.1)CALL LDIST
      IF(K.GT.1)GO TO 93700
93700 CONTINUE

C
C     555555555555555555555555555555555555555555555555555555555555
C     BEGIN CALC ON MOTHER EXCITATION
C
      DO 510 J=LMN,LMX
      I=LMN+LMX-J
      IF(I.LE.IJJ.AND.LMX.GT.1)GO TO 510
      IF(PP(1,IA,I).EQ.0.D0.AND.K.EQ.1)GO TO 510
      IF(PP(1,IA,I).EQ.0.D0.AND.Q(I).EQ.0.D0.AND.K.GT.1)GO TO 510
  380 IF(K-1)385,385,470
  385 UCLA=0.0D0
      DO 440 KJ=1,M3
      EMAX=EXCZA-BE(IZ,IA,KJ)-BB
      M=IDINT(EMAX/ED+1.D0)
      IF(M-JMAX)415,415,410
  410 M=JMAX
  415 IF(M-1)440,420,420
  420 BI=10.D0*EMAX+.05D0-PAIRX(KJ)
      IB=IDINT(BI)
      IF(IB.LE.0) GO TO 440
      NTS=IDINT((EMAX-PAIRX(KJ)/10.D0)/ED+1.D0)
      MT=M
      IF(NTS.LT.M)MT=NTS
      IF(MT.LT.1)GO TO 440
      DO 435 L=1,MT
      IF(IB.LT.1)GO TO 435
      PT=POW(KJ,IB)*SIG(KJ,L)
      UCLA=UCLA+PT
      BI=BI-TENED
      IB=BI
  435 CONTINUE
  440 CONTINUE
      IXC=IDINT((EXC(IZ,IA)-BB+ED/2.D0)/ED)
      IF(IXC.LT.1)IXC=1
      II=1
      IF(JCAL)445,445,460
  445 II=IDINT(10.D0*(EXC(IZ,IA)-DELSP-BB+ED/2.D0) - DELCN)
      IF(II)450,450,455
  450 II=1
  455 UCLA=UCLA+GAM(II)
  460 I=LMN+LMX-J
      IF(I.LT.1)I=1
      IF(I.GT.300)Write(7,*) I,I,I,I
      KX=IDINT(40.D0/ED)
C== 05-FEBRUARY-1994
C      KX=IDINT(80.D0/ED)
      IF(UCLA)510,510,464
  464 UCLA=UCLA+RINT(IXC)
```

```
  465 Q(I)=PP(1,IA,I)/UCLA
      GAMFT(I)=GAM(II)/UCLA
      SIFIS(I)=GAMFT(I)*PP(1,IA,I)
      AFIS=AFIS+SIFIS(I)
C==
           CORG(IA) = CORG(IA) + PP(1,IA,I)*RINT(IXC)/UCLA
      PP(1,IA,I)=0.D0
      FISS=FISS+SIFIS(I)
      GEMAX=EXC(IZ,IA)-BB+ED/2.D0
      MGAM=IDINT(GEMAX/ED-1.D0)
      IF(MGAM.LT.1)GO TO 470
      IF(MGAM.GT.KX)MGAM=KX
      IF(MGAM.GT.KX) Write(7,*) MGAM,KX,MGAM
      IF(MGAM.GT.300) Write(7,*) MGAM,MGAM
      IF(MGAM.GE.JMAX)MGAM=JMAX
C       IF(MGAM.GE.I.AND.IA.GT.1.OR.IZ.GT.1)MGAM=I-1
C-CHANGE 23 - SEPTEMBER - 1993
      IF(MGAM.GE.I.AND.IA.GT.1.OR.IZ.GT.1)MGAM=I-2
      DO 9465 IG=1,MGAM
C
      IF(IA.GT.1.OR.IZ.GT.1.AND.(I-IG).LT.1)GO TO 470
      IF(I.LE.IG)GO TO 470
      AIU=10.D0*(GEMAX-FLOAT(IG)*ED)+.05D0
      IU=IDINT(AIU)
      IF(IU.LT.1)IU=1
C
      EGM=5.36766D-4*Q(I)*SIGT(IG)*GOW(IU)*ED
      EQGAM(IG)=EQGAM(IG)+EGM
C
 9465 CONTINUE
  470 IF(JA-22)475,475,510
  475 I=LMN+LMX-J
      IF(I.LT.1)I=1
      IF(Q(I).EQ.0.D0)GO TO 510
      XAJ=EXCZA-BE(IZ,IA,K)-BB
      M=IDINT(XAJ/ED+1.D0)
      IF(M-JMAX)490,490,485
  485 M=JMAX
  490 IF(M-1)510,495,495
  495 BI=10.D0*XAJ+0.05D0-PAIRX(K)
      IB=IDINT(BI)
      IF(IB.LE.0) GO TO 510
      NDEX=IDINT(XAJ/ED+1.D0)
      MT=M
      NTS=IDINT((XAJ-PAIRX(K)/10.D0)/ED+1.D0)
      IF(NTS.LT.M)MT=NTS
      IF(MT.LT.1)GO TO 510
      DO 505 L=1,MT
      IF(NDEX.LT.1.OR.IB.LT.1)GO TO 510
      PPAT=Q(I)*POW(K,IB)*SIG(K,L)
      PP(JZ,JA,NDEX)=PP(JZ,JA,NDEX)+PPAT
      EN(K,L)=EN(K,L)+PPAT/ED
      BI=BI-TENED
      IB=IDINT(BI)
  505 NDEX=NDEX-1
C
  510 BB=BB+ED
C
C     555555555555555555555555555555555555555555555555555555555555
```

```
C
  515 CONTINUE
C
C     44444444444444444444444444444444444444444444444444444444
C
      IF(IKE.NE.1.AND.IKE.NE.3)GO TO 520
      K3=4
C
      CALL SHAFT
C
  520 IF(IZ.NE.1.OR.IA.NE.1)GO TO 530
      JMIN=1
      GO TO 545
  530 JP=IDINT(EXCZA)
      JMIN=IDINT(BAR-1.D0)
      IF(JP-JMIN)560,560,540
  540 IF(JP)545,545,555
  545 JP=1
      IF(TEST.NE.0.D0)GO TO 555
      Write(7,675)(GAMFT(I),I=JMIN,JP)
  555 FS(IA)=AFIS
  560 CONTINUE
C
      DO 595 IA=1,NA
      SA=0.0D0
      NDMX=IDINT(25.D0/ED)
      DO 580 NDEX=1,NDMX
      SA=SA+PP(1 ,IA,NDEX)
  580  SP(NDEX)=SA
      IF(IA.EQ.1.AND.IZ.EQ.1)GO TO 590
      LA=JAMMA(IZ,IA)
      IF(LA.LE.0)LA=1
      DO 597 IX=1,NDMX
      PPGAM(IX)=PPGAM(IX)+PP(1,IA,IX)
  597 CONTINUE
  590 CX(IA)=SP(NDMX)
                     CX(IA)=CX(IA)+CORG(IA)
5803  FORMAT(1X,' IA=',I5,' CX(IA)=',G12.5,' CORG(IA)=',G12.5)
C
  595 CONTINUE
C     33333333333333333333333333333333333333333333333333333333
C
      MAS=NIA-IZ+1
      K3=1
      CALL SHAFT
      DO 600 IA=1,NA
      DO 600 NDEX=1,300
      PP(1,IA,NDEX)=PP(2,IA,NDEX)
      PP(2,IA,NDEX)=PP(3,IA,NDEX)
  600 PP(3,IA,NDEX)=0.0D0
C
  605 CONTINUE
C     22222222222222222222222222222222222222222222222222222222
  610 CONTINUE
C     11111111111111111111111111111111111111111111111111111111
      IF(IGAM.EQ.1)CALL GAMMA
      IZ=IIIZ
      IA=IIIA
      IF(IKE.EQ.4)K3=4
```

```
      IF(IKE.EQ.4)CALL SHAFT
      Write(7,670)FISS
      IF(KPLT.GT.0)K2=2
      IF(KPLT.GT.0)CALL PLT
      GO TO 50
  620 IF(KPLT.GT.0)K2=3
      IF(KPLT.GT.0)CALL PLT
      GO TO 5
C
  625 FORMAT(7E11.4)
  630 FORMAT(2F5.1,3I1,I2,F3.0,I2,2I5,8F5.1,I5,I5)
  635 FORMAT(31X,'EXCITATION ENERGY OF COMPOUND NUCLEUS =',F6.1,'MEV  J=
     1',I4/)
  640 FORMAT(2H  )
  645 FORMAT(1H1,33X,'COMPOUND NUCLEUS ATOMIC NUMBER = ',I3,'   MASS NUMBER
     1= ',I3/)
  650 FORMAT (32X,'COMPOUND NUCLEUS (EQUILIBRIUM) CROSS SECTION =',
     1 E10.3/)
  655 FORMAT(6F5.1,I1,F4.1,I1,I4,3I5,I1,I4,F4.1,I1,I5,F5.1,I1,A1,I3)
 6550 FORMAT(4F7.1,F7.3,I5)
  660 FORMAT(50X,'EVAPORATION CODE ALICE/LIVERMORE/91',//30X,' THIS CODE IS'
     1 IS DESCRIBED IN LLNL REPORT UCID 19614(1982)',//' USERS SENDING A LETT'
     2 LETTER TO M.BLANN WILL BE ADVISED OF FUTURE CORRECTIONS OR IMPROVEMEN
     3EMENTS TO THIS CODE.'/' MAILING ADDRESS IS',//50X,' M.BLANN',//50X,
     4, ' E DIVISION-L289',//50X ,' LAWRENCE LIVERMORE LABORATORY' ,
     1//50X,' P.O. BOX 808',
     5 //50X,' LIVERMORE, CALIFORNIA, 94550, USA')
  670 FORMAT(31H TOTAL FISSION CROSS SECTION = E10.3)
  675 FORMAT(48X,'GAMF/GAMTOT = ',E10.3)
  680 FORMAT(//33X,'INVERSE REACTION CROSS SECTIONS WERE PROVIDED BY USE
     1R'/)
  685 FORMAT (41X,'TOTAL REACTION CROSS SECTION = ',F8.1/)
 1685 FORMAT (41X,'TOTAL REACTION CROSS SECTION = ',F8.1,' IS TAKEN ',
     #'FROM FILE  ',a12/)
 2685 FORMAT (' ATTENTION: TOTAL REACTION CROSS SECTION WAS TAKEN',
     #' FROM FILE  ',a12)
  690 FORMAT(' DAS IST ALICE DAS IST ALICE DAS IST ALICE DAS IST ALICE')
  701 FORMAT (44X,'REACTION CROSS SECTION',F8.1/)

9876  FORMAT(11F5.1)
 7010 FORMAT(' NZ EXCEEDS DIMENSIONED LIMIT. DEFAULT TO NZ=9')
 7015 FORMAT(' NA EXCEEDS DIMENSIONED LIMIT. DEFAULT TO 22')
 7005 FORMAT(20A4)
 7465 FORMAT(/34X,'QVAL =',F5.1,'  AP =',F5.1,'  AT =',F5.1,'  ZP =',F5.
     11,2X,'ZT =',F5.1/1X,' CLD =',F5.1,'  NA =',I3,'  NZ =',I3,'  MC =
     2',I3,'  MP =',I3,'  INVER =',I3,'  IKE =',I3,'   IPCH =',I3
     3 ,'   PLD =',F5.1,'  KPLT=',I3,'  M3=',I3)
 7466 FORMAT(40X,'LDOPT = ',I1)
 7475 FORMAT(1H1,///20A4///)
65500 Write(7,65501)
      WRITE(8,65501)
65501 FORMAT(1X,'INVERSE REACTION CROSS SECTIONS CAN NOT BE READ BECAUSE
     $ DIFFERENCE OLD AND NEW INPUT VARIABLES'/1X,72('!'))
      STOP
76543 Write(7,76544)EQ
      WRITE(8,76544)EQ
76544 FORMAT(1X,'FOR LDOPT=2 AND EQ=',G12.5,' MAXOBN IS TOO SMALL...')
      STOP
      END
```

```
*
**********************************************************************
*
      Subroutine ADIST
*     ----------------
*
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/PL3/EB(70),RCSP(70),Z,A,PLEX,NEPR
      COMMON/DIST/PROB(37,301),B(3),ALMIN(300),ALMAX(300),FIN,DTUP
     1 ,DSIGP(36,301),DSIGT(36,301),POT,PCS,N,NI,JK,EJ,DADEG,TDEG,TDEG2
     2,AMN(300),AMX(300),XMAX
      COMMON/DIST1/GDPR(36,301),GL(36,301),CFRAC
     3,DTAU,SIGN(36),TMIX,IREFR,BJI(10)
      COMMON/INCR/ED
      COMMON/NR34/NR3,NR4,KE5,TEM(36),I3D,IRTST,I3T2,IJKL
C
      IJKL=0
      I3T2=0
      EK=EJ*ED-ED/2.
      KE=DFLOAT(JK)*ED
C
C    PUT FINITE ANGLE CALC IN-KEEP HEISENBERG HAPPY
C
      CR=1.18D0*A**.33333333
      CRR=1.D0-1.D0/CR**2
      RMXX=CRR*CR-1.1D0
      FIN=0.5D0*29.44D0/(RMXX*DSQRT(EK))
      FIN=FIN*180.D0/3.1415926D0
      NFIN=IDINT(FIN/5.D0+1.D0)
      IF(NFIN.GT.36)NFIN=36
C
      DEL=180.D0/(3.1415926*5.D0)
      N1=IDINT(AMN(KE))
      N2=IDINT(AMX(KE))
C     KE5=KE/5
C
C     BEGIN MOD FOR REFR/NO REFR
      IF(IREFR.LT.2)NFIN=1
      IF(N.GT.NI)GO TO 200
C
C   MODIFY FOR HEISENBERG EXIT CHANNEL SPREAD
C
      DO 90 I=1,36
   90 TEM(I)=0.D0
C
C   ADD BRANCH FOR HEIS EXIT SPREAD
      NR3=1
      NR4=NFIN
      I3T2=2
      IJKL=3
      IF(NFIN.EQ.1)GO TO 990
      GO TO 995
  990   DO 991 I=1,36
991   TEM(I)=GL(I,KE5)
      GO TO 992
995   IF(I3D.EQ.0)CALL TREED
      I3T2=0
      IF(I3D.EQ.0)GO TO 992
996   DO 102 IT1=1,NFIN
```

```
C
      ITROT=IT1
      IF(IREFR.LT.2)ITROT=0
C
      DO 102 IT2=1,36
      IF(GL(IT2,KE5).LE.0.D0)GO TO 102
      ITM=ITROT-IT2
      ITP=ITROT+IT2
C
      IF(IREFR.LT.2)ITM=ITP
C
      IF(ITM.LT.1)ITM=IT2-ITROT+1
      IF(ITP.GT.36)ITP=73-IT2-ITROT
      TEM(ITM)=TEM(ITM)+GL(IT2,KE5)*SIGN(IT2)/SIGN(ITM)
      TEM(ITP)=TEM(ITP)+GL(IT2,KE5)*SIGN(IT2)/SIGN(ITP)
102   CONTINUE
C
992   CONTINUE
      AREA=0.D0
      DO 103 IT=1,36
      AREA=AREA+SIGN(IT)*TEM(IT)
103   GL(IT,KE5)=TEM(IT)
C
      IF(AREA.EQ.0.D0)GO TO 300
      ELT=PCS*DEL/AREA
C
      DO 100 ITH=1,36
      ELE=ELT*GL(ITH,KE5)
      DSIGP(ITH,KE5)=ELE
  100 DSIGT(ITH,KE5)=ELE+DSIGT(ITH,KE5)
C
      GO TO 300
C
  200 N11=IDINT(AMN(KE))
C
C   BRANCH POINT FOR NUCLEON NUCLEON SCATTERING BEYOND NZERO
C
      N22=IDINT(AMX(KE))
      DO 210 IT=1,36
  210 TEM(IT)=0.D0
C
      AREA=0.D0
      I3T2=4
C
      IJKL=4
      IF(I3D.EQ.0)CALL TREED
      I3T2=0
      IF(I3D.NE.0)GO TO 2400
      DO 2390 I=1,36
      GDPR(I,KE5)=TEM(I)
2390  AREA=AREA+SIGN(I)*TEM(I)
      I3T2=0
      GO TO 2501
2400  DO 250 IT1=1,36
      TEMP=GDPR(IT1,KE5)
      IF(TEMP.LE.0.D0)GO TO 250
C
      DO 240 IT2=1,36
      ITM=IT1-IT2
```

```
      ITP=IT1+IT2
      IF(ITM.LT.1)ITM=IT2-IT1+1
      IF(ITP.GT.36)ITP=73-IT2-IT1
      EL=TEMP*PROB(IT2,KE5)*SIGN(IT2)
      TEM(ITM)=TEM(ITM)+EL/SIGN(ITM)
      TEM(ITP)=TEM(ITP)+EL/SIGN(ITP)
      AREA=AREA+2.D0*EL
  240 CONTINUE
  250 CONTINUE
2500  IF(AREA.EQ.0.D0)GO TO 300
C
      DO 251 IT=1,36
  251 GDPR(IT,KE5)=TEM(IT)
2501  IF(AREA.EQ.0.D0)GO TO 300
C
C   MODIFY FOR HEISENBERG EXIT CHANNEL SPREAD
C
      IF(NFIN.EQ.1)GO TO 2113
      IF(I3D.EQ.0)I3T2=3
      IF(I3D.EQ.0)CALL TREED
      I3T2=0
      IJKL=1
      IF(I3D.EQ.0)GO TO 2112
      DO 95 I=1,36
   95 TEM(I)=0.D0
      DO 112 IT1=1,NFIN
C
      ITROT=IT1
      IF(IREFR.LT.2)ITROT=0
C
      DO 112 IT2=1,36
      IF(GDPR(IT2,KE5).LE.0.)GO TO 112
      ITM=ITROT-IT2

      ITP=ITROT+IT2
      IF(IREFR.LT.2)ITM=ITP
      IF(ITM.LT.1)ITM=IT2-ITROT+1
      IF(ITP.GT.36)ITP=73-IT2-ITROT
      TEM(ITM)=TEM(ITM)+GDPR(IT2,KE5)*SIGN(IT2)/SIGN(ITM)
      TEM(ITP)=TEM(ITP)+GDPR(IT2,KE5)*SIGN(IT2)/SIGN(ITP)
112   CONTINUE

 2112  CONTINUE
C
      AREA=0.D0
      DO 108 IT=1,36
      AREA=AREA+SIGN(IT)*TEM(IT)
108   GDPR(IT,KE5)=TEM(IT)
      IJKL=2
C
2113   CONTINUE
      DO 252 IT=1,36
      DSIGP(IT,KE5)=DSIGP(IT,KE5)+PCS*DEL*GDPR(IT,KE5)/AREA
252   DSIGT(IT,KE5)=DSIGT(IT,KE5)+PCS*DEL*GDPR(IT,KE5)/AREA
C
  300 CONTINUE
      RETURN
      END
*
```

```
************************************************************************
*
       Subroutine ALPH05(TT9,EX9,X9,L91,L92,GIB,GE,G,DEP,
     $                   XMAX,ED9,BA,CNCS, PAIRXA)
*      ------------------------------------------------
*
C     ALPHA PRECOMPOUND ROUTINE FOR ALICE/ASH
C
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/IALPH/IALPHA
      COMMON/MEMO/SCRS(300,4)
      COMMON/IWAALP/FLM(300,4),WIMAG
      COMMON/HOT/KPG,MPG
      COMMON/WOO/WBREAK
      DIMENSION GIB(4,300),GE(4),DEP(2)
C
C BA IS ALPHA-PARTICLE SEPARATION ENERGY,
C XMAX IS MAXIMAL EXCTITATION ENERGY OF COMPOSITE NUCLEUS,
C N=TT9 IS CURRENT NUMBER OF EXCITONS, CNCS IS TOTAL NONELASTIC CR.SECT.
C EX9 IS NUMBER OF PARTICLES, X9 IS NUMBER OF HOLES,
C WIMAG IS COMPLEX PART OF OPTICAL POT. FOR ALPHA
C
      IF(IALPHA.LT.10)CALL IWAMOA(IALPHA)
C TO BE SURE THAT FOR THE OPTION GDO=1 SUBR.ALPHAI IS CALLED SINGLE TIME
      IF(L91.NE.L92.AND.L92.NE.1) IALPHA=IALPHA+1
         N=IDINT(TT9+0.01D+00)
      E=XMAX
      ED=ED9
         NP=IDINT(EX9+0.01D+00)
         P=DFLOAT(NP)
         NH=IDINT(X9+0.01D+00)
      IF(NH.NE.(N-NP)) GOTO 23232
C
      IF(NP.EQ.0)GOTO 33333
      U=XMAX-BA-ED/2.
      NU=U/ED+1.
      IF(NU.LE.0)GOTO 111
      IF(NU.GT.300)GOTO 44444
      LMAX=MIN0(NP,4)
      BAA=(BA /ED) + DSIGN(0.5D0,BA)
      ISHIFT=IDINT(BAA)
C
      DO 1000 L=1,LMAX
      U=XMAX-BA-ED/2. - PAIRXA
                        UU = U
      IF(PAIRXA.LT.0.0) UU = XMAX-BA-ED/2.
      NU=UU/ED+1.
C
      AKOEF=1.
          DO 100 K1=1,L
100       AKOEF=AKOEF*DFLOAT(NP-K1+1)*DFLOAT(N-K1)
C     AKOEF=CNCS*DEP(2)*GE(3)*AKOEF
      GALPHA = GE(3)
C SEE ALSO GALPHA IN SUBR.ALPNUC
      GALPHA = G
      AKOEF=CNCS*DEP(2)*GALPHA*AKOEF
C
      DO 777 KE=1,NU
      RW=((U/E)**(N-1-L))/((G*E)**L)
```

```
      EALP=DFLOAT(KE)*ED-ED/2.
                           WIMAG2 = WIMAG
      IF(EALP.LE.WBREAK)  WIMAG2 = (EALP/WBREAK)*WIMAG
      IF(EALP.gt.72.   )  WIMAG2 = WIMAG2*DEXP( 0.06*(EALP-72.d0) )
C
      RV=2.*GIB(3,KE)/(2.*GIB(3,KE)+8.27E+03*WIMAG2)
C
      IF(RW.LT.0..OR.RV.LT.0.)GOTO 55555
      KESUM=ISHIFT+KE
      IF(KESUM.GT.300) KESUM=300
      IF(KESUM.LT.1  ) KESUM=1
      FLMSH=FLM(KESUM,L)
C
C ADD KNOCK-OUT MECHANISM  (See also Subr.ALPTWO)
C Factor G from Oblozinsky, Ribansky, Phys. Lett. 74B (1978) 6
      GNA = (G/GALPHA)/P
C
      IF(L.EQ.1) FLMSH = FLMSH + GNA * 0.006*2.
C
      SCRS(KE,3)=SCRS(KE,3)+AKOEF*FLMSH    *RW*RV
      AFRRE=AKOEF*FLMSH    *RW*RV*ED
C NPX,NHX-NUMBER OF PARTICLES AND HOLES AFTER FIRST ALPHA EMISSION
      NPX=NP-L
      NHX=NH
      IF(MPG.eq.1) CALL ALPTWO(3,NPX,NHX,U,AFRRE,GALPHA,GIB,G,ED)
C
      IF(RW.LT.1.0E-50)GOTO 1000
      U=U-ED
      IF(U.LE.0.)GOTO 1000
  777 CONTINUE
 1000 CONTINUE
C
      RETURN
C
  111 WRITE(7,112)U,XMAX,BA,ED,NU
      WRITE(8,112)U,XMAX,BA,ED,NU
  112 FORMAT(1X,80('+')/1X,'PRECOMPOUND ALPHA COULD NOT EMITTED, BECAU
     1SE:'/1X,' U=',G12.5,' XMAX=',G12.5,' BA=',G12.5,' ED=',G12.5,' NU=
     2',I6/1X,80('+'))
      RETURN
C
23232 WRITE(7,23233)
      WRITE(8,23233)
23233 FORMAT(1X,'SUBR.ALPH05: STRANGE ERROR...')
      STOP
33333 WRITE(7,33334)NP
      WRITE(8,33334)NP
33334 FORMAT(1X,'SUBR.ALPH05: number of particles = 0      ',I3)
      STOP
44444 WRITE(7,44445)U,XMAX,BA,ED,NU
      WRITE(8,44445)U,XMAX,BA,ED,NU
44445 FORMAT(1X,'SUBR.ALPH05: ERROR NU > 300 '/1X,' U=',G12.5,' XMAX='
     1,G12.5,' BA=',G12.5,' ED=',G12.5,' NU=',I6)
      STOP
55555 WRITE(7,55556)RW,RV,KE,U,E,N,L
      WRITE(8,55556)RW,RV,KE,U,E,N,L
55556 FORMAT(1X,'SUBR.ALPH05:ERROR RW OR RV < 0'/1X,' RW=',G12.5,' RV
     1=',G12.5,' KE=',I5/1X,' U=',G12.5,' E=',G12.5,' N=',I5,' L=',I5)
      STOP
```

```
      END
*
*********************************************************************
*
      Subroutine ALPNUC(IFLAG,MPARIN,U9,EX9,X9,GIB,GE,G,P,CF,ED9)
*     ------------------------------------------------------
*
C ROUTINE FOR DATA PREPARATION TO CALL ALPTWO FOR N-A AND P-A EMISSION
C
C MPARIN- TYPE OF FIRST EMITTED NUCLEON
C
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/IALPH/IALPHA
      DIMENSION GIB(4,300),GE(4)
C
      IF(IFLAG.EQ.1) GOTO 1
      CALL IWAMOA(IALPHA)
      IALPHA=IALPHA-10
1     IFLAG=1
C
      U=U9
      ED=ED9
         NP=IDINT(EX9+0.01D+00)
         NH=IDINT(X9+0.01D+00)
C
      GALPHA = GE(3)
      GALPHA = G
C NO ED MULTIPLICATION (SEE.HYBRID)
      AFRRE=P*CF
C NPX,NHX - NUMBER OF PARTICLES AND HOLES AFTER NUCLEON EMISSION
      NPX=NP-1
      NHX=NH
C ONLY 5 TERMS WILL BE CONSIDERED FOR MULTIPLE PRECOMPOUND EMISSION
           NPX=NPX-1
           NHX=NHX-1
      DO 1000  II=1,5
           NPX=NPX+1
           NHX=NHX+1
      CALL ALPTWO(MPARIN,NPX,NHX,U,AFRRE,GALPHA,GIB,G,ED)
      CALL DEPLET(MPARIN,NPX,NHX,U,AFRRE,GIB,G,ED)
C
1000  CONTINUE
      RETURN
      END
*
*********************************************************************
*
      Subroutine ALPTWO(MPARIN,NP9,NH9,U9,AFRRE,GALPHA,GIB,G,ED)
*     ------------------------------------------------------
*
* EMISSION OF SECONDARY PRECOMPOUND A-PARTICLE
*
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/MEMO2/SCRA2(300,3)
      COMMON/IWAALP/FLM(300,4),WIMAG
      COMMON/WOO/WBREAK
      CHARACTER*4 SYMB,SYMBP,SYMBS
      COMMON/LYM1/BE(11,24,4),SYMB(11,24),PAIR(11,24),SYMBP(11,24),
     1SYMBS(11,24),XMAS(11,24),DELSHL(11,24),AMAS(11,24)
```

```
      DIMENSION GIB(4,300)
      XMAX = U9
         NP=NP9
         P=DFLOAT(NP)
         NH=NH9
         N=NP+NH
      E=XMAX
C
      IF(NP.LE.0)RETURN
C SEPARATION ENERGY FOR SECONDARY A-PARTICLE
      IF(MPARIN.EQ.1) BA=BE(1,2,3)
      IF(MPARIN.EQ.2) BA=BE(2,1,3)
      IF(MPARIN.EQ.3) BA=BE(3,3,3)
C
      U=XMAX-BA-ED/2.
      NU=U/ED+1.
      IF(NU.LE.0)RETURN
      IF(NU.GT.300)GOTO 44444
      LMAX=MIN0(NP,4)
      BAA=(BA /ED) + DSIGN(0.5D0,BA)
      ISHIFT=IDINT(BAA)
C
      DO 1000 L=1,LMAX
      U=XMAX-BA-ED/2.
      NU=U/ED+1.
      AKOEF=1.
          DO 100 K1=1,L
100       AKOEF=AKOEF*DFLOAT(NP-K1+1)*DFLOAT(N-K1)
      AKOEF=AFRRE*GALPHA*AKOEF
C
      DO 777 KE=1,NU
      RW=((U/E)**(N-1-L))/((G*E)**L)
      EALP=DFLOAT(KE)*ED-ED/2.
                          WIMAG2 = WIMAG
      IF(EALP.LE.WBREAK)  WIMAG2 = (EALP/WBREAK)*WIMAG
      IF(EALP.gt.72.   )  WIMAG2 = WIMAG2*DEXP( 0.06*(EALP-72.d0) )
      RV=2.*GIB(3,KE)/(2.*GIB(3,KE)+8.27E+03*WIMAG2)
      IF(RW.LT.0..OR.RV.LT.0.)GOTO 55555
      KESUM=ISHIFT+KE
      IF(KESUM.GT.300) KESUM=300
      IF(KESUM.LT.1  ) KESUM=1
      FLMSH=FLM(KESUM,L)
C
C ADD KNOCK-OUT MECHANISM  (See also Subr.ALPH05)
      GNA = (G/GALPHA)/P
      IF(L.EQ.1) FLMSH = FLMSH + GNA * 0.006*2.
C
      SCRA2(KE,MPARIN)=SCRA2(KE,MPARIN)+AKOEF*FLMSH    *RW*RV
C
      IF(RW.LT.1.0E-50)GOTO 1000
      U=U-ED
      IF(U.LE.0.)GOTO 1000
  777 CONTINUE
 1000 CONTINUE

      RETURN
C
44444 WRITE(6,44445)U,XMAX,BA,ED,NU
      WRITE(8,44445)U,XMAX,BA,ED,NU
```

```
44445 FORMAT(1X,'SUBR.ALPTWO: ERROR NU > 300 '/1X,' U=',G12.5,' XMAX='
     1,G12.5,' BA=',G12.5,' ED=',G12.5,' NU=',I6)
      STOP
55555 WRITE(6,55556)RW,RV,KE,U,E,N,L
      WRITE(8,55556)RW,RV,KE,U,E,N,L
55556 FORMAT(1X,'SUBR.ALPTWO: ERROR RW OR RV < 0'/1X,' RW=',G12.5,' RV
     1=',G12.5,' KE=',I5/1X,' U=',G12.5,' E=',G12.5,' N=',I5,' L=',I5)
      STOP
      END
*
*********************************************************************
*
       Subroutine ANGEL
*      ----------------
*
C Alpha angular distribution included
C
C THE IB INDICES TO BE USED IN ALICE MUST NOW BE CORRECT THERMO VALUES
C
C     CONTINUUM ANGULAR DISTRIBUTIONS
C     FROM EMPIRICAL SYSTEMATICS BASED ON EXPONENTIALS OF COS THETA
C          SE PHYS. REV. C 37 (1988) 2350
C
C     WRITTEN BY C. KALBACH
C         APRIL 1987
C
C     TRANSITION ENERGY TENTATIVELY SET AT 130*JIN
C     (ONLY NUCLEON VALUE KNOWN)
C     THIRD TERM IN 'A' TENTATIVELY USED FOR INCIDENT DEUTERONS
C
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/INCR/ED
      COMMON/DIST/PROB(37,301),XZ(3),ALMIN(300),ALMAX(300),FIN,DTUP
     1 ,DSIGP(36,301),DSIGT(36,301),POD,PCS,N,NI,KE,EK,DADEG,TDEG,TDEG2

      COMMON/SFT5/EXC(10,24),XMAX
      COMMON/SEND/IRFR,DLT,IADST
      COMMON/MEMO/SCRS(300,4)
      COMMON/NHY/TD,EX1,EX2,TMX,AV,GAV,IJ,COST,JL,JI,JJ,B(3)
      COMMON/PARO/PQ,CROSS
      COMMON/SHFT/QVAL,AP,AT,ZP,ZT,CLD,MC,MP,INVER,IKE,IPCH,BARFAC
      CHARACTER*4 SYMB,SYMBP,SYMBS
      COMMON/LYM1/BE(11,24,4),SYMB(11,24),PAIR(11,24),SYMBP(11,24),
     1SYMBS(11,24),XMAS(11,24),DELSHL(11,24),AMAS(11,24)
      DIMENSION SIGMA(36),ANG(36),XCOS(36),XS(5,5),
     1SLOPE(301),XNORM(301),EPS(301),TOTAL(301)
      DO 100 I=1,10
  100 SIGMA(I)=0.D0
      DO 102 I=1,36
      THETA=DFLOAT(I)*5.D0-2.5D0
      ANG(I)=THETA
      THETA=THETA*3.141159263/180.D0
  102 XCOS(I)=DCOS(THETA)
C
C     STORE ARRAY OF MASS EXCESSES
C     I=Z+1, J=N+1
C
      DO 104 I=1,5
      DO 104 J=1,5
```

```
  104 XS(I,J)=0.D0
      XS(2,2)=2.22
      XS(2,3)=8.48
      XS(3,2)=7.72
      XS(3,3)=28.30
C
C     REACTION I.D. INPUT
C
      JPIN=IDINT(ZP)
      JIN=IDINT(AP)
      JNIN=IDINT(AP-ZP)
      JNOUT=1

      IF(IADST.EQ.3)JPOUT=0
      IF(IADST.EQ.4)JPOUT=1
      IF(IADST.EQ.5)then
                    JPOUT=2
                    JNOUT=2
                    endif
C
      JCOM=IDINT(AT+ZP)
      JZCOM=IDINT(ZP+ZT)
      IF(JCOM.LE.0)GO TO 40
C
C     CALCULATE ENERGY INDEPENDENT QUANTITIES
C     AND PRINT HEADINGS
C
      ACOM=DFLOAT(JCOM)
      AZCOM=DFLOAT(JZCOM)
      JIN=JPIN+JNIN
      XIN=DFLOAT(JIN)
      JOUT=JPOUT+JNOUT
      ESYS=PQ+QVAL
      IF(IADST.EQ.3)BIN=B(1)
      IF(IADST.EQ.4)BIN=B(2)
      IF(IADST.EQ.5)BIN=BE(1,1,3)
C
      E1=130.*XIN
      IF(ESYS.LT.E1)E1=ESYS
C                     If the projectile is not a nucleon
      IF(JIN.GT.2)GO TO 20
      E3=DMIN1(ESYS,4.1D1)
      XMB=1.D0
C                     If ejectile is alpha-particle
      IF(JOUT.EQ.4)XMB=2.D0
C                     If ejectile is neutron
      IF(JPOUT.EQ.0)XMB=0.5D0
C
C     ENERGY DEPENDENT INPUT
C     CALCULATE AND PRINT ANGULAT DISTRIBUTIONS
C
   20 CONTINUE
      IF(IADST.EQ.3)II=1
      IF(IADST.EQ.4)II=2
      IF(IADST.EQ.5)II=3
C
C
      AVAIL=XMAX-BIN
      IMX=IDINT(AVAIL/DLT)
```

```
          IF(IMX.gt.300) GOTO 5000
        EPS(1)=DLT+ED/2.
        DO 28 NE=1,IMX
        IF(NE.EQ.1)GO TO 30
        EPS(NE)=EPS(NE-1)+DLT
   30   CONTINUE
        K=1+NE*IDINT(DLT/ED+0.1)
          IF(K.gt.300) GOTO 5000
        TOTAL(NE)=SCRS(K,II)
        FMSD=1.D0
        IF(FMSD.LE.0.)FMSD=1.D0
        EPSCM=EPS(NE)+BIN
        Y=EPSCM*E1/ESYS
        A=0.04*Y+1.8D-06*Y*Y*Y
        IF(JIN.GT.2)GO TO 22
        Y=EPSCM*E3/ESYS
        A=A+6.7D-07*Y*Y*Y*Y*XMB
   22   XNORM(NE)=A*TOTAL(NE)/(12.5664*DSINH(A))
        SLOPE(NE)=A
        DO 24 I=1,36
        ARG=A*XCOS(I)
        SIG=FMSD*DSINH(ARG)+DCOSH(ARG)
        SIGMA(I)=SIG*XNORM(NE)
        DSIGT(I,NE)=SIGMA(I)
   24   CONTINUE
   28   CONTINUE
   40   RETURN
5000    PRINT 5001,K,IMX
        WRITE(7,5001)K,IMX
5001    FORMAT(//1X,' ERROR: SUBR ANGEL: DIMENSION OF ARRAYS EXCEEDED'/
       #' K=',I5,' IMX=',I5)
        STOP
        END
*
*************************************************************************
*
        Subroutine ANGL
*       ---------------
*
        IMPLICIT REAL*8 (A-H,O-Z)
        COMMON/PL3/EB(70),RCSP(70),Z,A,PLEX,NEPR
        COMMON/DIST/PROB(37,301),B(3),ALMIN(300),ALMAX(300),FIN,DTUP
       1 ,DSIGP(36,301),DSIGT(36,301),POT,PCS,JN,JNI,IK,AK,DADEG,TDEG,
       2 TDEG2
       3,AMN(300),AMX(300),XMAX
         COMMON/DIST1/GDPR(36,301),GL(36,301),CFRAC
       3,DTAU,SIGN(36),TMIX,IREFR,BJI(10)
        COMMON/SEND/IRFR,DLT,IADST
        COMMON/INCR/ED
        COMMON/NR34/NR3,NR4,KE5,TEM(36),I3D,IRTST,I3T2,IJKL
        IREFR=IRFR
        I3T2=0
C       I3T2 WILL SWITCH KERNELS FOR DIFFERENT SCATT/REFRACT OPTIONS
C
        DO 5 ITH=1,36
        DO 5 KE5=1,301
      7 PROB(ITH,KE5)=0.D0
      5 CONTINUE
C
```

```
C  DEFINE COULOMB/REFRACTIVE SHIFT IN 5 DEG INCREMENTS
C
      NROT=IDINT((DABS(TDEG-DADEG)+2.5D0)/5.D0)
      NFIN=IDINT((FIN+2.5D0)/5.D0)
      NFIN=IDINT((DABS(TDEG2-DTUP)+2.5D0)/5.D0)
C
      DO 8 KE=1,300
      AMN(KE)=0.D0
      AMX(KE)=0.D0
      ALMIN(KE)=0.D0
    8 ALMAX(KE)=0.D0
      E1=XMAX+POT
      MAX=IDINT(XMAX-B(IADST)+1.D0)
C
      UU=XMAX-B(IADST)-ED/2.D0
      NU=IDINT(UU/ED+1.D0)
      IF(NU.LT.1)NU=1
      DO 100 KE=1,NU
      BTST=1.D0
      RKE=ED*DFLOAT(KE)-ED/2.D0
      RKE=RKE/DLT
      KE5=IDINT(RKE)
      FDEL=ED/(2.D0*DLT)
      EDEL=RKE-DFLOAT(KE5)
C
      JEDEL=IDINT(1000.*EDEL)
      JFDEL=IDINT(1000.*FDEL)
      IF(JEDEL.EQ.JFDEL)BTST=0.D0
      IF(KE5.LT.1)GO TO 100
      IF(BTST.NE.0.D0)GO TO 100
      EK=DFLOAT(KE)*ED-ED/2.D0
      EF=EK+B(IADST)+POT
      BRAK=DSQRT(EF*E1)
      BRAK2=DSQRT(POT*(E1+POT-EF))
      ALF2=(EF-POT-BRAK2)/BRAK
      BET2=(EF-POT+BRAK2)/BRAK
      THMIN=DACOS(BET2)
      THMAX=DACOS(ALF2)
      AMN(KE)=(THMIN+.043633D0)/.087266D0+1.D0
      AMX(KE)=(THMAX-.043633D0)/.087266D0+1.D0
C
C   MODIFY TO ROUND FORWARD/BACK ANGLES
C
      DMN=0.D0
      EMN=0.D0
      BMN=THMIN/.087266D0
      IMN=IDINT(BMN)
      CMN=BMN-DFLOAT(IMN)-0.5D0
      IF(CMN.GT.0.D0)DMN=THMIN+.01D0
      FMN=THMAX/.087266D0
      JMN=IDINT(FMN)
      GMN=FMN-DFLOAT(JMN)-0.5D0
      IF(GMN.LT.0.D0)EMN=THMAX-.01D0
      DGMIN=57.296D0*THMIN
      DGMAX=57.296D0*THMAX
      ALMIN(KE)=DGMIN
      ALMAX(KE)=DGMAX
      IF(EF.LT.XMAX)GO TO 200
      BRAK1=DSQRT(POT*(POT+EF-E1))
```

```
      ALF1=(E1-POT-BRAK1)/BRAK
      BET1=(E1-POT+BRAK1)/BRAK
      THB1=DACOS(BET1)
      THA1=DACOS(ALF1)
      N1=IDINT((THB1+.043633D0)/.087266D0+1.D0)
      N2=IDINT((THA1-.043633D0)/.087266D0+1.D0)
      PQSUM=0.D0
      DO 129 ITH=N1,N2
      THETA=DFLOAT(ITH)*.087266D0-.043633D0
      Q=E1+EF-2.D0*BRAK*DCOS(THETA)
      PQ=(E1-EF)/(  DSQRT(Q*E1))
      IF(PQ.LT.0.D0)PQ=0.D0
      PQSUM=PQSUM+PQ
  129 PROB(ITH,KE5)=PROB(ITH,KE5)+PQ

      N11=IDINT((THMIN+.043633D0)/.087266D0+1.D0)
      N22=IDINT((THB1)/.087266D0+1.D0)
      IF(N22.GE.N1)N22=N22-1
      SWC=0.D0
      PQ1=0.D0
      IF(N11.GT.N22)GO TO 133
      IF(N11.LT.1.OR.N22.LT.1)GO TO 131
125   DO 130 ITH=N11,N22
      THETA=DFLOAT(ITH)*.087266D0-.043633D0
      Q=E1+EF-2.D0*BRAK*DCOS(THETA)
      PQ=(E1*EF*(DSIN(THETA))**2-Q*(EF-POT))/(Q*DSQRT(Q*E1))
      IF(PQ.LT.0.D0)PQ=0.D0
      PQ1=PQ1+PQ
130   PROB(ITH,KE5)=PQ
  133 CONTINUE
C
      IF(N11.EQ.1.OR.SWC.NE.0.D0.OR.DMN.LE.0.D0)GO TO 131
      AMN(KE)=AMN(KE)-1.D0
      Q=E1+EF-2.D0*BRAK*DCOS(DMN)
      PQ=0.5D0*(E1*EF*(DSIN(DMN))**2-Q*(EF-POT))/(Q*DSQRT(Q*E1))
      IF(PQ.LT.0.D0)PQ=0.D0
      PQ1=PQ1+PQ
      ITH=IDINT(AMN(KE))
      N11=IDINT(AMN(KE))
      PROB(ITH,KE5)=PQ
131   SWC=SWC+1.D0
      IF(SWC.GT.1.1D0)GO TO 150
      N1T=IDINT((THA1+.043633D0)/.087266D0+1.D0)
      N2T=IDINT((THMAX-.043633D0)/.087266D0+1.D0)
      IF(N1T.EQ.N2)N11=N1T+1
      IF(N1T.GT.N2)N11=N1T
      N22=N2T
      GO TO 125
150   N1=IDINT((THMIN+.043633D0)/.087266D0+1.D0)
      N2=IDINT((THMAX-.043633D0)/.087266D0+1.D0)
C
C  DO BACK ANGLE ROUND
C
      IF(N22.EQ.36.OR.EMN.LE.0.D0)GO TO 155
      AMX(KE)=AMX(KE)+1.D0
      Q=E1+EF-2.D0*BRAK*DCOS(EMN)
      PQ=(E1*EF*(DSIN(EMN))**2-Q*(EF-POT))/(Q*DSQRT(Q*E1))
      IF(PQ.LT.0.D0)PQ=0.D0
      PQ1=PQ1+PQ
```

```
      ITH=IDINT(AMX(KE))
      PROB(ITH,KE5)=PQ
  155 CONTINUE
      N1=IDINT(AMN(KE))
      N2=IDINT(AMX(KE))
      DO 160 ITH=N1,N2
160   PROB(ITH,KE5)=PROB(ITH,KE5)/(PQ1+PQSUM)
      GO TO 500
200   N1=IDINT((THMIN+.043633D0)/.087266D0+1.D0)
      N2=IDINT((THMAX-.043633D0)/.087266D0+1.D0)
      PRSUM=0.D0
      DO 300 ITH=N1,N2
      THETA=DFLOAT(ITH)*.087266D0-.043633D0
      Q=E1+EF-2.D0*BRAK*DCOS(THETA)
      PR=(E1*EF*(DSIN(THETA))**2-Q*(EF-POT))/(Q*DSQRT(Q*E1))
      PRSUM=PRSUM+PR
  300 PROB(ITH,KE5)=PR
      IF(N1.EQ.1.OR.DMN.LE.0.D0)GO TO 320
       AMN(KE)=AMN(KE)-1.D0
      Q=E1+EF-2.D0*BRAK*DCOS(DMN)
      PR=0.5D0*(E1*EF*(DSIN(DMN))**2-Q*(EF-POT))/(Q*DSQRT(Q*E1))
      PRSUM=PRSUM+PR
      ITH=IDINT(AMN(KE))
      PROB(ITH,KE5)=PR
  320 CONTINUE
      IF(N2.EQ.36.OR.EMN.LE.0.D0)GO TO 339
       AMX(KE)=AMX(KE)+1.D0
      Q=E1+EF-2.D0*BRAK*DCOS(EMN)
      PR=0.5*(E1*EF*(DSIN(EMN))**2-Q*(EF-POT))/(Q*DSQRT(Q*E1))
      PRSUM=PRSUM+PR
      ITH=IDINT(AMX(KE))
      PROB(ITH,KE5)=PR
  339 CONTINUE
      N1=IDINT(AMN(KE))
      N2=IDINT(AMX(KE))
      DO 400 ITH=N1,N2
400   PROB(ITH,KE5)=PROB(ITH,KE5)/PRSUM
500   CONTINUE
C
      IF(JN.GT.JNI)GO TO 100
      DO 104 IT=1,36
  104 TEM(IT)=0.D0
C
C CALCULATE THE AVERAGE SINGLE SCATTERING DISTRIBUTION
C FOR A SINGLE PARTIAL WAVE(GL) AND SUMMED OVER ALL
C PARTIAL WAVES WHEN THERE IS A NON ZERO OFFSET,AS
C E.G. FROM COULOMB TRAJECTORY OR REFRACTION
C
C
C  MODIFY TO SPREAD REFR/COUL SHIFT
      NR1=IDINT((DABS(TDEG-DADEG)+2.5D0)/5.D0)
      NR2=IDINT((DABS(TDEG2-DTUP)+2.5D0)/5.D0)
      IF(NR1.EQ.0)NR1=1
      IF(NR2.EQ.0)NR2=1
      NR3=MIN0(NR1,NR2)

      NR4=MAX0(NR1,NR2)
      AREA1=0.D0
      DO 11040 IT=1,36
```

```
11040 AREA1=AREA1+SIGN(IT)*PROB(IT,KE5)
      AREA3=0.D0
C
C    PUT FINITE ANGLE CALC IN-KEEP HEISENBERG HAPPY
C
      CR=1.18D0*A**.33333333
      CRR=1.D0-1.D0/CR**2
      RMXX=CRR*CR-1.1D0
      FIN=0.5D0*29.44D0/(RMXX*DSQRT(EK))
      FIN=FIN*180.D0/3.1415926D0
      NFIN=IDINT(FIN/5.D0+1.D0)
      IF(NFIN.GT.36)NFIN=36
C
C  BEGIN MOD FOR REFR/NO REFR
C
C   IF IREFR=0, NO REFRACTION
C   IF IREFR=1 OR 2,ENTRANCE CHANNEL REFRACTION
C   IF IREFR=3, HEISENBERG ENTRANCE AND EXIT REFRACTION
C     IF IREFR=2,STD ENTRANCE REFRACTION AND HEISENBERG EXIT CHANNEL
C
      IF(IREFR.EQ.0)NR4=1
      IF(IREFR.EQ.0)NR3=1
C
      IF(IREFR.EQ.3)NR4=NFIN
      IF(IREFR.EQ.3)NR3=1
C
C   CALL 3D ROUTINE OR USE 2D FOLDING FOR REFRACTION/HEIS SPREAD
C   OR SKIP AND USE UNFOLDED KERNEL IF IREFR=0.
C
      IJKL=0
      I3T2=1
      IRTST=0
      IF(NR3.EQ.1.AND.NR4.EQ.1)IRTST=1
      IF(IRTST.EQ.0.AND.I3D.EQ.0)CALL TREED
      I3T2=0
      IF(I3D.EQ.0.AND.IRTST.EQ.0)GO TO 1047
      IF(I3D.GT.0.AND.IRTST.EQ.0)GO TO 1050
      DO 1049 IT=1,36
1049  TEM(IT)=PROB(IT,KE5)
      AREA3=AREA1
      GO TO 1051
1047  DO 1048 IT=1,36
1048  AREA3=AREA3+SIGN(IT)*TEM(IT)
      IF(IRTST.EQ.0.AND.I3D.EQ.0)GO TO 1051
C
1050  DROT=1.D0+DFLOAT(NR4-NR3)
      DO 105 ISIZE=NR3,NR4
      NROT=ISIZE
       IF(IREFR.EQ.0)NROT=0
      DO 105 IT=1,36
      ELE=0.5D0*PROB(IT,KE5)/DROT
      IF(ELE.LE.0.D0)GO TO 105
C
      IM=NROT-IT
      IP=NROT+IT
      IF(IREFR.EQ.0)IM=IP
      IF(IM.LT.1)IM=IT-NROT+1
      IF(IP.GT.36)IP=73-IT-NROT
C
```

```
      TEM(IM)=TEM(IM)+ELE*SIGN(IT)/SIGN(IM)
      TEM(IP)=TEM(IP)+ELE*SIGN(IT)/SIGN(IP)
      AREA3=AREA3+2.D0*ELE*SIGN(IT)
  105 CONTINUE
C
1051  IF(JN.GT.JNI)CFRAC=1.D0
C
      FNOR=AREA1/AREA3
      DO 106 IT=1,36
      GL(IT,KE5)=TEM(IT)*FNOR
  106 GDPR(IT,KE5)=GDPR(IT,KE5)+TEM(IT)*FNOR*CFRAC
C
100   CONTINUE
  110  CONTINUE
120   CONTINUE
      RETURN
      END
*
***********************************************************************
*
      Subroutine ASIERK(IZ,IA,IL,BFIS,SEGS,SELMAX)
*     ----------------------------------------
*
C    THIS SUBROUTINE RETURNS THE BARRIER HEIGHT BFIS, THE GROUND-STATE
C    ENERGY SEGS, IN MEV, AND THE ANGULAR MOMENTUM AT WHICH THE FISSION
C    BARRIER DISAPPEARS,  LMAX,  IN UNITS OF H-BAR,
C    WHEN CALLED WITH INTEGER ARGUMENTS IZ, THE ATOMIC NUMBER,
C    IA, THE ATOMIC MASS NUMBER, AND IL,  THE ANGULAR MOMENTUM IN UNITS
C    OF H-BAR, (PLANCK'S CONSTANT DIVIDED BY 2*PI).
C
C         THE FISSION BARRIER FOR  IL = 0  IS CALCULATED FROM A 7TH ORDER
C    FIT IN TWO VARIABLES TO 638 CALCULATED FISSION BARRIERS FOR Z VALUES
C    FROM 20 TO 110.  THESE  638 BARRIERS ARE FIT WITH AN RMS DEVIATION OF
C    0.10 MEV BY THIS 49-PARAMETER FUNCTION.
C    IF  BARFIT  IS CALLED WITH (IZ,IA) VALUES OUTSIDE THE RANGE OF THE FIT
C    THE BARRIER HEIGHT IS SET TO 0.0, AND A MESSAGE IS
C    PRINTED ON THE DEFAULT OUTPUT FILE.
C
C         FOR IL VALUES NOT EQUAL TO ZERO, THE VALUES OF
C    L AT WHICH THE BARRIER IS  80% AND 20% OF THE L=0 VALUE ARE
C    RESPECTIVELY FIT TO 20-PARAMETER FUNCTIONS OF  Z  AND  A, OVER A MORE
C    RESTRICTED RANGE OF  A  VALUES, THAN IS THE CASE FOR  L = 0.
C    THE VALUE OF L WHERE THE BARRIER DISAPPEARS, LMAX
C    IS FIT TO A 24-PARAMETER FUNCTION OF Z AND A,  WITH THE SAME RANGE OF
C    Z  AND  A  VALUES AS 1-80  AND  1-20.
C         ONCE AGAIN, IF AN  (IZ,IA) PAIR IS OUTSIDE OF THE RANGE OF
C    VALIDITY OF THE FIT, THE BARRIER VALUE IS SET TO  0.0  AND A MESSAGE
C    IS PRINTED.  THESE THREE VALUES  (BFIS(L=0),L-80, AND L-20) AND THE
C    CONSTRAINTS  OF  BFIS = 0 AND  D(BFIS)/DL = 0 AT L = LMAX AND L = 0
C    LEAD TO A FIFTH-ORDER FIT TO BFIS(L) FOR L> L-20.  THE FIRST THREE
C    CONSTRAINTS LEAD TO A THIRD-ORDER FIT FOR THE REGION L < L-20.
C
C         THE GROUND-STATE ENERGIES ARE CALCULATED FROM A 120-PARAMETER
C    FIT IN Z. A. AND L TO 214 GROUND-STATE ENERGIES FOR 36 DIFFERENT
C    Z  AND  A  VALUES.
C    (THE RANGE OF Z AND A IS THE SAME AS FOR L-80, L-20, AND L-MAX)
C
C         THE CALCULATED BARRIERS FROM WHICH THE FITS WERE
C    MADE WERE CALCULATED IN 1983-1984 BY A. J. SIERK OF LOS ALAMOS
```

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C     NATIONAL LABORATORY  GROUP T-9, USING  YUKAWA-PLUS-EXPONENTIAL DOUBLE
C     FOLDED NUCLEAR ENERGY, EXACT COULOUB DIFFUSENESS CORRECTIONS,
C     AND DIFFUSE-MATTER MOMENTS OF INERTIA.  THE PARAMETERS OF THE MODEL
C     ARE THOSE DERIVED BY MOLLER AND NIX IN 1979:
C     R-0 = 1.16 FM, AS = 21.13 MEV, KAPPA-S = 2.3 A = 0.68 FM.
C     THE DIFFUSENESS OF THE MATTER AND CHARGE DISTRIBUTIONS USED
C     CORRESPONDS TO A SURFACE DIFFUSENESS PARAMETER (DEFINED BY MYERS)
C     OF 0.99 FM.  THE CALCULATED BARRIERS FOR L = 0 ARE
C     ACCURATE TO A LITTLE LESS THAN 0.1 MEV;  THE OUTPUT FROM THIS
C     SUBROUTINE IS A LITTLE LESS ACCURATE.  WORST ERRORS MAY BE AS LARGE
C     AS 0.5 MEV; CHARACTERISTIC UNCERTAINTY IS IN THE RANGE OF 0.1-0.2
C     MEV.  THE RMS DEVIATION OF THE GROUND-STATE FIT FROM THE 214 INPUT
C     VALUES IS 0.20 MEV.  THE MAXIMUM ERROR OCCURS FOR LIGHT NUCLEI
C     IN THE REGION WHERE THE GROUND STATE IS PROLATE, AND MAY BE GREATER
C     THAN 1.0 MEV FOR VERY NEUTRON-DEFICIENT NUCLEI, WITH L NEAR LMAX.  FOR
C     MOST NUCLEI LIKELY TO BE ENCOUNTERED IN REAL EXPERIMENTS, THE MAXIMUM
C     ERROR IS CLOSER TO 0.5 MEV, AGAIN FOR LIGHT NUCLEI AND L NEAR LMAX.
C
C     WRITTEN BY A. J. SIERK,  LANL  T-9
C     VERSION 1.0  FEBRUARY, 1984
C
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION ELZCOF(7,7),ELMCOF(5,4),EMNCOF(5,4),PA(7),PZ(7),PL(10)
      DIMENSION EMXCOF(6,4),EGSCOF(5,6,4),EGS1(5,6),EGS2(5,6),
     1 EGS3(5,6),EGS4(5,6)
      EQUIVALENCE (EGS1(1,1),EGSCOF(1,1,1)),(EGS2(1,1),EGSCOF(1,1,2)),
     1(EGS3(1,1),EGSCOF(1,1,3)),(EGS4(1,1),EGSCOF(1,1,4))
      DATA EMNCOF
     1/-9.01100E+2,-1.40818E+3, 2.77000E+3,-7.06695E+2, 8.89867E+2,
     2  1.35355E+4,-2.03847E+4, 1.09384E+4,-4.86297E+3,-6.18603E+2,
     3 -3.26367E+3, 1.62447E+3,1.36856E+3, 1.31731E+3, 1.53372E+2,
     4  7.48863E+3,-1.21581E+4, 5.50281E+3,-1.33630E+3, 5.05367E-02/
      DATA ELMCOF
     1 /1.84542E+3,-5.64002E+3,5.66730E+3,-3.15150E+3, 9.54160E+2,
     2 -2.24577E+3, 8.56133E+3,-9.67348E+3, 5.81744E+3,-1.86997E+3,
     3  2.79772E+3,-8.73073E+3, 9.19706E+3,-4.91900E+3, 1.37283E+3,
     4 -3.01866E+1, 1.41161E+3,-2.85919E+3, 2.13016E+3,-6.49072E+2/
      DATA EMXCOF /
     19.43596E4,-2.241997E5,2.223237E5,-1.324408E5,4.68922E4,-8.83568E3,
     2-1.655827E5,4.062365E5,-4.236128E5,2.66837E5,-9.93242E4,1.90644E4,
     3 1.705447E5,-4.032E5,3.970312E5,-2.313704E5,7.81147E4,-1.322775E4,
     4-9.274555E4,2.278093E5,-2.422225E5,1.55431E5,-5.78742E4,9.97505E3/
      DATA ELZCOF
     1 /5.11819909E+5,-1.30303186E+6, 1.90119870E+6,-1.20628242E+6,
     2  5.68208488E+5, 5.48346483E+4,-2.45883052E+4,
     3 -1.13269453E+6, 2.97764590E+6,-4.54326326E+6, 3.00464870E+6,
     4 -1.44989274E+6,-1.02026610E+5, 6.27959815E+4,
     5  1.37543304E+6,-3.65808988E+6, 5.47798999E+6,-3.78109283E+6,
     6  1.84131765E+6,  1.53669695E+4,-6.96817834E+4,
     7 -8.56559835E+5, 2.48872266E+6,-4.07349128E+6, 3.12835899E+6,
     8 -1.62394090E+6, 1.19797378E+5, 4.25737058E+4,
     9  3.28723311E+5,-1.09892175E+6, 2.03997269E+6,-1.77185718E+6,
     A  9.96051545E+5,-1.53305699E+5,-1.12982954E+4,
     B  4.15850238E+4, 7.29653408E+4,-4.93776346E+5, 6.01254680E+5,
     C -4.01308292E+5, 9.65968391E+4,-3.49596027E+3,
     D -1.82751044E+5, 3.91386300E+5,-3.03639248E+5, 1.15782417E+5,
     E -4.24399280E+3,-6.11477247E+3, 3.66982647E+2/
      DATA EGS1 /
     2 1.927813E5, 7.666859E5, 6.628436E5, 1.586504E5,-7.786476E3,
```

```
     3-4.499687E5,-1.784644E6,-1.546968E6,-4.020658E5,-3.929522E3,
     4 4.667741E5, 1.849838E6, 1.641313E6, 5.229787E5, 5.928137E4,
     5-3.017927E5,-1.206483E6,-1.124685E6,-4.478641E5,-8.682323E4,
     6 1.226517E5, 5.015667E5, 5.032605E5, 2.404477E5, 5.603301E4,
     7-1.752824E4,-7.411621E4,-7.989019E4,-4.175486E4,-1.024194E4/
      DATA EGS2 /
     1-6.459162E5,-2.903581E6,-3.048551E6,-1.004411E6,-6.558220E4,
     2 1.469853E6, 6.564615E6, 6.843078E6, 2.280839E6, 1.802023E5,
     3-1.435116E6,-6.322470E6,-6.531834E6,-2.298744E6,-2.639612E5,
     4 8.665296E5, 3.769159E6, 3.899685E6, 1.520520E6, 2.498728E5,
     5-3.302885E5,-1.429313E6,-1.512075E6,-6.744828E5,-1.398771E5,
     6 4.958167E4, 2.178202E5, 2.400617E5, 1.167815E5, 2.663901E4/
      DATA EGS3 /
     1 3.117030E5, 1.195474E6, 9.036289E5, 6.876190E4,-6.814556E4,
     2-7.394913E5,-2.826468E6,-2.152757E6,-2.459553E5, 1.101414E5,
     3 7.918994E5, 3.030439E6, 2.412611E6, 5.228065E5, 8.542465E3,
     4-5.421004E5,-2.102672E6,-1.813959E6,-6.251700E5,-1.184348E5,
     5 2.370771E5, 9.459043E5, 9.026235E5, 4.116799E5, 1.001348E5,
     6-4.227664E4,-1.738756E5,-1.795906E5,-9.292141E4,-2.397528E4/
      DATA EGS4 /
     1-1.072763E5,-5.973532E5,-6.151814E5, 7.371898E4, 1.255490E5,
     2 2.298769E5, 1.265001E6, 1.252798E6,-2.306276E5,-2.845824E5,
     3-2.093664E5,-1.100874E6,-1.009313E6, 2.705945E5, 2.506562E5,
     4 1.274613E5, 6.190307E5, 5.262822E5,-1.336039E5,-1.115865E5,
     5-5.715764E4,-2.560989E5,-2.228781E5,-3.222789E3, 1.575670E4,
     6 1.189447E4, 5.161815E4, 4.870290E4, 1.266808E4, 2.069603E3/
C
C    THE PROGRAM STARTS HERE
C
      IF (IZ.LT.19 .OR. IZ.GT.111) GO TO 900
      IF (IZ.GT.102 .AND. IL.GT.0) GO TO 902
      Z = DFLOAT(IZ)
      A = DFLOAT(IA)
      EL = DFLOAT(IL)
      AMIN = 1.2*Z + 0.01*Z*Z
      AMAX = 5.8*Z - 0.024*Z*Z
      IF (A.LT.AMIN .OR. A.GT.AMAX) GO TO 910
      AA = A/400.
      ZZ = Z/100.
      ELL = EL/100.
      BFIS0 = 0.D0
      CALL LPOLY(ZZ,7,PZ)
      CALL LPOLY(AA,7,PA)
       DO 10 I = 1,7
       DO 10 J = 1,7
       BFIS0=BFIS0 + ELZCOF(J,I)*PZ(J)*PA(I)
 10    CONTINUE
      BFIS = BFIS0
      EGS = 0.D0
      SEGS = EGS
      AMIN2 = 1.4*Z + 0.009*Z*Z
      AMAX2 = 20. + 3.0*Z
      IF ((A.LT.AMIN2-5. .OR. A.GT.AMAX2+10.) .AND. IL.GT.0) GO TO 920
      CALL LPOLY(ZZ,5,PZ)
      CALL LPOLY(AA,4,PA)
      ELMAX = 0.D0
      EL80 = 0.D0
      EL20 = 0.D0
       DO 20 I = 1,4
```

```
       DO 20 J = 1,5
       EL80 = EL80 + ELMCOF(J,I)*PZ(J)*PA(I)
       EL20 = EL20 + EMNCOF(J,I)*PZ(J)*PA(I)
 20    CONTINUE
      SEL80 = EL80
      SEL20 = EL20
      CALL LPOLY(ZZ,6,PZ)
      CALL LPOLY(ELL,9,PL)
       DO 30 I = 1,4
       DO 30 J = 1,6
       ELMAX = ELMAX + EMXCOF(J,I)*PZ(J)*PA(I)
C      ELMAX = ELMAX + DBLE(EMXCOF(J,I))*PZ(J)*PA(I)
 30    CONTINUE
      SELMAX = ELMAX
      IF (IL.LT.1) RETURN
      X = SEL20/SELMAX
      Y = SEL80/SELMAX
      IF (EL.GT.SEL20) GO TO 40
      Q = 0.2/(SEL20**2*SEL80**2*(SEL20-SEL80))
      QA = Q*(4.*SEL80**3 - SEL20**3)
      QB = -Q*(4.*SEL80**2 - SEL20**2)
      BFIS = BFIS*(1.D0 + QA*EL**2 + QB*EL**3)
      GO TO 50
   40 AJ = (-20.*X**5 + 25.*X**4 -4.)*(Y-1.)**2*Y*Y
      AK = (-20.*Y**5 + 25.*Y**4 - 1.)*(X-1.)**2*X*X
      Q = 0.2/((Y-X)*((1.-X)*(1.-Y)*X*Y)**2)
      QA =  Q*(AJ*Y - AK*X)
      QB = -Q*(AJ*(2.*Y+1.) - AK*(2.*X+1.))
      Z = EL/SELMAX
      A1 = 4.*Z**5 - 5.*Z**4 + 1.
      A2 = QA*(2.*Z+1.)
      BFIS = BFIS*(A1 + (Z-1.)*(A2 + QB*Z)*Z*Z*(Z-1.))
   50 IF (BFIS.LE.0.D0) BFIS = 0.D0
      IF (EL.GT.SELMAX) FBIS = 0.D0
C
C    NOW CALCULATE ROTATING GROUND-STATE ENERGY
C
      IF (EL.GT.SELMAX) RETURN
         DO 70 K=1,4
            DO 70 L=1,6
              DO 70 M = 1,5
            EGS=EGS+EGSCOF(M,L,K)*PZ(L)*PA(K)*PL(2*M-1)
   70         CONTINUE
      SEGS = EGS
      IF (SEGS.LT.0.D0) SEGS = 0.D0
      RETURN
 900  WRITE(7,1000)
      BFIS = 0.D0
      SEGS = 0.D0
      SELMAX = 0.D0
      RETURN
 902  WRITE(7,1002)
      BFIS = 0.D0
      SEGS = 0.D0
      SELMAX = 0.D0
      RETURN
 910  WRITE(7,1010)IA
      BFIS = 0.D0
      SEGS = 0.D0
```

```
      SELMAX = 0.D0
      RETURN
 920  WRITE(7,1020)IA,IL
      BFIS = 0.D0
      SEGS = 0.D0
      SELMAX = 0.D0
      RETURN
C
 1000 FORMAT(/,10X,'*  *  *  *  BARFIT CALLED WITH  Z  LESS THAN 19 OR ',
     1 ' GREATER THAN 111.  BFIS IS SET TO 090.  *  *  *  *')
 1002 FORMAT(/,10X,'*  *  *  *  BARFIT CALLED WITH  Z  GREATER THAN 102',
     1 ' AND  L  NOT EQUAL TO ZERO.  BFIS IS SET TO 0.0,  *  *  *  *')
 1010 FORMAT(/,10X,'*  *  *  *  BARFIT CALLED WITH A =',I3,', OUTSIDE ',
     1 'THE ALLOWED VALUES FOR Z = ',I3,' *  *  *  *')
 1020 FORMAT(/,10X,'*  *  *  *  BARFIT CALLED WITH A =',I3,', OUTSIDE',
     1 ' THE ALLOWED VALUES FOR Z = ',I3/26X,'FOR NONZERO L =',I3,
     2 '  *  *  *  *')
      END
*
*********************************************************************
*
      Subroutine BCS(PAR,RES)
*     ----------------------
*
C Written by A.V.Ignatyuk
C
C PHENOMEN.DESCRIPTION BCS+COLL
C
C  INPUT DATA:
C      PAR(1)= Z
C      PAR(2)= A
C      PAR(3)= AASYMPTOTIC = 0.073*A +  0.115*A**(2/3)
C      PAR(4)= GAMMA  =  0.4/A**(1/3)
C      PAR(5)= SHELL CORRECTION
C      PAR(6)= DELTA = 12.0/A**(1/2)
C      PAR(7)= DSHIFT
C      PAR(8)= POSITION OF FIRST 2+ LEVEL
C      PAR(9)=DEFORMATION=BETA FROMN LYSEKIL FORMULA
C      RES(1)=  EXCITATION ENERGY U IN MEV
C
C  OUTPUT RESULTS:
C      RES(2)=  LOGARITHM NAT( STATE DENSITY )
C      RES(3)=  LOGARITHM NAT( LEVEL DENSITY )
C      RES(4)=    SIGMA**2  /SPIN CUTOFF PARAMETER/
C      RES(5)=   TEMPERATURE IN MEV
C
C
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION PAR(9),RES(7)
      FU(X,DX,GX)=1.+(1.-DEXP(-GX*X))*DX/X
      TM2=.24*PAR(2)**.6666666
      Z=PAR(1)
      A=PAR(2)
      OM2=PAR(8)
      IF(OM2.LE.0.) OM2=30./A**.66666666
      OM3=50./A**.66666666
      BET=PAR(9)
      IF(PAR(9).LT.0.15)BET=0.D0
      U=RES(1)
```

```
      IF(U-.01D0) 10,10,11
   10 DO 12 I=1,6
   12 RES(I+1)=0.D0
      RETURN
   11 AP=PAR(3)
      DL0=PAR(6)
      GAM=PAR(4)
C 14-MAR-1992
      DW=PAR(5)
      NNZ=IDINT(Z)
      NZ=(NNZ/2)*2
      IZ=0
      IF(NNZ.GT.NZ) IZ=1
      NNNN=IDINT(A-Z)
      NN=((NNNN)/2)*2
      IN=0
      IF(NNNN.GT.NN) IN=1
      DEL=DL0*DFLOAT(IZ+IN)+PAR(7)
      U=U+DEL
      TKP=0.567*DABS(DL0)
      TKP2=TKP**2
      AX=AP*(1.+DW*GAM)
      DO 8 LX=1,5
      X=AX*TKP2
      AKP=AP*FU(X,DW,GAM)
      IF(DABS(AKP-AX)/AKP.LE.0.001D0) GO TO 9
      AX=AKP
    8 CONTINUE
    9 ECOH=0.152*AKP*DL0**2
      UKP=AKP*TKP2+ECOH
      SKP=2.*AKP*TKP
      DTKP=45.84*AKP**3*TKP**5
      FKP=0.608*AKP*TM2*(1.-0.6667*BET)
      FKP1=0.608*AKP*TM2*(1.+0.333*BET)
      IF(U.GE.UKP) GO TO 30
      IF(UKP.NE.0.) FI2=1-U/UKP
      FI=DSQRT(FI2)
      T=2.*TKP*FI/DLOG((FI+1.)/(1.-FI))
      T1=T
      SK=SKP*TKP/T*(1-FI2)
      DET=DTKP*(1.-FI2)*(1.+FI2)**2
      FM=FKP*TKP/T*(1.-FI2)
      FM1=FKP1*(1.+2.*TKP/T*(1.-FI2))/3.
      GO TO 40
   30 UX=U-ECOH
      AS=AP*FU(UX,DW,GAM)
      IF(AS.LE.0.D0) RETURN
      T=DSQRT(UX/AS)
      T1=T
      SK=2.*AS*T
      DET=45.84*AS**3*T1**5
      FM=0.608*AS*TM2*(1.-.6667*BET)
      FM1=0.608*AS*TM2*(1.+0.333333*BET)
   40 SIG=FM*T1
      SIG1=FM1*T1
      IF(DABS(BET).GT.0.D0) SIG=FM1**.6666666*FM**.3333333*T1
      RES(2)=SK-DLOG(DSQRT(DET))
      RES(3)=SK-DLOG(DSQRT(6.283*SIG*DET))
      RES(4)=SIG
```

```
      RES(5)=T1
      CGA=.0075*A**.33333333
      IF(BET.EQ.0.D0)GO TO 51
      Q3=1.D0
      OM=1.D0
      CALL QVIBR(T1,OM,CGA,3,Q2)
      CALL QROT(A,BET,SIG1,U,QR)
      GO TO 52
   51 CALL QVIBR(T1,OM2,CGA,5,Q2)
      CALL QVIBR(T1,OM3,CGA,7,Q3)
C      CALL QROT(A,BET,SIG1,U,QR)
      QR=1.D0
   52 RES(6)=Q2*Q3
      RES(7)=QR
      COL=DLOG(Q2*Q3*QR)
      RES(2)=RES(2)+COL
      RES(3)=RES(3)+COL
    2 RETURN
      END
*
*****************************************************************************
*

      Subroutine BETAK_DOBES(E,N,P,H,G,GH,EF,W)
*     ----------------------------------------
*
c E    : energy of excitation,
c N,P,H: number of excitons, particles, holes
c G,GH : single state density for particles and holes
c EF   : Fermi energy
c
        IMPLICIT REAL*8 (A-H,O-Z)
        INTEGER P,H
c
c Ericson, Strutinsky
c
c        WES=G*( (G*E)**(N-1) )/
c     c  (Factorial(P)*Factorial(H)*Factorial(N-1))
c
c Betak, Dobes
c
        sum=0.0
               h1=H+1
        Do 1 i1=1,h1
        L=i1-1
        RL=dfloat(L)
        if((E-RL*EF).eq.0.0.and.(N-1).eq.0) goto 1
        sum=sum+CHL(L,H)* Heaviside(E-RL*EF)* (  (-1.)**L  )*
     c  ( (E-RL*EF)**(N-1) )/(Factorial(P)*Factorial(H)*Factorial(N-1))
    1   Continue
        W=(G**P)*(GH**H)*sum
        Return
        End
*
*****************************************************************************
*
      Subroutine BINDEN(ZEE,AMASS,NZ,NA,AP,AT,ZP,ZT,QVAL,M3,MP,MC,LDOPT)
*     ------------------------------------------------------------------
*
```

```
      IMPLICIT REAL*8 (A-H,O-Z)
      CHARACTER*4 BLANK,TAB,FOR,RINP,ABE,SYMB(11,24),SYMBP(11,24),
     1SYMBS(11,24),AAA,AAB
      COMMON/LYM1/BE(11,24,4),SYMB,PAIR(11,24),SYMBP,SYMBS,XMAS(11,24),
     1DELSHL(11,24),AMAS(11,24)
      COMMON/HOT/KPG,MPG
      DIMENSION EXCES(4),RES(4),ERR(4)
      DATA BLANK,TAB,FOR,RINP,ABE/4H    ,4H TAB,4H MSL,4H INP,4H ABE/
      IZEE=IDINT(ZEE)
      IMASS=IDINT(AMASS)
      IAP=IDINT(AP)
      IAT=IDINT(AT)
      IZP=IDINT(ZP)
      IZT=IDINT(ZT)
      INP=IAP-IZP
      INTT=IAT-IZT
      IRET=0
      N=IMASS-IZEE
      CALL MASS(IZP,INP,EXCES(1),ERR(1),IRET)
      CALL MASS(IZT,INTT,EXCES(2),ERR(2),IRET)
      CALL MASS(IZEE,N,EXCES(3),ERR(3),IRET)
      IF(IRET.GT.0) GO TO 10
      IF(QVAL.NE.0.D0)GO TO 10
      QVAL=-EXCES(3)+EXCES(2)+EXCES(1)
      Write(7,4)
    4 FORMAT(//,20X,'*****************************************'//)
      Write(7,5)QVAL
      Write(7,4)
5     FORMAT(20X,' QVAL USED (CALCULATED FROM MASS TABLE) = ',F5.1)
10    IRET=0
      CALL MASS(0,1,EXCES(1),ERR(1),IRET)
      CALL MASS(1,0,EXCES(2),ERR(2),IRET)
      CALL MASS(2,2,EXCES(3),ERR(3),IRET)
      IF(KPG.eq.0) CALL MASS(1,1,EXCES(4),ERR(4),IRET)
      IF(KPG.eq.1) CALL MASS(1,2,EXCES(4),ERR(4),IRET)
      IF(KPG.eq.2) CALL MASS(2,1,EXCES(4),ERR(4),IRET)
      IF(IRET.GT.0) RETURN
      Write(7,6)
6     FORMAT(30X,'BINDING ENERGIES CALCULATED FROM MASS TABLE',
     1 ' WHERE POSSIBLE.')
      IF(MP.EQ.0)Write(7,7)
7     FORMAT(35X,'PAIRING REMOVED FROM MASSES IN TABLE')
      IF (MP.EQ.0.AND.MC.EQ.1) Write(7,8)
    8 FORMAT (35X,'SHELL CORRECTION REMOVED FROM MASSES IN TABLE')
      DO 65 IZ=1,NZ
      DO 65 IA=1,NA
      IZZ=IZEE-IZ+1
      INN=IMASS-IZEE-IA+1
      IZZ1=IZZ-1
      INN1=INN-1
      INN2=INN-2
      IZZ2=IZZ-2
      IRET=0
      CALL MASS(IZZ,INN,XMASS,ERR(1),IRET)
      CALL MASS(IZZ,INN1,RES(1),ERR(1),IRET)
      IF(M3.GE.2)CALL MASS(IZZ1,INN,RES(2),ERR(2),IRET)
      IF(M3.GE.3)CALL MASS(IZZ2,INN2,RES(3),ERR(3),IRET)
      IF(M3.EQ.4.and.KPG.EQ.0)CALL MASS(IZZ1,INN1,RES(4),ERR(4),IRET)
      IF(M3.EQ.4.and.KPG.EQ.1)CALL MASS(IZZ1,INN2,RES(4),ERR(4),IRET)
```

```
      IF(M3.EQ.4.and.KPG.EQ.2)CALL MASS(IZZ2,INN1,RES(4),ERR(4),IRET)
      XMAS(IZ,IA)=XMASS
      IF(IRET.GT.0) GO TO 65
      IF(MP.NE.0)GO TO 55
      XMASS=XMASS+PAIR(IZ,IA)
      RES(1)=RES(1)+PAIR(IZ,IA+1)
      RES(2)=RES(2)+PAIR(IZ+1,IA)
      RES(3)=RES(3)+PAIR(IZ+2,IA+2)
      IF(KPG.EQ.0) RES(4)=RES(4)+PAIR(IZ+1,IA+1)
      IF(KPG.EQ.1) RES(4)=RES(4)+PAIR(IZ+1,IA+2)
      IF(KPG.EQ.2) RES(4)=RES(4)+PAIR(IZ+2,IA+1)
   55 DO 60 I=1,M3
60    BE(IZ,IA,I)=-XMASS+EXCES(I)+RES(I)
      SYMB(IZ,IA)=TAB
65    CONTINUE
      AAA=ABE
      AAB=FOR
      RETURN
      END
*
*-----------------------------------------------------------------------
*
      BLOCK DATA
*     ----------
*
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/FLMIH1/FLMIH(28,4)
      COMMON/FLMIH2/FLMIH2(42,3)
      COMMON/FLMIH3/FLMIH3(42,3)
C
C  Data of IWAMOTO,HARADA for alpha-particles
       DATA FLMIH/10., 6., 3.5, 2., 1., 0.5, 22*0.,
     # 21., 22., 20., 17., 13.5, 11., 8., 5., 3., 1.5, 0.5, 17*0.,
     # 3.5, 9.5, 13.5, 17., 20., 22.5, 23.5, 24.5, 24.5, 23.5, 21.5,
     # 19.5, 16.5, 14.5, 12.5, 10.5, 9., 7.5, 6., 5., 4., 3., 2., 1.2,
     # 0.8, 0.5, 0., 0.,
     # 28*0./
C
C  Data of IWAMOTO,HARADA for tritons
       DATA FLMIH2/20.0, 14.5, 11.2, 8.15, 5.85, 3.85, 2.5, 1.5, 0.7,
     1 0.1, 32*0.0,
     2 14.5, 19.5, 22.25, 24., 24.75, 24.75, 24., 22.6, 20.7, 18.7,
     2 16.4, 14.4, 12., 10., 8., 6.25, 4.8, 3.3, 2.15, 1.45, 0.9,
     2 0.5, 0.1, 0.05, 18*0.0,
     3 42*0./
C
C  Data of IWAMOTO,HARADA for He-3 (temporarily = triton)
       DATA FLMIH3/20.0, 14.5, 11.2, 8.15, 5.85, 3.85, 2.5, 1.5, 0.7,
     1 0.1, 32*0.0,
     2 14.5, 19.5, 22.25, 24., 24.75, 24.75, 24., 22.6, 20.7, 18.7,
     2 16.4, 14.4, 12., 10., 8., 6.25, 4.8, 3.3, 2.15, 1.45, 0.9,
     2 0.5, 0.1, 0.05, 18*0.0,
     3 42*0./
       END
*
*-----------------------------------------------------------------------
*
      Real*8 Function CHL(L,H)
*     ------------------------
```

```
*
      Implicit real*8 (A-H,O-Z)
      Integer H
      CHL=Factorial(H)/(Factorial(H-L)*Factorial(L))
      Return
      End
*
*********************************************************************
*
      Subroutine DDIREC(IALPHA,WIMAG,
     +                  L91,L92,GIB,GE,G,XMAX,ED9,BA,CNCS,POT)
*     ------------------------------------------------------
*
C     DEUTERON QUASI-DIRECT ROUTINE FOR ALICE/ASH
C
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/SHFT/QVAL,AP,AT,ZP,ZT,CLD,MC,MP,INVER,IKE,IPCH,BARFAC
      COMMON/MEMO/SCRS(300,4)
      COMMON/EFD/EFERMI,GH
      COMMON/PAR3/EQ,SIGML999(300),ACRS999(300)
      COMMON/ADDKD/FID,EDEUMIN,EDEUEXP
      DIMENSION GIB(4,300),GE(4)
C
      IF(L91.NE.L92.AND.L92.NE.1) IALPHA=IALPHA+1
      E=XMAX
      ED=ED9
      U=XMAX-BA-ED/2.
      NU=U/ED+1.
      IF(NU.LE.0)GOTO 111
      IF(NU.GT.300)GOTO 44444
      U=XMAX-BA-ED/2.
      NU=U/ED+1.
C
C PARAMETERS FOR DIRECT PEAK IN SPECTRA
      CALL DEUPARD(ZP,AP,ZT,AT,AKOEF,EFermi2,csigmad,crwd)
C
      AKOEF=CNCS*      AKOEF
      Sigma=Efermi2/csigmad
C
      DO 777 KE=1,NU
      RW=EXP(  -((U-crwd*EFermi2)**2)/(2*(Sigma**2))  )
      EDEU=DFLOAT(KE)*ED-ED/2.
                           WIMAG2 = WIMAG
C  WIMAG2 must be the same as in other subroutines
      IF(EDEU.gt.EDEUMIN) WIMAG2 =WIMAG2*DEXP( -EDEUEXP*(EDEU-EDEUMIN) )
C
      RV=2.*GIB(4,KE)/(2.*GIB(4,KE)+8.27E+03*WIMAG2)
      IF(RW.LT.0..OR.RV.LT.0.)GOTO 55555
      SCRS(KE,4)=SCRS(KE,4) + AKOEF * RW * RV
  707 U=U-ED
      IF(U.LE.0.)GOTO 1000
  777 CONTINUE
 1000 IALPHA=IALPHA+10
      RETURN
C
  111 WRITE(7,112)U,XMAX,BA,ED,NU
      WRITE(8,112)U,XMAX,BA,ED,NU
  112 FORMAT(1X,80('+')/1X,'DIRECT      DEUTR COULD NOT EMITTED, BECAU
     1SE:'/1X,' U=',G12.5,' XMAX=',G12.5,' BA=',G12.5,' ED=',G12.5,' NU=
```

```
     2',I6/1X,80('+'))
      RETURN
44444 WRITE(7,44445)U,XMAX,BA,ED,NU
      WRITE(8,44445)U,XMAX,BA,ED,NU
44445 FORMAT(1X,'SUBR.DDIREC: ERROR NU > 300 '/1X,' U=',G12.5,' XMAX='
     1,G12.5,' BA=',G12.5,' ED=',G12.5,' NU=',I6)
      STOP
55555 WRITE(7,55556)RW,RV,KE,U,E
      WRITE(8,55556)RW,RV,KE,U,E
55556 FORMAT(1X,'SUBR.DDIREC: ERROR RW OR RV < 0'/1X,' RW=',G12.5,' RV
     1=',G12.5,' KE=',I5/1X,' U=',G12.5,' E=',G12.5)
      STOP
      END
*
*********************************************************************
*
      Subroutine DEPLET(MPARIN,NP9,NH9,U9,AFRRE,GIB,G,ED)
*     ---------------------------------------------
*
* DEPLETION ALGORITHM FOR SECOND PRECOMPOUND NUCLEONS
*
      IMPLICIT REAL*8 (A-H,O-Z)
      CHARACTER*4 SYMB,SYMBP,SYMBS
      COMMON/LYM1/BE(11,24,4),SYMB(11,24),PAIR(11,24),SYMBP(11,24),
     1SYMBS(11,24),XMAS(11,24),DELSHL(11,24),AMAS(11,24)
      DIMENSION GIB(4,300)
C WIM: COMPLEX PART OF OPTICAL POTENTIAL FOR NUCLEONS
      WIM=10.
      XMAX = U9
         NP=NP9
         NH=NH9
         N=NP+NH
      E=XMAX
      IF(NP.LE.0)RETURN
C
      AKOEF=G*DFLOAT(NP)*DFLOAT(N-1)
C
         SUM=0.
C I-OUTGOING PARTICLE TYPE
      DO 9000 I=1,2
      IF(MPARIN.EQ.1) BA=BE(1,2,I)
      IF(MPARIN.EQ.2) BA=BE(2,1,I)
C
      U=XMAX-BA-ED/2.
      NU=U/ED+1.
      IF(NU.LE.0)GOTO 9000
      IF(NU.GT.300)GOTO 44444
      DO 777 KE=1,NU
      RW=((U/E)**(N-2))/(G*E)
      RV=2.*GIB(I,KE)/(2.*GIB(I,KE)+8.27E+03*WIM)
      IF(RW.LT.0..OR.RV.LT.0.)GOTO 55555
      SUM=SUM+AKOEF   *RW*RV
C
      IF(RW.LT.1.0E-50)GOTO 9000
      U=U-ED
      IF(U.LE.0.)GOTO 9000
  777 CONTINUE
C
 9000 CONTINUE
```

```
C *ED
      SUM=SUM*ED
                        AFRRE=AFRRE*(1.-SUM)
      IF(SUM.GE.1.D+00) AFRRE  = 0.0
      IF(AFRRE.LT.0.D+00) GOTO 88888
      RETURN
C
44444 WRITE(6,44445)U,XMAX,BA,ED,NU
      WRITE(8,44445)U,XMAX,BA,ED,NU
44445 FORMAT(1X,'SUBR.DEPLET: ERROR NU > 300 '/1X,' U=',G12.5,' XMAX='
     1,G12.5,' BA=',G12.5,' ED=',G12.5,' NU=',I6)
      STOP
55555 WRITE(6,55556)RW,RV,KE,U,E,N
      WRITE(8,55556)RW,RV,KE,U,E,N
55556 FORMAT(1X,'SUBR.DEPLET: ERROR RW OR RV < 0'/1X,' RW=',G12.5,' RV
     1=',G12.5,' KE=',I5/1X,' U=',G12.5,' E=',G12.5,' N=',I5)
      STOP
88888 WRITE(6,88889)SUM,NP,NH,U
      WRITE(8,88889)SUM,NP,NH,U
      WRITE(6,*)SUM
88889 FORMAT(1X,'SUBR.DEPLET: ERROR SUM > 1 '/1X,' SUM =',G12.5,
     1  ' NP,NH= ',2I5/1X,' U=',G12.5)
      STOP
      END
*
*********************************************************************
*
      Subroutine DEUNUC(IFLAG,MPARIN,U9,EX9,X9,GIB,GE,G,P,CF,ED9)
*     ------------------------------------------------------------
*
C ROUTINE FOR DATA PREPARATION TO CALL ALPTWO FOR N-D AND P-D EMISSION
C
C MPARIN- TYPE OF FIRST EMITTED NUCLEON (1=N, 2=P)
C
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/IALPH/IALPHA
      DIMENSION GIB(4,300),GE(4)
C
      IF(IFLAG.EQ.1) GOTO 1
      ialphatmp=ialpha
      ialpha=20
      CALL IWAMOD(IALPHA,WIMAG)
      ialpha=ialphatmp
1     IFLAG=1
      U=U9
      ED=ED9
         NP=IDINT(EX9+0.01D+00)
         NH=IDINT(X9+0.01D+00)
C
      GDEUT = GE(4)
C NO ED MULTIPLICATION (SEE.HYBRID)
      AFRRE=P*CF
C NPX,NHX - NUMBER OF PARTICLES AND HOLES AFTER NUCLEON EMISSION
      NPX=NP-1
      NHX=NH
C ONLY 5 TERMS WILL BE CONSIDERED FOR MULTIPLY (SECONDARY) EMISSION
           NPX=NPX-1
           NHX=NHX-1
      DO 1000  II=1,5
```

```
           NPX=NPX+1
           NHX=NHX+1
      CALL DEUTWO(MPARIN,NPX,NHX,U,AFRRE,GDEUT,GIB,G,ED,WIMAG)
      CALL DEPLET(MPARIN,NPX,NHX,U,AFRRE,GIB,G,ED)
1000  CONTINUE
      RETURN
      END
*
*********************************************************************
*
      Subroutine DEUPARD(ZP,AP,ZT,AT,AKOEF,EFermi2,csigmad,crwd)
*     ----------------------------------------------------------
*
      IMPLICIT REAL*8 (A-H,O-Z)
* PARAMETERS
*     AKOEF=CNCS*      AKOEF
*     Sigma=Efermi2/csigmad
*     RW=EXP(  -((U-crwd*EFermi2)**2)/(2*(Sigma**2))  )
*
          EFermi2=10.
          AKOEF  = 1.5E-3
          csigmad=3.
          crwd   =0.5
      IZP=idint(ZP+0.0001d0)
      IAP=idint(AP+0.0001d0)
      IZT=idint(ZT+0.0001d0)
      IAT=idint(AT+0.0001d0)
      if(IZP.eq.0.and.IAP.eq.1) goto 1
      if(IZP.eq.1.and.IAP.eq.1) goto 2
      return
c
c Neutron incident
C C-12
    1  If(IZT.eq.6.and.IAT.eq.12)  then
       AKOEF  = 3.e-3
       csigmad= 4.
       crwd   = 0.1
                                   endif
       If(IZT.eq.13.and.IAT.eq.27) then
       AKOEF  = 1.5e-3
       csigmad= 3.
       crwd   = 0.5
                                   endif
C Si
       If(IZT.eq.14              ) then
       AKOEF  = 3.5e-3
       csigmad= 3.
       crwd   = 0.5
                                   endif
C V-51
       If(IZT.eq.23.and.IAT.eq.51) then
       AKOEF  = 1.5e-3
       csigmad= 3.
       crwd   = 0.5
                                   endif
C Fe-56
       If(IZT.eq.26.and.IAT.eq.56) then
       AKOEF  = 0.3e-3
       csigmad= 3.
```

```
       crwd   = 0.01
                                    endif
       If(IZT.eq.82.and.IAT.eq.208) AKOEF  = 0.0
c
       return
c
c Proton incident
C C-12
    2  If(IZT.eq.6.and.IAT.eq.12)  then
       AKOEF  = 8.5e-3
       csigmad= 4.
       crwd   = 0.1
                                    endif
C Al-27
       If(IZT.eq.13.and.IAT.eq.27) then
       AKOEF  = 1.5e-3
       csigmad= 3.
       crwd   = 0.5
                                    endif
C Iron
       If(IZT.eq.26)               then
       AKOEF  = 1.5e-3
       csigmad= 3.
       crwd   = 0.5
                                    endif
C Ni-58
       If(IZT.eq.28.and.IAT.eq.58) then
       AKOEF  = 1.5e-3
       csigmad= 3.
       crwd   = 1.
                                    endif
C Y-89
       If(IZT.eq.39.and.IAT.eq.89) then
       AKOEF  = 1.5e-3
       csigmad= 5.
       crwd   = 0.05
                                    endif
C Zr-90
       If(IZT.eq.40.and.IAT.eq.90) then
       AKOEF  = 3.0e-3
       csigmad= 9.
       crwd   = 0.2
                                    endif
C Sn-120
       If(IZT.eq.50.and.IAT.eq.120)then
       AKOEF  = 1.5e-3
       csigmad= 5.
       crwd   = 0.4
                                    endif
C Au-197
       If(IZT.eq.79.and.IAT.eq.197)then
       AKOEF  = 1.5e-3
       csigmad= 3.
       crwd   = 0.1
                                    endif
C Pb
       If(IZT.eq.82)               then
       AKOEF  = 0.0
       csigmad= 3.
```

```
       crwd   = 0.1
                                  endif
C Bi-209
       If(IZT.eq.83.and.IAT.eq.209)then
       AKOEF  =  1.5e-3
       csigmad=  8.
       crwd   =  0.5
                                  endif
       return
       end
*
*********************************************************************
*
      Subroutine DEUT05(TT9,EX9,X9,L91,L92,GIB,GE,G,DEP,
     $                  XMAX,ED9,BA,CNCS, PAIRXA,POT)
*     ------------------------------------------------
*
C     DEUTERON PRECOMPOUND ROUTINE FOR ALICE/ASH
C
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/IALPH/IALPHA
      COMMON/MEMO/SCRS(300,4)
      COMMON/IWADEU/FLM(300,2)
      COMMON/EFD/EFERMI0,GH
      COMMON/ADDKD/FID,EDEUMIN,EDEUEXP
      DIMENSION GIB(4,300),GE(4),DEP(2)
C
C BA IS DEUTERON SEPARATION ENERGY,
C XMAX IS MAXIMAL EXCTITATION ENERGY OF COMPOSITE NUCLEUS,
C N TT9 IS CURRENT NUMBER OF EXCITONS, CNCS IS TOTAL NONELASTIC CR.SECT.
C EX9 IS NUMBER OF PARTICLES, X9 IS NUMBER OF HOLES,
C WIMAG IS COMPLEX PART OF OPTICAL POT. FOR DEUTERON
C
      IF(IALPHA.LT.20)CALL IWAMOD(IALPHA,WIMAG)
      IF(IALPHA.LT.30)CALL DDIREC(IALPHA,WIMAG,
     + L91,L92,GIB,GE,G,XMAX,ED9,BA,CNCS,POT)
         EFermi=EFERMI0
         N=IDINT(TT9+0.01D+00)
      E=XMAX
      ED=ED9
         NP=IDINT(EX9+0.01D+00)
         P=DFLOAT(NP)
         NH=IDINT(X9+0.01D+00)
      IF(NH.NE.(N-NP)) GOTO 23232
      IF(NP.EQ.0)GOTO 33333
      U=XMAX-BA-ED/2.
      NU=U/ED+1.
      IF(NU.LE.0)GOTO 111
      IF(NU.GT.300)GOTO 44444
      LMAX=MIN0(NP,2)
      BAA=(BA /ED) + DSIGN(0.5D0,BA)
      ISHIFT=IDINT(BAA)
C
      DO 1000 L=1,LMAX
      U=XMAX-BA-ED/2. - PAIRXA
                        UU = U
      IF(PAIRXA.LT.0.0) UU = XMAX-BA-ED/2.
      NU=UU/ED+1.
      Call BETAK_DOBES(E,N,NP,NH,G,GH,EFermi,WE)
```

```
      AKOEF=CNCS*DEP(2)*GE(4)
C
      DO 777 KE=1,NU
      Call BETAK_DOBES(U,N-L,NP-L,NH,G,GH,EFermi,WU)
      RW=WU/WE
      EDEU=DFLOAT(KE)*ED-ED/2.
                          WIMAG2 = WIMAG
C  WIMAG2 must be the same as in other subroutines
      IF(EDEU.gt.EDEUMIN) WIMAG2 =WIMAG2*DEXP( -EDEUEXP*(EDEU-EDEUMIN) )
      RV=2.*GIB(4,KE)/(2.*GIB(4,KE)+8.27E+03*WIMAG2)
      IF(RW.LT.0..OR.RV.LT.0.)GOTO 55555
      KESUM=ISHIFT+KE
      IF(KESUM.GT.300) KESUM=300
      IF(KESUM.LT.1  ) KESUM=1
      FLMSH= FLM(KESUM,L)
C
C ADD KNOCK-OUT MECHANISM  for DEUTERONS
      GND = (G/GE(4))/P
        IF(L.EQ.1) FLMSH = FLMSH + GND * FID
C
      SCRS(KE,4)=SCRS(KE,4)+AKOEF*FLMSH    *RW*RV
      IF(RW.LT.1.0E-50)GOTO 1000
      U=U-ED
      IF(U.LE.0.)GOTO 1000
  777 CONTINUE
 1000 CONTINUE
      RETURN
C
C
  111 WRITE(7,112)U,XMAX,BA,ED,NU
      WRITE(8,112)U,XMAX,BA,ED,NU
  112 FORMAT(1X,80('+')/1X,'PRECOMPOUND DEUTR COULD NOT EMITTED, BECAU
     1SE:'/1X,' U=',G12.5,' XMAX=',G12.5,' BA=',G12.5,' ED=',G12.5,' NU=
     2',I6/1X,80('+'))
      RETURN
23232 WRITE(7,23233)
      WRITE(8,23233)
23233 FORMAT(1X,'SUBR.DEUT05: STRANGE ERROR...')
      STOP
33333 WRITE(7,33334)NP
      WRITE(8,33334)NP
33334 FORMAT(1X,'SUBR.DEUT05: number of particles = 0      ',I3)
      STOP
44444 WRITE(7,44445)U,XMAX,BA,ED,NU
      WRITE(8,44445)U,XMAX,BA,ED,NU
44445 FORMAT(1X,'SUBR.DEUT05: ERROR NU > 300 '/1X,' U=',G12.5,' XMAX='
     1,G12.5,' BA=',G12.5,' ED=',G12.5,' NU=',I6)
      STOP
55555 WRITE(7,55556)RW,RV,KE,U,E,N,L
      WRITE(8,55556)RW,RV,KE,U,E,N,L
55556 FORMAT(1X,'SUBR.DEUT05: ERROR RW OR RV < 0'/1X,' RW=',G12.5,' RV
     1=',G12.5,' KE=',I5/1X,' U=',G12.5,' E=',G12.5,' N=',I5,' L=',I5)
      STOP
      END
*
*********************************************************************
*
      Subroutine DEUTWO(MPARIN,NP9,NH9,U9,AFRRE,GDEUT,GIB,G,ED,WIMAG)
*     ----------------------------------------------------------------
```

```
*
* EMISSION OF SECONDARY PRECOMPOUND DEUTERON
*
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/MEMO2D/SCRD2(300,3)
      COMMON/IWADEU/FLM(300,2)
      COMMON/EFD/EFERMI0,GH
      CHARACTER*4 SYMB,SYMBP,SYMBS
      COMMON/LYM1/BE(11,24,4),SYMB(11,24),PAIR(11,24),SYMBP(11,24),
     1SYMBS(11,24),XMAS(11,24),DELSHL(11,24),AMAS(11,24)
      COMMON/ADDKD/FID,EDEUMIN,EDEUEXP
      DIMENSION GIB(4,300)
      XMAX = U9
         NP=NP9

         P=DFLOAT(NP)
         NH=NH9
         N=NP+NH
      E=XMAX
         EFermi=EFERMI0
      IF(NP.LE.0)RETURN
C SEPARATION ENERGY FOR SECONDARY DEUTERON
      IF(MPARIN.EQ.1) BA=BE(1,2,4)
      IF(MPARIN.EQ.2) BA=BE(2,1,4)
C not used    alpha-d:  IF(MPARIN.EQ.3) BA=BE(3,3,4)
      U=XMAX-BA-ED/2.
      NU=U/ED+1.
      IF(NU.LE.0) RETURN
      IF(NU.GT.300)GOTO 44444
      LMAX=MIN0(NP,2)
      BAA=(BA /ED) + DSIGN(0.5D0,BA)
      ISHIFT=IDINT(BAA)
C
      DO 1000 L=1,LMAX
      U=XMAX-BA-ED/2.
      NU=U/ED+1.
C
      Call BETAK_DOBES(E,N,NP,NH,G,GH,EFermi,WE)
      AKOEF=AFRRE*GDEUT
C
      DO 777 KE=1,NU
      Call BETAK_DOBES(U,N-L,NP-L,NH,G,GH,EFermi,WU)
C
      RW=WU/WE
      EDEU=DFLOAT(KE)*ED-ED/2.
                           WIMAG2 = WIMAG
C  WIMAG2 must be the same as in other subroutines
      IF(EDEU.gt.EDEUMIN) WIMAG2 =WIMAG2*DEXP( -EDEUEXP*(EDEU-EDEUMIN) )
      RV=2.*GIB(4,KE)/(2.*GIB(4,KE)+8.27E+03*WIMAG2)
C
      IF(RW.LT.1.d-17)GOTO 1000
      IF(RW.LT.0..OR.RV.LT.0.)GOTO 55555
      KESUM=ISHIFT+KE
      IF(KESUM.GT.300) KESUM=300
      IF(KESUM.LT.1  ) KESUM=1
      FLMSH= FLM(KESUM,L)
C
C ADD KNOCK-OUT MECHANISM  for DEUTERONS
      GND = (G/GDEUT)/P
```

```
      IF(L.EQ.1) FLMSH = FLMSH + GND * FID
C
      SCRD2(KE,MPARIN)=SCRD2(KE,MPARIN)+AKOEF*FLMSH    *RW*RV
C
      IF(RW.LT.1.0E-50)GOTO 1000
      U=U-ED
      IF(U.LE.0.)GOTO 1000
  777 CONTINUE
 1000 CONTINUE
C
      RETURN
C
44444 WRITE(6,44445)U,XMAX,BA,ED,NU
      WRITE(8,44445)U,XMAX,BA,ED,NU
44445 FORMAT(1X,'SUBR.DEUTWO: ERROR NU > 300 '/1X,' U=',G12.5,' XMAX='
     1,G12.5,' BA=',G12.5,' ED=',G12.5,' NU=',I6)
      STOP
55555 WRITE(6,55556)RW,RV,KE,U,E,N,L
      WRITE(8,55556)RW,RV,KE,U,E,N,L
55556 FORMAT(1X,'SUBR.DEUTWO: ERROR RW OR RV < 0'/1X,' RW=',G12.5,' RV
     1=',G12.5,' KE=',I5/1X,' U=',G12.5,' E=',G12.5,' N=',I5,' L=',I5)
      STOP
      END
*
*********************************************************************
*
      Subroutine EX1EX2(ZP,AP,ZT,AT,EP,EX1,EX2)
*     ----------------------------------------
*
      IMPLICIT REAL*8 (A-H,O-Z)
          IZP=Idint(ZP+0.0001d0)
          IAP=Idint(AP+0.0001d0)
          If(IAP.ne.1) goto 9000
      T=EP
*
* Ratio of elementary XS(pn)/XS(pp) cross-sections  (T < 300 MeV)
* Fermi motion and Pauli correction are taken into acount.
      R=1.375d-5*(T**2)-8.734d-3*T+2.776
*
      Write(7,1)R
      Write(8,1)R
      IF(IAP.EQ.1.AND.IZP.EQ.0)GO TO 1002
      IF(IAP.EQ.1.AND.IZP.EQ.1)GO TO 1003
* n-incident
 1002 EX1=2.*(R*ZT+2.*(AT-ZT))/(2.*R*ZT+2.*(AT-ZT))
      EX2=2.-EX1
      Return
* p-incident
 1003 EX2=2.*(R*(AT-ZT)+2.*ZT)/(2.*R*(AT-ZT)+2.*ZT)
      EX1=2.-EX2
      Return
 9000 Print 9001,IZP,IAP
      Write(7,9001)IZP,IAP
      Write(8,9001)IZP,IAP
 9001 FORMAT(//' NO DEFAULT DEFINITION FOR EX1 AND EX2 FOR INCIDENT',
     c' PARTICLE ',i2,i3//' !')
      STOP
    1 Format(' INITIAL NEUTRON AND PROTON EXCITON NUMBER ARE OBTAI',
     c'NED FOR CS(PN)/CS(PP)= ',f5.2)
```

```
      End
*
**********************************************************************
*
      Real*8 Function FACTORIAL(N)
*     ----------------------------
*
      Implicit real*8 (A-H,O-Z)
      FACTORIAL=1.
      Do i=1,N
      FACTORIAL=FACTORIAL*dfloat(i)
      Enddo
      If(N.le.0) FACTORIAL=1.0
      Return
      End
*
**********************************************************************
*
      Subroutine FASTG(GIB,N,PR,DEP,B,I,CF,TT,X,G,KEY)
*     ------------------------------------------------
*
C VERSION: No angular distributions
C
C To include angular distributions delete comments ***ANG in this
C routine and QUASID
C
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/SFT5/EXC99(10,24),XMAX
      COMMON/HYBSUB/RS(2,420),C99,POT99,IAV,R199 /INCR/ED
      COMMON/GIANI/PRE99, SIGT(500),SIGA99(500),SIGP99(500),GSP99(500),
     1 EQG99(500),IGAM /MEMO5/SCRSG(400),SCRSGI(400)
      COMMON/PARO/PQ,CROS99
      COMMON/SHFT/QVAL99,AP,AT99,ZP,ZT99,CLD99,MC99,MP99,INVE99,IKE99,
     1 IPCH99,BARF99
      COMMON/NHY/TD99,EX199,EX299,TMX,AV99,GAV99,IJ99,COST99,JL99,
     1 JI99,JJ99,B99(3)
      DIMENSION GIB(4,300),PR(3),DEP(3),B(3)
      DIMENSION SCRSGA(400)
      IF(IGAM.NE.1) RETURN
          IF(TMX.ne.0.D+00) Goto 70000
      IF(KEY.NE.1) GOTO 1000
      U=XMAX - ED/2.D0
      NU=IDINT(U/ED)+1
      H = 0.D0
      AN=DFLOAT(N)
            E=XMAX
      EPRIM=E
      DO 260 KE2=1,NU
      KE = KE2 - IDINT(B(I)/ED)
      IF(U-H)175,175,180
  175 FRT=0.D0
      GO TO 185
  180 FRT=((U-H)/(EPRIM))**(N-2)
  185 IF(IAV) 195,195,200
C                                "1"-arbitrary approximation
  195 IF(KE.LE.0) DC=1.D0/RS(I,1)
      IF(KE.GT.0) DC=1.D0/(GIB(I,KE)+RS(I,KE))
      GO TO 210
  200 JE=KE2
```

```
      IF(KE.LE.0) DC=1.D0/RS(I,JE)
      IF(KE.GT.0) DC=1.D0/(GIB(I,KE)+RS(I,JE))
  210 IF(FRT-1.D-20)260,260,215
  215 CONTINUE
      P=(AN-1.D0)*FRT*PR(I)*DC/E
      P=P*ED
      P=P*DEP(2)
          EESCO = DFLOAT(KE2)*ED-ED/2.
          EESC= EESCO-B(I)
                                RLAMI = 0.D+00
                                RLAMZ = 0.D+00
                                RLAMM = 0.D+00
          PCF =  P*CF/ED
C Contribution of p+n -> d+g process         (1-3/4T/mc2) - relat.correction
          If(EESC.GT.0.D0)
     #    RLAMI= 0.75D0*1.42D+00 * DSQRT(EESCO+38.D0) * PCF *
     #    (1.D0-0.75D0*(EESCO+38.D0)/940.)
C Contribution of Oblozinsky picture     (/1000  (SIGT in microbarns))
          RLAMZ= 5.355D-04 * G * PCF      / 1000.D+00
C                        h(n-2)/g /(E-e)
          IF((U-H).GT.0.D0)
     #    RLAMM= ((RLAMZ * X * (TT-2.D+00) / G ) / (U-H) )
C
      DO 2460 KEG=1,400
          EESCG= DFLOAT(KEG)*ED-ED/2.
          If(XMAX-EESCG) 2461,2461, 499
499       IF(EESCO-EESCG) 500, 700, 700
C E < Eg, Lam-
500       IF(N-3) 800, 501, 502
501   SCRSG(KEG)=SCRSG(KEG) + ED * (EESCG**2) * SIGT(KEG) *
     # (RLAMM/(G*(TT-2.D+00)+G*G*EESCG))
        Goto 800
502   SCRSG(KEG)=SCRSG(KEG) +  ED * (EESCG**2) * SIGT(KEG) *
     #  (RLAMM/(G*(TT-2.D+00)+G*G*EESCG)) *
     #  ( ((XMAX-EESCG)/(U-H))**(N-3) )
        Goto 800
C E > Eg, Lam0
700   SCRSG(KEG)=SCRSG(KEG) +  ED * (EESCG**2) * SIGT(KEG) *
     #  (RLAMZ/(G*TT+G*G*EESCG))
C p+n -> d+g

800           continue
      SCRSGI(KEG)=SCRSGI(KEG) + RLAMI * QUASID(EESC,EESCG,DANG) * ED
2460  CONTINUE
C
2461  IF(P)260,260,255
  255 IF(P-1.D-20)265,265,260
  260 U=U-ED
  265 RETURN
C
C FIRST INTERACTION
1000   IF(AP.NE.1.D0) PRINT *,'°°°°°° No N=1 TREATMENT'
       IF(AP.NE.1.D0) RETURN
                      II=2
          IF(ZP.EQ.0.D0) II=1
          KE = IDINT(PQ/ED)
       IF(IAV) 1951,1951,2001
 1951  DC=1.D0/RS(II,KE)
          GO TO 2101
```

```
 2001  JE=IDINT(XMAX/ED)
       DC=1.D0/RS(II,JE)
 2101     CONTINUE
C
          PCF =  CF*DC
C Contribution of p+n -> d+g process           (1-3/4T/mc2) - relat.correction
          RLAMI= 0.75D0*1.42D+00 * DSQRT(XMAX+38.D0) * PCF *
     #    (1.D0-0.75D0*(XMAX+38.D0)/940.)
C
      DO 24601 KEG=1,400
          EESCG= DFLOAT(KEG)*ED-ED/2.
          If(XMAX-EESCG) 24611,24611, 4991
4991      SCRSGI(KEG)=SCRSGI(KEG) + RLAMI * QUASID(PQ,EESCG,DANG)
C
***ANG          SCRSGA(KEG)= RLAMI * DANG
***ANG           If(SCRSGA(KEG).gt.0.D+0) Write(801,80180)EESCG,SCRSGA(KEG)
***ANG 80180     Format(2e12.5)
C
24601     CONTINUE
C
24611    RETURN
C
70000    Print 70001
         Write(7,70001)
70001    Format(1X,'FAST GAMMA EMISSION TREATMENT IS NOT TESTED ',
     #   'NOW FOR GDH OPTION (TMX=1)'/1X,'USE TMX=0 IN THE INPUT CARD')
         STOP
         END
*
*********************************************************************
*
      Real*8 Function FIDCORR(ZP,AP,ZT,AT)
*     ------------------------------------
*
      IMPLICIT REAL*8 (A-H,O-Z)
c
      IZP=idint(ZP+0.0001d0)
      IAP=idint(AP+0.0001d0)
      IZT=idint(ZT+0.0001d0)
      IAT=idint(AT+0.0001d0)
c
      FIDCORR=0.1
c
      if(IZP.eq.0.and.IAP.eq.1) goto 1
      if(IZP.eq.1.and.IAP.eq.1) goto 2
      return
c
c The difference in FIDCORR for incident neutrons and protons, if
c exist, has no deep sense and reflects the general uncertainty
c of such kind of calculations
c
c neutron incident
    1  If(IZT.eq.13.and.IAT.eq.27) FIDCORR=0.09
       If(IZT.eq.23.and.IAT.eq.51) FIDCORR=0.07
       If(IZT.eq.26.and.IAT.eq.54) FIDCORR=0.08
       If(IZT.eq.26.and.IAT.eq.56) FIDCORR=0.12
       If(IZT.eq.28.and.IAT.eq.58) FIDCORR=0.12
       If(IZT.eq.28.and.IAT.eq.60) FIDCORR=0.12
       return
```

```
c
c proton incident
    2  If(IZT.eq.6.and.IAT.eq.12)  FIDCORR=0.14
       If(IZT.eq.13.and.IAT.eq.27) FIDCORR=0.12
       If(IZT.eq.26.and.IAT.eq.54) FIDCORR=0.075
       If(IZT.eq.26.and.IAT.eq.56) FIDCORR=0.08
       If(IZT.eq.28.and.IAT.eq.58) FIDCORR=0.07
       If(IZT.eq.40.and.IAT.eq.90) FIDCORR=0.11
       If(IZT.eq.40.and.IAT.eq.92) FIDCORR=0.08
       If(IZT.eq.79.and.IAT.eq.197)FIDCORR=0.11
       return
       end
*
*********************************************************************
*
      Subroutine FISROT(A,Z,AN,AL,DELR,DELSP,ERO,BARFAC)
*     ------------------------------------------------
*
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X1B(6,11),X2B(6,11),X3B(10,20),X1H(6,11),X2H(6,11),X3H(1
     10,20)
      COMMON/PL3/EB(70),RCSP(70),ZEE,AMASS,PLEX,NEPR
      COMMON/PARFS/DELRR(300),K6
      DATA X1B/.28,.243,.221,.208,.195,.18,.211,.186,.17,.1506,.136,.12,
     1.152,.131,.1155,.096,.0795,.0625,.09725,.0795,.065,.0506,.0375,.02
     153,.05771,.0455,.03414,.0235,.014,.0065,.03325,.0235,.0153,.0081,.
     1001,.0,.01625,.009,.0032,.0,.0,.0,.0071,23*.0/
      DATA X1H/.0,.0,.0,.0,.0,.0,-.0057,-.0058,-.006,-.0061,-.0062,-.006
     13,-.0193,-.0203,-.0211,-.022,-.023,-.0245,-.0402,-.0427,-.0456,-.0
     1497,-.054,-.0616,-.0755,-.0812,-.0899,-.0988,-.109,-.12,-.1273,-.1
     1356,-.147,-.1592,-.1745,-.1897,-.1755,-.1986,-.2128,-.2296,-.251,-
     1.26,-.255,-.271,-.291,-.301,-.327,-.335,-.354,-.36,-.365,-.372,-.4
     103,-.42,12*-.35/
      DATA X2B/.18,.1695,.1515,.133,.1155,.0949,.1495,.1363,.1165,.099,.
     10815,.0594,.12,.1032,.0864,.0678,.0469,.028,.09,.0725,.0556,.037,.
     1019,.0057,.0625,.045,.0304,.016,.005,0.,.0406,.0264,.0151,.0052,0.
     1,0.,.0253,.0144,.0027,0.,0.,0.,.0141,.006,0.,0.,0.,0.,.0065,.0008,
     10.,0.,0.,0.,.002,0.,0.,0.,0.,0.,0.,0.,0.,0.,0./
      DATA X2H/0.,0.,0.,0.,0.,0.,-.0018,-.0019,-.00215,-.0024,-.0025,-.0
     103,-.0063,-.00705,-.0076,-.0083,-.0091,-.0095,-.015,-.0158,-.0166,
     1-.0192,-.0217,-.025,-.0245,-.0254,-.029,-.0351,-.0478,-.0613,-.038
     1 7,-.0438,-.0532,-.0622,-.0845,-.0962,-.0616,-.0717,-.0821,-.0972,
     1-.1123,-.1274,-.0793,-.1014,-.1138,-.1262,-.1394,-.1526,-.12,-.134
     1,-.1503,-.1666,-.1829,-.1992,-.1528,-.171,-.1907,-.2104,-.2301,-.2
     1498,6*-.23/
      DATA X3H/10*0.,-.00012,-.00014,-.00016,-.0
     10018,-.0002,-.00024,-.00029,-.00036,-.00065,-.00089,-.00047,-.0005
     1,-.00058,-.00065,-.00074,-.00085,-.00101,-.00124,-.00138,-.00178,-
     1.001,-.00105,-.00124,-.00138,-.00156,-.00179,-.00275,-.00292,-.003
     1,-.003,-.00176,-.0019,-.00211,-.00235,-.00263,-.00298,-.00449,-.00
     153,-.0053,-.0053,-.003,-.00308,-.00318,-.00352,-.00392,-.00417,-.0
     1062,-.0062,-.0062,-.0062,-.00374,-.0041,-.00444,-.00488,-.00521,-.
     100545,-.0066,-.0066,-.0066,-.0066,-.0053,-.0055,-.00585,-.0064,-.0
     10695,5*-.007,-.00632,-.007,-.00742,-.00792,-
     1.00856,-.009,-.009,-.009,-.009,-.009,-.0079,-.0085,-.01022,-.0119,
     16*-.012,-.00944,-.0102,-.0142,-.0182,
     16*-.019,-.0112,-.0133,-.0182,-.0238,
     16*-.024,-.01303,-.0178,-.0226,-.0274,
     16*-.028,-.0165,-.0254,-.0343,-.0343,6*-.034,
```

```
  1-.0203,-.033,8*-.04,
  1-.025,-.0406,-.046,7*-.047,
  1-.03036,-.0482,8*-.048,
  1-.0363,-.0558,8*-.056,
  1-.04234,-.0634,18*-.064/
   DATA X3B/.0949,.0755,.0564,.0382,.0223,.0121,.00588,.00242,.00069,
  1.0001,.0873,.0684,.049,.0306,.0162,.0074,.00267,.00055,0.,0.,.0801
  1,.061,.0418,.0235,.0108,.00373,.00071,0.,0.,0.,.073,.054,.035,.017
  18,.0062,.00125,0.,0.,0.,0.,.0661,.047,.0284,.012,.0025,0.,0.,0.,0.
  1,0.,.0594,.0404,.022,.0065,0.,0.,0.,0.,0.,0.,.0528,.034,.0159,.002
  1,6*0.,.0465,.0277,.01,7*0.,.0401,.021
  17,.0044,7*0.,.0339,.0158,.00024,7*0.,

  1.028,.0106,8*0.,.0219,.0064,8*0.,
  1.0164,.0025,8*0.,.0122,9*0.,
  1.0085,9*0.,.0057,9*0.,
  1.0035,9*0.,.0016,29*0./
   IF(K6.GT.0)A=AMASS
   IF(K6.GT.0)Z=ZEE
   IF(K6.GT.0)AN=A-Z
   PAREN=1.-1.7826*((AN-Z)/A)**2
   ESO=17.9439*PAREN*A**.666666
   X=0.019655*Z*(Z/A)/PAREN
   JM=1
   IF(K6.GT.0)JM=300
   DO 100 J=1,JM
   IF(K6.GT.0)AL=J-1
   ERO=34.548*AL*AL/A**1.666666
   Y=1.9254*AL*AL/(PAREN*A**2.3333333)
   IX=20.*X+1.
   CX=IX

   BX=20.*X+1.
   DX=BX-CX
   IF(X-.25)5,5,30
 5 BY=10.*Y+1.
   IF(BY-9.)15,15,10
10 BY=9.
15 IF(BY-1.)20,20,25
20 BY=1.
25 IY=BY
   CY=IY
   DY=BY-CY
   H1=(X1H(IX+1,IY)-X1H(IX,IY))*DX+X1H(IX,IY)
   H2=(X1H(IX+1,IY+1)-X1H(IX,IY+1))*DX+X1H(IX,IY+1)
   HF=(H2-H1)*DY+H1
   B2=(X1B(IX+1,IY+1 )-X1B(IX,IY+1))*DX+X1B(IX,IY+1)
   B1=(X1B(IX+1,IY)-X1B(IX,IY))*DX+X1B(IX,IY)
   BF=(B2-B1)*DY+B1
   GO TO 95
30 IF(X-.5)35,35,60
35 BY=20.*Y+1.
   IF(BY-10.)45,45,40
40 BY=10.
45 IF(BY-1.)50,50,55
50 BY=1.
55 IX=IX-5
   IY=BY
   CY=IY
```

```
      DY=BY-CY
      H1=(X2H(IX+1,IY)-X2H(IX,IY))*DX+X2H(IX,IY)
      H2=(X2H(IX+1,IY+1)-X2H(IX,IY+1))*DX+X2H(IX,IY+1)
      HF=(H2-H1)*DY+H1
      B1=(X2B(IX+1,IY)-X2B(IX,IY))*DX+X2B(IX,IY)
      B2=(X2B(IX+1,IY+1 )-X2B(IX,IY+1))*DX+X2B(IX,IY+1)
      BF=(B2-B1)*DY+B1
      GO TO 95
   60 IF(X-.95)70,70,65
   65 X=.95
   70 IX=20.*X+1.
      IX=IX-10
      BY=100.*Y+1.
      IF(BY-19.)80,80,75
   75 BY=19.
   80 IF(BY-1.)85,85,90
   85 BY=1.
   90 IY=BY
      CY=IY
      DY=BY-CY
      H1=(X3H(IX+1,IY)-X3H(IX,IY))*DX+X3H(IX,IY)
      H2=(X3H(IX+1,IY+1)-X3H(IX,IY+1))*DX+X3H(IX,IY+1)
      HF=(H2-H1)*DY+H1
      B1=(X3B(IX+1,IY)-X3B(IX,IY))*DX+X3B(IX,IY)
      B2=(X3B(IX+1,IY+1 )-X3B(IX,IY+1))*DX+X3B(IX,IY+1)
      BF=(B2-B1)*DY+B1
   95 DELR=ERO+HF*ESO
  100 IF(K6.GT.0)DELRR(J)=DELR
      K6=0
      BF=BF*BARFAC
      DELSP=DELR+BF*ESO
      RETURN
      END
*
*************************************************************************
*
      Subroutine GAMMA
*     ----------------
*
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/GIANI/PRE, SIGT(500),SIGAM(500),SIGPRE(500),GSP(500),
     1 EQGAM(500),IGAM
      COMMON/INCR/ED /QQ/GOW(3000)
      COMMON/GAM/PPGAM(300),GMSPEC(300),LA,BETA,AMS
      COMMON/UG/IZ,IA /PL5/TITLE(20),NA,NZ
      COMMON/HJK/RCSS,JANG /SFT5/EXC(10,24),XMAX
      COMMON/GRL/AGA,AXSG /PARO/PQ,CROSS
      COMMON/NHY/TD77,EX177,EX277,TMX77,AV77,GAV77,
     1           IJ77,COST77,JL77,JI77,JJ77,B77(3)
      COMMON/SHFT/QVAL,AP,AT,ZP,ZT,CLD,MC,MP,INVER,IKE,IPCH,BARFAC
      COMMON/MEMO5/SCRSG(400),SCRSGI(400)
      COMMON/PAR3/EQ9,SIGML9(300),ACRS9(300)
      EINIT=EQ9

      BETA=0.D0
      MAX=IDINT(70.D0/ED)
      IF(PRE.EQ.1.D0)MAX=300
      IF(PRE.EQ.0.D0)GO TO 3000
            DO 27 KE=1,400
```

```
           SCRSG(KE)=0.D0
27         SCRSGI(KE)=0.D0
      MX=MAX
      DO 1 I=1,300
      GSP(I)=0.D0
   1  CONTINUE
C     DEFINE LORENTZIAN CONSTANTS AND SQUARES OF VALUES
      E0=43.4D0*AMS**(-0.215)
      E1=E0*(1.D0-BETA/3.D0)**2
      E1SQ=E1*E1
C 26 SEPTEMBER - 1993
      SIG1=14.5D0*AMS/E1
      GAM1=0.232D0*E1
      Write(7,1001) SIG1,GAM1
C 15-SEPT-1993
      SIG1=AXSG*SIG1
           GAM1=AGA*GAM1
      Write(7,1001) SIG1,GAM1
 1001 FORMAT(12X,'SIG1=',E12.5,'GAM1=',E12.5)
      GAM1SQ=GAM1*GAM1
      E2=E0*(1.D0-0.16D0*BETA)
      E2SQ=E2*E2
C 26 SEPTEMBER - 1993
      SIG2=23.5D0*AMS/E2

      GAM2=0.275D0*E2
      GAM2SQ=GAM2*GAM2
      Write(7,10021) SIG2,GAM2
C 15-SEPT-1993
      SIG2=AXSG*SIG2
           GAM2=AGA*GAM2
      Write(7,10021) SIG2,GAM2
10021 FORMAT(12X,'SIG2=',E12.5,'GAM2=',E12.5)
C     SET UP SPECTRAL SHAPE ON MAXIMUM EXCITATION ENERGY
C     BELOW PARTICLE BINDING ENERGY
      DO 2 IEPS=1,MAX
C     EPS IS GAMMA RAY ENERGY IN MEV
C     SIGT IN MICROBARNS?
      EPS=DFLOAT(IEPS)*ED
      EPSQ=EPS*EPS
      SIGT(IEPS)=SIG1*EPSQ*GAM1SQ/((EPSQ-E1SQ)**2+EPSQ*GAM1SQ)
     1+SIG2*EPSQ*GAM2SQ/((EPSQ-E2SQ)**2+EPSQ*GAM2SQ)
      SIGT(IEPS)=SIGT(IEPS)*EPSQ
    2 CONTINUE
C     DEFINE KOPECKIY-UHL CONSTANTS AND SQUARES OF VALUES
C        EK1=8.68000D-8
C        EG1=43.4D0*(AMS)**(-.215)
C        GAM1=.232D*EG1
C        SIG1=0.0145D0*AMS/EG1
      IF(PRE.EQ.1.D0)RETURN
 3000 CONTINUE
      MX=IDINT(70.D0/ED)
      IF(MX.GT.300)MX=300
      DO 4 JE=1,MX
      IE=MX-JE+1
      IF(PPGAM(IE).EQ.0.D0)GO TO 4
      E=DFLOAT(IE     )*ED
C     E IS ENERGY IN MEV OF A BIN WHICH WILL EMIT A GAMMA CASCADE
      SMGM=0.D0
```

```
C     DO NORMALIZATION SUMMATION FOR EMISSION OF ALL GAMMA ENERGIES
      MAP=IE-1
      IF(MAP.LT.1)GO TO 4
      DO 3 IEPS=1,MAP
      EPS=DFLOAT(IEPS)*ED
      U=E-EPS
      BI=10.D0*U+.05D0
      IB=IDINT(BI)
      IF(IB.LE.0)GO TO 3
      SIGAM(IEPS)=SIGT(IEPS)*GOW(IB)
      SMGM=SMGM+SIGAM(IEPS)
    3 CONTINUE
      DO 5 IEPS=1,MAP
      SPEC=PPGAM(IE     )*SIGAM(IEPS)/SMGM
      GMSPEC(IEPS)=GMSPEC(IEPS)+SPEC
      IF((IE-IEPS).LE.0)GO TO 5
      PPGAM(IE-IEPS)=PPGAM(IE-IEPS)+SPEC
    5 CONTINUE
    4 CONTINUE
      BNZER=PPGAM(1)
      SGM=0.D0
      DO 14 I=1,MX
      SGM=SGM+GMSPEC(I)
   14 CONTINUE
      SGM=SGM+BNZER
      Write(7,15)SGM,BNZER
   15 FORMAT(/'  SUMMED GAMMA RAY CROSS SECTION = ',E10.3,
     1//,'  GAMMA SPECTRUM SUMMED OVER ALL EMITTING NUCLIDES',E10.3)
           If(MAX.GT.300) MAX = 300
      DO 13 I=1,MAX
      GMSPEC(I)=GMSPEC(I)/ED
      GSP(I)=GMSPEC(I)/12.6D0
   13 CONTINUE
      RK1 = 0.0011
      RK2 = 0.028
      ECOMP=EINIT+QVAL
      MMM=IDINT(ECOMP/ED)
C
      Open(503,file='gamma.spe')
      Write(7,301)
      Write(503,302)
      IF(MMM.GT.300)MMM=300
           DO 200 JX=1,MMM
           EGAM=ED*DFLOAT(JX)
           EQGAM(JX)=EQGAM(JX)/ED
                   IF(ABS(SCRSG(JX)). lt.1.D-100) SCRSG(JX) =1.D-39
                   IF(ABS(SCRSGI(JX)).lt.1.D-100) SCRSGI(JX)=1.D-39
                   IF(ABS(EQGAM(JX)). lt.1.D-100) EQGAM(JX) =1.D-39
                   IF(ABS(GMSPEC(JX)).lt.1.D-100) GMSPEC(JX)=1.D-39
           UU = ECOMP-EGAM
           PREG = (CROSS/(AT*(ECOMP**2))) * (EGAM**2)  *
     #     ( RK1*UU + RK2*(UU**3)/(ECOMP**2) )
C
C Nakayama, Bertch  Phys. Rev.C, 1986
           BREM=CROSS*2.5E-06*(UU**2)/(EGAM*ECOMP)
           SIGPRE(JX)=GMSPEC(JX)+EQGAM(JX) + SCRSG(JX) + SCRSGI(JX)
           SIGPR2    =GMSPEC(JX)+EQGAM(JX) + PREG
           SIGPR3    =GMSPEC(JX)+EQGAM(JX) + BREM
           GSP(JX)=SIGPRE(JX)/12.6
```

```
            Write(7,300)EGAM,GMSPEC(JX),EQGAM(JX),SIGPRE(JX),
     #      SCRSG(JX),SCRSGI(JX),GSP(JX),SIGPR2,SIGPR3
            Write(503,300)EGAM,GMSPEC(JX),EQGAM(JX),SIGPRE(JX),
     #      SCRSG(JX),SCRSGI(JX),GSP(JX),SIGPR2,SIGPR3
  200 CONTINUE
  300 FORMAT(F9.2, 1PE12.3, 7E12.3)
  301 FORMAT(///'E GAMMA(MEV) BOUND EQ   UNBOUND EQ  SUM PRE+EQ   ',
     #'PRE(OBL)    PRE QD      SUM/4PI     SUM PRE(APPROX)+EQ'//)
  302 FORMAT('"E GAMMA(MEV) BOUND EQ   UNBOUND EQ  SUM PRE+EQ   ',
     #'PRE(OBL)    PRE QD      SUM/4PI     SUM PRE(APPROX)+EQ"'//)
  600 CONTINUE
  800 CONTINUE
            DO 271 KE=1,400
            SCRSG(KE)=0.D0
271         SCRSGI(KE)=0.D0
      Close(503)
      RETURN
      END
*
*********************************************************************
*
      Subroutine GOINLCS(III,AP,AT,E0,AKE,RKALB,RLSCAN)
*     ------------------------------------------------
*
* Outgoing energy in LC system  (approximately, with average cos(Kalbach))
*
      IMPLICIT REAL*8 (A-H,O-Z)
* AKE0 is a channel energy
      AKE0=AKE
      VCM=(AP/(AP+AT))*DSQRT(2.*E0/AP)
      If(III.le.2) APO=1.
      If(III.eq.3) APO=4.
      If(III.eq.4) APO=2.
      If(III.eq.5.or.III.eq.6) APO=3.
      ATO=AP+AT-APO
      EPAR=AKE0*ATO/(ATO+APO)
*
* define average cos value
      Call KALBACH(III,RKALB,AKE0,AVECOS)
      AKE=EPAR+ APO*(VCM**2)/2.+ APO*VCM*DSQRT(2.*EPAR/APO)*AVECOS
* ratio of the energy in LCS to channel energy
                    RLSCAN=1.0
      If(AKE0.ne.0.0) RLSCAN=AKE/AKE0
      Return
      End
*
*********************************************************************
*
      Subroutine HE395(TT9,EX9,X9,L91,L92,GIB,GE,G,DEP,
     $                 XMAX,ED9,BA,CNCS, PAIRXA)
*     ------------------------------------------------
*
C     HE3 PRECOMPOUND ROUTINE FOR ALICE/ASH
C
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/IALPH/IALPHA
      COMMON/MEMO/SCRS(300,4)
      COMMON/IWAHE3/FLM(300,3)
      DIMENSION GIB(4,300),GE(4),DEP(2)
```

```
      IF(IALPHA.LT.20)CALL IWAMOH(IALPHA,WIMAG)
      IF(L91.NE.L92.AND.L92.NE.1) IALPHA=IALPHA+1
         N=IDINT(TT9+0.01D+00)
      E=XMAX
      ED=ED9
         NP=IDINT(EX9+0.01D+00)
         P=DFLOAT(NP)
         NH=IDINT(X9+0.01D+00)
      IF(NH.NE.(N-NP)) GOTO 23232
      IF(NP.EQ.0)GOTO 33333
      U=XMAX-BA-ED/2.
      NU=U/ED+1.
      IF(NU.LE.0)GOTO 111
      IF(NU.GT.300)GOTO 44444
      LMAX=MIN0(NP,3)
      BAA=(BA /ED) + DSIGN(0.5D0,BA)
      ISHIFT=IDINT(BAA)
C
      DO 1000 L=1,LMAX
      U=XMAX-BA-ED/2. - PAIRXA
                        UU = U
      IF(PAIRXA.LT.0.0) UU = XMAX-BA-ED/2.
      NU=UU/ED+1.
      AKOEF=1.
          DO 100 K1=1,L
100       AKOEF=AKOEF*DFLOAT(NP-K1+1)*DFLOAT(N-K1)
      AKOEF=CNCS*DEP(2)*GE(4)*AKOEF
C
      DO 777 KE=1,NU
      RW=((U/E)**(N-1-L))/((G*E)**L)
      RV=2.*GIB(4,KE)/(2.*GIB(4,KE)+8.27E+03*WIMAG)
      IF(RW.LT.0..OR.RV.LT.0.)GOTO 55555
      KESUM=ISHIFT+KE
      IF(KESUM.GT.300) KESUM=300
      IF(KESUM.LT.1  ) KESUM=1
      FLMSH=FLM(KESUM,L)
      SCRS(KE,4)=SCRS(KE,4)+AKOEF*FLMSH    *RW*RV
      IF(RW.LT.1.0E-50)GOTO 1000
      U=U-ED
      IF(U.LE.0.)GOTO 1000
  777 CONTINUE
 1000 CONTINUE
C
      RETURN
C
  111 WRITE(7,112)U,XMAX,BA,ED,NU
      WRITE(8,112)U,XMAX,BA,ED,NU
  112 FORMAT(1X,80('+')/1X,'PRECOMPOUND TRIT  COULD NOT EMITTED, BECAU
     1SE:'/1X,' U=',G12.5,' XMAX=',G12.5,' BA=',G12.5,' ED=',G12.5,' NU=
     2',I6/1X,80('+'))
      RETURN
23232 WRITE(7,23233)
      WRITE(8,23233)
23233 FORMAT(1X,'SUBR.HE395: STRANGE ERROR...')
      STOP
33333 WRITE(7,33334)NP
      WRITE(8,33334)NP
33334 FORMAT(1X,'SUBR.HE394: —^C‹O —ACT^- = 0      ',I3)
      STOP
```

```
44444 WRITE(7,44445)U,XMAX,BA,ED,NU
      WRITE(8,44445)U,XMAX,BA,ED,NU
44445 FORMAT(1X,'SUBR.HE394: ERROR NU > 300 '/1X,' U=',G12.5,' XMAX='
     1,G12.5,' BA=',G12.5,' ED=',G12.5,' NU=',I6)
      STOP
55555 WRITE(7,55556)RW,RV,KE,U,E,N,L
      WRITE(8,55556)RW,RV,KE,U,E,N,L
55556 FORMAT(1X,'SUBR.HE394: ERROR RW OR RV < 0'/1X,' RW=',G12.5,' RV
     1=',G12.5,' KE=',I5/1X,' U=',G12.5,' E=',G12.5,' N=',I5,' L=',I5)
      STOP
      END
*
**********************************************************************
*
      Real*8 Function HEAVISIDE(X)
*     ----------------------------
*
      Implicit real*8 (A-H,O-Z)
      if(X.ge.0.0) then
                   HEAVISIDE=1.
                   else
                   HEAVISIDE=0.
                   endif
      Return
      End
*
**********************************************************************
*
      Subroutine HYBRID
*     -----------------
*
      IMPLICIT REAL*8 (A-H,O-Z)
      Character Partix(3)*9, Partx(3)*5
      COMMON/GIANI/PRE, SIGT(500),SIGAM(500),SIGPRE(500),GSP(500),
     1 EQGAM(500),IGAM
      DIMENSION GIB(4,300),PR(3),GE(4),ZZ(3),
     1DELTA(3),TS(3),PAIRX(3),DEP(3),SMSCR(300),ASUM(10)
      COMMON/SHFT2/K3,FS(22),DSP(22),BRR(22),DER(22),ER(22),FISS,SUMIZ
     1,CX(22),BILSUM,JCAL,XMISS
      COMMON/SHFT/QVAL,AP,AT,ZP,ZT,CLD,MC,MP,INVER,IKE,IPCH,BARFAC
      COMMON/NHY2/BDO,BISP /HYBSUB/RS(2,420),C,POT,IAV,R1
      COMMON/HYB2/PP(3,22,300) /PARFS/DELRR(300),K6
      COMMON/SFT9/K5,PLD,JMAX,D(4),DELT,ALT
      COMMON/SFT5/EXC(10,24),XMAX /PAR2/CNCS
      COMMON/NHY/BD,BX1,BX2,CMX,CV,BAV,IJ,BOST,JL,JI,JJ,B(3)
      COMMON/LAB3/SIG(4,300) /PL3/EB(70),RCSP(70),Z,A,PLEX,NEPR
      COMMON/PAR3/EP,SIGML(300),ACRS(300) /SF6/AOZ,ZOZ,EN(4,300)
      COMMON/MEMO/SCRS(300,4) /ISO/QPN(3),QPNC /INCR/ED
      COMMON/SEND/IRFR,DLT,IADST
      CHARACTER*4 SYMB,SYMBP,SYMBS
      COMMON/LYM1/BE(11,24,4),SYMB(11,24),PAIR(11,24),SYMBP(11,24),
     1SYMBS(11,24),XMAS(11,24),DELSHL(11,24),AMAS(11,24)
      COMMON/DIST/PROB(37,301),XZ(3),ALMIN(300),ALMAX(300),FIN,DTUP
     1 ,DSIGP(36,301),DSIGT(36,301),POD,PCS,N,NI,KE,EK,DADEG,TDEG,TDEG2
     2,AMN(300),AMX(300),XMIX
       COMMON/DIST1/GDPR(36,301),GL(36,301),CFRAC

     3,DTAU,SIGN(36),TMIX,IREFR,BJI(10)
      COMMON/NR34/NR3,NR4,KE5,PRB(36),I3D,IRTST,I3T2,IJKL
```

```
      COMMON/TST/TEST /SF/M3,KPLT /IALPH/IALPHA
      COMMON/RATMP/RATMP1,SUMAPR,SUMDER
      COMMON/MEMO2/SCRA2(300,3) /MEMO2D/SCRD2(300,3)
      COMMON/HOT/KPG,MPG
      DATA PARTIX/9H DEUTRONS,9H  TRITONS,9H  HELIONS/
      DATA PARTX/5HDEUTR,5HTRIT ,5HHE-3 /
      IFLAG=0
C store mean alpha-energy
      Open(100,file='mean_a.0')
      IF(TEST.EQ.0.D0)Write(7,9898)JCAL
      TMIX=187.D0/((AP+AT)*XMAX)
      DELTA(3)=0.0D0
      RNEX=(ZP+ZT)/(AP+AT)
      RPEX=1.D0-RNEX
      RNEX=RNEX*RNEX
      RPEX=RPEX*RPEX
C   THE ABOVE NUMBERS ARE TO MODIFY GAMMA DECAY RATES FOR POLARIZATION
      PAIRX(3)=0.D0
      ZZ(3)=0.D0
      TS (3)=0.D0
      QPN(3)=0.D0
      PRE=1.D0
      CALL GAMMA
      PRE=0.D0
      B(3)=0.D0
      GDO=BDO
      TD=BD
      EX1=BX1
      EX2=BX2
      TMX=CMX
      GAV=BAV
          IPOT=IDINT(BAV+0.00001D+00)
          IF(TMX.eq.0.D+00.or.AP.ne.1.D+00) IPOT=0
          RR0=1.322-.00076*(AP+AT)+4.0*((AP+AT)**2)*1.0E-06
     #    -8.0*((AP+AT)**3)*1.0E-09
      COST=BOST
      CNSIG=CNCS
      BMX=0.D0
      AV=CV
      XZ(1)=B(1)
      XZ(2)=B(2)
      IF(JCAL.NE.1.AND.IALPHA.NE.0)Write(7,9779)
      IF(JCAL.NE.1.AND.IALPHA.NE.0)WRITE(8,9779)
      IF(JCAL.NE.1.AND.IALPHA.NE.0)IALPHA=0
      BALPHA=BE(1,1,3)
      IF(KPG.eq.0) BDEUTR=BE(1,1,4)
      IF(KPG.eq.1) BTRIT =BE(1,1,4)
      IF(KPG.eq.2) BHE3  =BE(1,1,4)
      IVV=IDINT(DELT+0.0001)
      Write(7,9777)IVV
      WRITE(8,9777)IVV
C
C  ZERO ANG DIST BUFFER
      DO 35 II=1,36
      DO 35 KL=1,301
      GDPR(II,KL)=0.D0
   35 DSIGT(II,KL)=0.D0
C
C    CALCULATE SIN TABLE FOR NORMALIZATION IN 5 DEG STEPS
```

```
C
      DO 2 I=1,36
      DG=5.D0*DFLOAT(I)-2.5D0
      ARG=DG*3.14159D0/180.D0
    2 SIGN(I)=2.D0*3.14159D0*DSIN(ARG)
C
      IF(JCAL.EQ.0)TMX=1.D0
C

C   TCG(ISOC,ISOR,I) ARE CLEBSCH-GORDAN COEFFICIENTS FOR OUTGOING
C   PARTICLES WHERE INDICES ARE:ISOC =INITIAL STATE,1=TLOWER,2=
C   TUPPER;ISOR=FINAL STATE ISOSPIN INDICES,AND I=PARTICLE TYPE
C   INDEX,1=NEUTRON,2=PROTON.
C
C   DEFINE TCG FOR N OR P OR 3HE PROJECTILES
C   FIRST NEUTRONS
C
C   ZERO BUFFERS FOR FOUR ISOSPIN/KE SETS
C
C      ADD DEFAULT EXCITON PARAMETERS
C
      IF(EX1.GT.0.D0.OR.EX2.GT.0.D0)GO TO 1000
      IF(EX1.lt.0.d0.or.EX2.lt.0.d0) goto 1001
      CALL EX1EX2(ZP,AP,ZT,AT,EP,EX1,EX2)
      GOTO 1004
 1001 IF(AP.EQ.1.D0.AND.ZP.EQ.0.D0)GO TO 1002
      IF(AP.EQ.1.D0.AND.ZP.EQ.1.D0)GO TO 1003
 1002 EXNUT=3.D0*ZT+2.D0*(AT-ZT)
      EX1=2.D0*EXNUT/(EXNUT+3.D0*ZT)
      EX2=2.D0-EX1
C
C   DEFINE PAIRING CORRECTION PER GRIMES FOR NEUTRON IN/N,P
C
      GO TO 1004
 1003 EXPROT=3.D0*(AT-ZT)+2.D0*ZT
      EX2=2.D0*EXPROT/(EXPROT+3.D0*(AT-ZT))
      EX1=2.D0-EX2
C
C  DEFINE PAIRING FOR PROTONS IN,N/P OUT
C
 1004 IF(AP.EQ.1.D0)TD=3
      CV=1.D0
      GAV=1.D0
      IF(TMX.EQ.0.D0)COST=1.D0
      IF(TMX.GT.0.D0)GDO=1.D0
      IF(TEST.EQ.0.D0)Write(7,10010)
      IJ=0
      IF(AP.EQ.1.D0)GO TO 1000
      EX1=AP-ZP
      EX2=ZP
      TD=AP+1.D0
      IF(AP.EQ.4.D0)TD=AP
1000  CONTINUE
      ITYP=0
      IF(TMX.NE.0.D0.AND.GDO.EQ.0.D0)ITYP=1
      IF(TMX.NE.0.D0.AND.GDO.GT.0.D0)ITYP=2
      IF(JCAL.LE.0)TCS=SIGML(JL)
      IF(TEST.EQ.0.D0.AND.TMX.EQ.0.D0)Write(7,3200)
      IF(TEST.EQ.0.D0.AND.TMX.GE.1.D0)Write(7,3350)
```

```
      IF(TEST.EQ.0.D0.AND.TMX.GE.1.D0.and.IPOT.ne.0)Write(7,3351)
      IF(TEST.EQ.0.D0)Write(7,2700)
      CCCC=COST+1.D0
      IF(TEST.EQ.0.D0)Write(7,2750)CCCC
      IF(TEST.EQ.0.D0.AND.CV.EQ.0.D0)Write(7,2800)
      IF(TEST.EQ.0.D0.AND.CV.GE.1.D0)Write(7,2801)
      IF(TEST.EQ.0.D0.AND.CV.EQ.0.D0.AND.XMAX.GT.55.D0)Write(7,2851)
      IF(TEST.EQ.0.D0)Write(7,2900)TD,EX1,EX2,TMX,CV,GAV,COST,GDO,IJ
      DELCN=PAIR(1,1)/10.D0
      PAIRX(1)=PAIR(1,2)/10.D0
      PAIRX(2)=PAIR(2,1)/10.D0
      PAIRXA  =PAIR(3,3)/10.D0
      PAIRXD  =PAIR(2,2)/10.D0
      PAIRXT  =PAIR(2,3)/10.D0
      PAIRXH  =PAIR(3,2)/10.D0
    7 COR=CNCS
      IF (TMX.GT.0.D0.AND.JCAL.LE.0) COR=SIGML(JL)
      C=COST+1.D0
      NI=IDINT(TD)
      DO 5 I=1,4
      DO 5 IE=1,300
    5 GIB(I,IE)=SIG(I,IE)/ED
C
C     CALCULATE EFERMI AVERAGED OVER FERMI DENSITY DISTRIBUTION
C     REPLACE OLD FERMI RADIUS WITH DROPLET MODEL VALUE
C
      ECM=EP*AT/(AT+AP)
      DELR=4.6D0/DSQRT(AP*EP)
      CR=1.18D0*A**.333333333
      CRR=1.D0-1.D0/CR**2
      CD=CRR*CR+DELR
      RMXX=CD-DELR
      RRP=2.75D0+CD
      R2P=1.D0+DEXP((RRP-CD)/.55D0)
      C3=DEXP((-CD)/.55D0)+1.D0
      CAVE=(1.D0/(1.D0+(.55D0/RRP) *(DLOG(C3)-DLOG(R2P))))**.666666
      APT=40.D0/CAVE
      POT=APT
      FIN=0.5D0*29.44D0/(RMXX*DSQRT(ECM))
      FIN=FIN*180.D0/3.1415926D0
C
C    CALCULATE INVERSE C.S.*KINETIC ENERGY/SINGLE PARTICLE DENSITY
C
      G=A/14.D0
      GE(1)=((A-Z)/A)*G
      GE(2)=(Z/A)*G
      GE(3)=(A/14.)*0.25
      IF(KPG.eq.0) GE(4)=(A/14.)*0.50
      IF(KPG.eq.1) GE(4)=(A/14.)*0.333333333
      IF(KPG.eq.2) GE(4)=(A/14.)*0.333333333
      DO 15 IK=1,300
      DO 15 ID=1,4
      EK=DFLOAT(IK)*ED-ED/2.D0
   15 GIB(ID,IK)=GIB(ID,IK)/GE(ID)
C
      E=XMAX
      AV=CV
      IAV=IDINT(AV)
      M=300
```

```
      AT=A-AP
      L1=1
      L2=1
C
C    INITIALIZE KE SPECTRA
C
      DO 25 I=1,4
      DO 25 KE=1,300
   25 SCRS(KE,I)=0.D0
      DO 26 I=1,3
      DO 26 KE=1,300
      SCRA2(KE,I)=0.D0
   26 SCRD2(KE,I)=0.D0
C
C   ZERO DEPLETION  NUMBERS
C
      CSN=0.D0
      CSP=0.D0
      CSNN=0.D0
      CSPP=0.D0
      CSPN=0.D0
C
   30 NMAX=IDINT(DSQRT(1.5D0*G*E)-4.D0)
      IF(NMAX.LT.NI)NMAX=NI
      SMN=0.D0
      SMP=0.D0
      SMA=0.D0
      SMNA=0.D0
      SMPA=0.D0
      SMAA=0.D0
          SMD=0.D0
          SMND=0.D0
          SMPD=0.D0
          SMAD=0.D0
      L2=IDINT(TMX)
      IF(L2.LE.0)L2=1
      IF(JCAL.LT.1)L1=JL
      IF(JCAL.LT.1)L2=JL
   33 CRES=0.D0
C
C    BEGIN GDH CALCULATION OVER PARTIAL WAVES L1 TO L2 *****************
C
      DO 300 L=L1,L2
      DEP(1)=1.D0
      DEP(2)=1.D0
      TL=DFLOAT(L-1)
      IF(TMX.LE.0.D0) TL=0.D0
      CF=SIGML(L)
      IF(TMX.LE.0.D0.AND.JCAL.GE.0) CF=CNCS
      IF(CNCS.EQ.0.D0)CNCS=.000001D0
      CFRAC=CF/CNCS
      IF(CNCS.EQ..000001D0)CFRAC=0.D0
      RMX=RMXX
      IF(ZP.EQ.0.D0)GO TO 338
  338 CONTINUE
C
C     CALCULATE RADIUS OF L-TH PARTIAL WAVE
C
      IRES=0
```

```
      R=4.6D0*TL/DSQRT(AP*EP )
      R2=4.6D0*(TL+1.D0)/DSQRT(AP*EP)
      R1=R
9999  CONTINUE
C
C    CALL OPTICAL MODEL TRANSITION RATES
C
      C=CCCC
      IF(IAV.LE.0)CALL MFP
      XMIX=XMAX
C
C     IF(GAV)55,55,50
C     CALCULATE LOCAL DENSITY AVERAGES FOR GEOMETRY DEPENDENT OPTIONS
C
   50 IF(R-RRP)60,60,55
   55 C1=DEXP((R-CD)/.55D0)+1.D0
      C2=DEXP((R2-CD)/.55D0)+1.D0
      D2=1.D0/C2
      D1=1.D0/C1
      C3=2.D0/(D1+D2)
      DAVE=1.D0/C3
      C=C3*CCCC
      GO TO 65
   60 C1=DEXP((R-CD)/.55D0)+1.D0
      DAVE=(1.D0+(.55D0/(RRP-R))*(DLOG(C1)-DLOG(R2P)))
      C1=1.D0/DAVE
      C=C1*CCCC
   65  POT=40.D0*DAVE**.666666666
      IF(IRES.EQ.0)PTEMP=POT
      IF(IRES.EQ.0)CSAV=C
      IF(IRES.EQ.0)RSAV=R
      IF(POT.LE.1.D0)POT=1.D0
      POD2=(POT/30.D0)*(XMAX-ECM)+POT
      POD=POT*1.33D0
C
8877  R2=R
      R1=R
      IF(IRES.EQ.1)GO TO 9999
C
C  ESTIMATE REFRACTION WHEN COULOMB TRAJECTORY B?END IS PRESENT
C
 9068 CONTINUE
      N=NI
C
      IF(IADST.EQ.1.OR.IADST.EQ.2)CALL ANGL
      POT=PTEMP
      R=RSAV
      C=CSAV
C
C     CALL NUCLEON-NUCLEON TRANSITION RATES
      IF(IAV.GE.1)CALL NUCMFP
         RRR=4.6D0*TL/DSQRT(AP*EP )
         IF( L1.eq.L2 .or. IPOT.eq.0 ) goto 8899
         RKK= 1.D+00 * (
     #   1.D0+DEXP(  (RRR-RR0*(AT**0.333333D+00))/ 0.66D+0 )  )
         IF(ZP.eq.0.D+00) ITP=2   ! proton  spectra will be corrected
         IF(ZP.ne.0.D+00) ITP=1   ! neutron spectra will be corrected
         DO 8898  ITPKE=1,420
8898     RS(ITP,ITPKE)=RKK*RS(ITP,ITPKE)
```

```
8899    Continue
C
      ERT=0.D0
      SRT=0.D0
      NX=IDINT(XMAX/ED)+1
      E1=EX1
      E2=EX2
      TT=TD
      PSS=0.D0
      SS=0.D0
      IF(GDO.EQ.1.D0.AND.TMX.NE.0.D0)NMAX=NI
C
C   ADD LOOP ON COMPOUND NUCLEUS ISOSPIN
C
      NISOC=1
      IF(IJ.EQ.1)NISOC=2
C
C     LOOP ON EXCITON NUMBER ****************************************
C
      NTST=NI+6
      NMA=NI+18
      IF(NMAX.GT.NMA)NMAX=NMA
      DO 285 N=NI,NMAX,2
      If(MPG.ge.1) WRITE(*,22222)N
22222 FORMAT(1X,'Exciton number: ',I3)
      PS=0.D0
C
C   ZERO ONE EXCITON NO. ANGLE BUFFER
C
      DO 80 MJ=1,36
      DO 80 MK=1,301
   80 DSIGP(MJ,MK)=0.D0
      E=XMAX-DELCN
      IF(N-3)125,90,125
   90 IF(E-POT)120,120,95
   95 RHOD=POT*(2.D0*E-POT)/4.D0
      GO TO 125
  120 RHOD=E*E/4.D0
  125 EX=E1+E2
      AN=DFLOAT(N)
      PR(1)=E1
      PR(2)=E2
      X=TT-EX
      AN=DFLOAT(N)
       H=((X*X+EX*EX)/4.D0+(EX-3.D0*X)/4.D0)/G
      H=H/2.D0
C
C    BEGIN LOOP ON PARTICLE OUT TYPE,1=NEUTRON,2=PROTON ***************
C

  170 DO 265 I=1,2
C
      TS(I)=0.D0
      DELTA(2)=-1.12D0+1.443D0*(ZP+ZT-ZZ(I)-.5D0)/
     1 (AP+AT-1.D0)**.33333333+QPN(I)
      U=XMAX-B(I)+1.D0  -ED/2.D0-PAIRX(I)
      UU=XMAX-B(I)-ED/2.D0
      NU=IDINT(UU/ED)+1
      U=U-1.D0
```

```
       IF(NU.LE.0)GO TO 265
C
C    LOOP ON KINETIC ENERGY ******************************************
C
      EPRIM=E
      DO 260 KE=1,NU
      IF(U-H)175,175,180
  175 FRT=0.D0
      GO TO 185
  180  FRT=((U-H)/(EPRIM))**(N-2)
  185 EK=DFLOAT(KE)
      IF(IAV) 195,195,200
  195 DC=GIB(I,KE)/(GIB(I,KE)+RS(I,KE))
      GO TO 210
  200 JE=KE+IDINT(B(I)/ED)
      DC=GIB(I,KE)/(GIB(I,KE)+RS(I,JE))
  210 IF(FRT-1.D-20)260,260,215
  215 IF(N-3)240,220,240
  220 IF(U-POT)230,230,225
  225 RHON=POT/2.D0
      GO TO 235
  230 RHON=U/2.D0
  235 P=(RHON/RHOD)*PR(I)*DC
      GO TO 245
  240 P=(AN-1.D0)*FRT*PR(I)*DC/E
  245 P=P*ED
      TS(I)=TS(I)+P
      P=P*DEP(2)
      PCS=P*CF/ED
      BTST=1.D0
      IF(IADST.EQ.0)GO TO 246
      RKE=DFLOAT(KE)*ED-ED/2.D0
      RKE=RKE/DLT
      IRKE=IDINT(RKE)
C Corr. Oct. 95
      FDEL=(ED/(2.D0*DLT)     + 1.D-06)
      EDEL=(RKE-DFLOAT(IRKE)  + 1.D-06)
CHANGE SEPT 1984
C
      JEDEL=IDINT(1000.D0*EDEL)
      JFDEL=IDINT(1000.D0*FDEL)
      IF(JEDEL.EQ.JFDEL)BTST=0.D0
      IF(IRKE.LT.1)GO TO 246
      KE5=IRKE
      JK=1
      IF(IADST.EQ.2)JK=2
      IF(BTST.EQ.0.D0.AND.N.LT.NTST.AND.I.EQ.JK)CALL ADIST
246   SCRS(KE,I)=SCRS(KE,I)+P*CF/ED
      IF(IALPHA.NE.0 .AND. MPG.EQ.1)
     $CALL ALPNUC(IFLAG,I,U,EX,X,GIB,GE,G,P,CF,ED)
      IF(IALPHA.NE.0 .AND. MPG.EQ.2)
     $CALL DEUNUC(IFLAG,I,U,EX,X,GIB,GE,G,P,CF,ED)
C
      SS=SS+P
      PS=PS+P
      IF(P)260,260,255
  255 IF(P-1.D-20)265,265,260
  260 U=U-ED
C FAST GAMMA TREATMENT (N>=3)
```

```
      CALL FASTG(GIB,N,PR,DEP,B,I,CF,TT,X,G,1)
C
  265 CONTINUE
 2840 CONTINUE
 2850 CONTINUE
C
C COMPLEX PARTICLES PRECOMPOUND CALCULATIONS
C
      IF(IALPHA.EQ.0)              GOTO 2852
      IF(TMX.NE.0.AND.IALPHA.GT.10)GOTO 2852
      CALL ALPH05(TT,EX,X,L1,L2,GIB,GE,G,DEP,XMAX,ED,BALPHA,CNCS,
     #            PAIRXA)
      IF(M3.EQ.4 .AND.KPG.EQ.0)
     #CALL DEUT05(TT,EX,X,L1,L2,GIB,GE,G,DEP,XMAX,ED,BDEUTR,CNCS,
     #            PAIRXD,POT)
      IF(M3.EQ.4 .AND.KPG.EQ.1)
     #CALL TRIT95(TT,EX,X,L1,L2,GIB,GE,G,DEP,XMAX,ED,BTRIT,CNCS,
     #            PAIRXT)
      IF(M3.EQ.4 .AND.KPG.EQ.2)
     #CALL HE395(TT,EX,X,L1,L2,GIB,GE,G,DEP,XMAX,ED,BHE3,CNCS,
     #            PAIRXH)
 2852 CONTINUE
C
C   END LOOPS ON ISOSPIN
C
C   DEFINE DEPLETION/MULTIPLE EMISSION PROBABILITIES.
C   CSN=CS 1 N ONLY EMITTED
C   CSP=CS 1 P ONLY '
C   CSNN=CS 2 N IN COINCIDENCE,IE FROM SAME NUCLEUS.
C   CSPP=CS 2 P IN    '
C   CSPN=CS P-N IN   '
C   ABOVE NUMBERS/REACTION CS REPRESENTS FRACTION OF REACTION CROSS
C   SECTION INTO EACH CHANNEL.
C
      TTST=TS(1)*TS(2)
      IF(TTST.GT.TS(1))TTST=TS(1)
      IF(TTST.GT.TS(2))TTST=TS(2)
      TS1SQ=TS(1)*TS(1)/4.D0
      TS2SQ=TS(2)*TS(2)/4.D0
      DN=TTST+TS1SQ*2.D0
      DP=TTST+TS2SQ*2.D0
      SNGLN=TS(1)-TTST-TS1SQ*2.D0
      SNGLP=TS(2)-TTST-TS2SQ*2.D0
      IF(SNGLN.LT.0.D0)TS1SQ=TS(1)*TS1SQ/DN
      IF(SNGLN.LT.0.D0)TTST=TS(1)*TTST/DN
      IF(SNGLP.LT.0.D0)TS2SQ=TS(2)*TS2SQ/DP
      IF(SNGLP.LT.0.D0)TTST=TS(2)*TTST/DP
      SNGLN=TS(1)-TTST-2.D0*TS1SQ
      SNGLP=TS(2)-TTST-2.D0*TS2SQ
      IF(SNGLN.LT.0.D0)SNGLN=0.D0
      IF(SNGLP.LT.0.D0)SNGLP=0.D0
C
      CSN=CSN+SNGLN*CF*DEP(2)
      CSP=CSP+SNGLP*CF*DEP(2)
      CSNN=CSNN+TS1SQ*CF*DEP(2)*2.D0
      CSPP=CSPP+TS2SQ*CF*DEP(2)*2.D0
      CSPN=CSPN+TTST*CF*DEP(2)
C
      DEP(1)=1.-SNGLN-SNGLP-TTST-TS1SQ-TS2SQ
```

```
C
C  END NEW DEPLETION ALGORITHM
      IF(DEP(1).LT.0.D0)DEP(1)=0.D0
      DEP(2)=DEP(1)*DEP(2)
C
      TT=TT+2.D0
      E1=E1+.5D0
      E2=E2+0.5D0
      IBR=0
      IF(IBR.EQ.0)GO TO 422
      Write(7,400)N
  400 FORMAT(/'  ANGULAR DISTRIBUTION FOR N =',I5)
      IF(N.GT.9.OR.TMX.GT.0.D0)GO TO 422
      JMN=IDINT(XMAX/50.D0+.91D0)
      DO 420 J=1,JMN
      III=50*J-45
      I5=III+5
      I10=I5+5
      I15=I10+5
      I20=I15+5
      I25=I20+5
      I30=I25+5
      I35=I30+5
      I40=I35+5
      I45=I40+5
      Write(7,401)III,I5,I10,I15,I20,I25,I30,I35,I40,I45
  401 FORMAT(' ANGLE/DEG. KE=',F6.2,9(4X,F6.2))
      NII=J*10-9
      NIF=NII+9
  402 FORMAT(1X,F5.1,5X,10(E10.3))
      DO 410 ITH=1,36
      ANGLE=5.D0*DFLOAT(ITH)-2.5D0
      Write(7,402)ANGLE,(DSIGP(ITH,KEF),KEF=NII,NIF)
  410 CONTINUE
  420 CONTINUE
  422 CONTINUE
C
C    END LOOP OVER EXCITON NUMBER  ******************************
  285 CONTINUE
  290 CONTINUE
      PCR=SS*CF
      IF (TMX.EQ.0.D0.AND.JCAL.GT.0) GO TO 300
      SIGML(L)=SIGML(L)*DEP(2)
  301 CRES=CRES+SIGML(L)
  300 CONTINUE
C
C    END LOOP ON ORBITAL ANGULAR MOMENTUM FOR GDH OPTION
C
C FAST GAMMA TREATMENT (N=1)
      CALL FASTG(GIB,N,PR,DEP,B,I,CF,TT,X,G,2)
C
      E=XMAX
             SSS=0.0
             SSSA=0.0
             SSSD=0.0
C EMA is mean precompound alpha energy
           EMA=0.0
      DO 305 KE=1,300
      SMN=SMN+SCRS(KE,1)*ED
```

```
      SMP=SMP+SCRS(KE,2)*ED
*alphas
      SMA=SMA+SCRS(KE,3)*ED

           XEMA=DFLOAT(KE)*ED-ED/2.
           EMA=EMA+XEMA*SCRS(KE,3)*ED
      SMNA=SMNA+SCRA2(KE,1)*ED
      SMPA=SMPA+SCRA2(KE,2)*ED
      SMAA=SMAA+SCRA2(KE,3)*ED
      SSSA=SSSA+ED*(SCRS(KE,3)+SCRA2(KE,1)+SCRA2(KE,2)+SCRA2(KE,3))
*deuterons, tritons, He-3
      SMD=SMD+SCRS(KE,4)*ED
      SMND=SMND+SCRD2(KE,1)*ED
      SMPD=SMPD+SCRD2(KE,2)*ED
      SMAD=SMAD+SCRD2(KE,3)*ED
      SSSD=SSSD+ED*(SCRS(KE,4)+SCRD2(KE,1)+SCRD2(KE,2)+SCRD2(KE,3))
C
             SSS=SCRS(KE,1) + SCRS(KE,2) + SCRS(KE,3) + SCRS(KE,4)
             NX = KE
             IF(SSS.eq.0.0) goto 306
  305 CONTINUE
  306 IF(L1.EQ.L2.AND.TMX.NE.0.D0) Write(7,310) TL
      IF(TEST.NE.0.D0)GO TO 335
      If(MPG.ne.2) Write(7,440) SMN,SMP,SMA,SMNA,SMPA,SMAA,SSSA,
     c                          Partx(KPG+1),SMD
      If(MPG.eq.2) Write(7,4401)SMN,SMP,SMA,SMD,SMND,SMPD,SSSD
                           EMA1 = 9999999.
           IF(SMA.gt.0.0)   EMA1 = EMA/SMA
      Write(7,441)EMA1
      Write(100,442)ZT,AT,EMA1
441   Format(1x,'Mean energy for precompound alpha-particle=',g12.5)
442   Format(1x,2f6.2,g12.5,'   Mean energy for alpha precompound')
      IF(IKE.LT.1)GO TO 335
      KX=NX/10+1
      A1=ED-ED/2.D0
      A2=A1+ED
      A3=A2+ED
      A4=A3+ED
      A5=A4+ED
      A6=A5+ED
      A7=A6+ED
      A8=A7+ED
      A9=A8+ED
      A10=A9+ED
      Write(7,415)
      Write(7,315)A1,A2,A3,A4,A5,A6,A7,A8,A9,A10
      DO 339 KJ=1,KX
      R0=(DFLOAT(KJ)-1.)*ED*10.D0
      N0=10*(KJ-1)
      N1=10*(KJ-1)+1
      N2=N1+9
      Write(7,320)R0,(SCRS(N,1),N=N1,N2)
      Write(7,325)   (SCRS(N,2),N=N1,N2)
      IF(IALPHA.NE.0) then
      If(MPG.ne.2) then
                   Write(7,326)   (SCRS(N,3), N=N1,N2)
                   Write(7,328)   (SCRA2(N,1),N=N1,N2)
                   Write(7,329)   (SCRA2(N,2),N=N1,N2)
                   Write(7,330)   (SCRA2(N,3),N=N1,N2)
```

```
                  Write(7,327)   Partix(KPG+1),(SCRS(N,4), N=N1,N2)
                  else
                  Write(7,326)   (SCRS(N,3), N=N1,N2)
                  Write(7,327)   Partix(KPG+1),(SCRS(N,4), N=N1,N2)
                  Write(7,3281)  (SCRD2(N,1),N=N1,N2)
                  Write(7,3291)  (SCRD2(N,2),N=N1,N2)
                  endif
                     endif
  339 CONTINUE
C
C   ADD OUTPUT LOOP ON ISOSPIN SPECTRA
C
  335 IF(GDO.EQ.1.D0.AND.TMX.GE.1.D0)GO TO 340
      GO TO 350
  340 CNCS=CRES
      BMX=TMX
      TMX=0.D0
      NI=NI+2
      EX1=EX1+.5D0
      EX2=EX2+.5D0
      TD=TD+2.D0
      IF(ITYP.EQ.2)CCCC=CCCC+1.D0
      Write(7,345)
      GDO=0.D0
      GO TO 30
  350 CNT=SMN+SMP
C
      IF(IADST.EQ.0)GO TO 5200
      CONFAC=3.1415926D0*5.D0/180.D0
      IF(IADST.EQ.3.OR.IADST.EQ.4.or.iadst.eq.5)Write(7,407)
  407 FORMAT(//,'ANGULAR DISTRIBUTION CALCULATED USING KALBACH SYSTEMATI
     1CS',/,'           SEE PHYS. REV. C 37 (1988) 2350',/)
      Write(7,406)
  406 FORMAT('   TOTAL ANGULAR DISTRIBUTION PRECOMPOUND ONLY')
      NEND=IDINT(XMAX/(10.D0*DLT)+0.99D0)
      If(IADST.eq.5 .and. BE(1,1,3) .lt. 0.D+00)
     #  NEND=IDINT( (XMAX-BE(1,1,3))/(10.D0*DLT)+0.99D0)
C
      DO 520 J=1,NEND
      BJI(1)=DLT*DFLOAT(10*J-9)+ED/2.D0
      DO 8406 II=2,10
8406  BJI(II)=BJI(II-1)+DLT
C
      IF(J.GT.1)GO TO 6509
      IF(IADST.GT.2)CALL ANGEL
 6509 CONTINUE
      Write(7,401)(BJI(II),II=1,10)
      NII=J*10-9
      NIF=NII+9
C
      DO 6510 ID=1,10
6510  ASUM(ID)=0.D0
C
      DO 510 ITH=1,36
      III=0
      DO 6511 KEF=NII,NIF
      III=III+1
6511  ASUM(III)=ASUM(III)+SIGN(ITH)*DSIGT(ITH,KEF)*CONFAC
      ANGLE=5.D0*DFLOAT(ITH)-2.5D0
```

```
      Write(7,402)ANGLE,(DSIGT(ITH,KEF),KEF=NII,NIF)
  510 CONTINUE
      Write(7,6512)(ASUM(II),II=1,10)
6512  FORMAT(' INTEGRAL=',10(E10.3))
  520 CONTINUE
5200  CONTINUE
C
      IF(IKE.NE.4)GO TO 3511
      DO 351 I=1,300
      EN(1,I)=EN(1,I)+SCRS(I,1)
      EN(2,I)=EN(2,I)+SCRS(I,2)
      IF(IALPHA.EQ.0)GOTO 351
      EN(3,I)=EN(3,I)+SCRS(I,3)+SCRA2(I,1)+SCRA2(I,2)+SCRA2(I,3)
      EN(4,I)=EN(4,I)+SCRS(I,4)+SCRD2(I,1)+SCRD2(I,2)+SCRD2(I,3)
 351  CONTINUE
 3511 CONTINUE
C
C   SET APPLICABLE REACTION CS FOR TYPE OF CALCULATION
C
      IF(JCAL.LT.0)RCS=TCS
      IF(JCAL.GE.0)RCS=CNSIG
C
C  CALCULATE MAX RESIDUAL EXCITATION AFTER ONE N OUT AND 1 N OUT CS
C
      U=XMAX-BE(1,1,1)-ED/2.D0
      IUN=IDINT(U/ED+1.D0)
      PROBN=0.D0
      IF(IALPHA.NE.0)UA=XMAX-BE(1,1,3)-ED/2.
      IF(IALPHA.NE.0)IUA=UA/ED+1.0
      IF(IALPHA.EQ.0)GOTO 33933
      DO 33932 IAA=1,IUA
      KEA=IUA+1-IAA
33932 PP(3    ,3    ,IAA)=PP(3    ,3    ,IAA)+SCRS(KEA,3)*ED
C
33933 CONTINUE
      IF(IALPHA.NE.0)UH2=XMAX-BE(1,1,4)-ED/2.
      IF(IALPHA.NE.0)IUH2=UH2/ED+1.0
      IF(IALPHA.EQ.0)GOTO 34933
      DO 34932 IDD=1,IUH2
      KED=IUH2+1-IDD
      IF(KPG.EQ.0)PP(2  ,2  ,IDD)=PP(2  ,2  ,IDD)+SCRS(KED,4)*ED
      IF(KPG.EQ.1)PP(2  ,3  ,IDD)=PP(2  ,3  ,IDD)+SCRS(KED,4)*ED
      IF(KPG.EQ.2)PP(3  ,2  ,IDD)=PP(3  ,2  ,IDD)+SCRS(KED,4)*ED
34932 CONTINUE
34933 CONTINUE
C
      IF(IUN.LT.1)GO TO 51300
      DO 1300 I=1,IUN
1300  PROBN=PROBN+SCRS(I,1)
51300 CONTINUE
      IUNN=IDINT((U-BE(1,2,1)-ED/2.D0)/ED+1.D0)
      PROBNN=0.D0
C
C   CALC CS POSSIBLE 2 N EMISSION
C
      IF(IUNN.LT.1)GO TO 51301
      DO 1301 I=1,IUNN
1301  PROBNN=PROBNN+SCRS(I,1)
51301 CONTINUE
```

```
C
C   CALC CS POSSIBLE P&N OUT
C
      IUPN=IDINT((U-BE(1,2,2)-ED/2.D0)/ED+1.D0)
      PRBPNN=0.D0
      PRBPNP=0.D0
      IF(IUPN.LT.1)GO TO 51302
      DO 1302 I=1,IUPN
      PRBPNP=PRBPNP+SCRS(I,2)
1302  PRBPNN=PRBPNN+SCRS(I,1)
51302 CONTINUE
C
C   CS FOR P OUT PRODUCTS
      PROBP=0.D0
      U=XMAX-BE(1,1,2)-ED/2.D0
      IUP=IDINT(U/ED+1.D0)
      IF(IUP.LT.1)GO TO 53031
      DO 13031 I=1,IUP
13031  PROBP=PROBP+SCRS(I,2)
53031 CONTINUE
C
C  CS FOR POSSIBLE 2P OUT
C
      PROBPP=0.D0
      IUPP=IDINT((U-BE(2,1,2)-ED/2.D0)/ED+1.D0)
      IF(IUPP.LT.1)GO TO 53041
      DO 13041 I=1,IUPP
13041  PROBPP=PROBPP+SCRS(I,2)
53041 CONTINUE
C
C   STORE ONE N OUT CS
C
C MODIFY FOR 1 AND ONLY ONE N OUT
      IF(PROBN.LE.0.D0)GO TO 13070
      NONLY=IDINT((BE(1,2,1)-ED/2.D0)/ED+1.D0)
      NONLY=MIN0(NONLY,IUN)
      ROBN=0.D0
      IF(NONLY.LT.1)GO TO 63031
      DO 23031 IUL=1,NONLY
      KE=IUN+1-IUL
23031 ROBN=ROBN+SCRS(KE,1)
      DO 33931 INN=1,NONLY
      KE=IUN+1-INN
33931 PP(1    ,2    ,INN)=PP(1    ,2    ,INN)+SCRS(KE,1)*ED
C
      CHN=CSN/ED
      IF(ROBN.GE.PROBN.OR.ROBN.GE.CHN)GO TO 63031
      CN=(CSN/ED-ROBN)/(PROBN-ROBN)
      LOW=NONLY+1
      IF(IUN.LT.LOW)GO TO 63031
      DO 1306 INN=LOW,IUN
      KE=IUN+1-INN
1306  PP(1    ,2    ,INN)=PP(1    ,2    ,INN)+SCRS(KE,1)*CN*ED
63031 CONTINUE
C
C   STORE 2N OUT CS
C
      IF(PROBNN.LE.0.D0)GO TO 13070
      CNN=0.5D0*CSNN/(PROBNN*ED)
```

```
C
C  MODIFY FOR KE DECREMENT FOR BOTH PRECOMPOUND PARTICLES
C  IUNN IS MAX KE INDEX FOR 2 NEUTS OUT
C  K2AV IS THE AVERAGE KE OF THE SECOND PARTICLE FOR A GIVEN KE PARTICLE
C
      DO 13071 INN=1,IUNN
13071 SMSCR(INN)=0.D0
      SMSCR(1)=SCRS(1,1)
      DO 13072 INN=2,IUNN
13072 SMSCR(INN)=SCRS(INN,1)+SMSCR(INN-1)
      IUNNF=IUNN-1
      DO 13079 IFIN=1,IUNNF
      IFNN=IUNN-IFIN
      STEST=SMSCR(IFNN)/2.D0
      DO 13075 INN=1,IFNN
      K2AV=INN
      IF(SMSCR(INN).GE.STEST)GO TO 13076
13075 CONTINUE
13076 CONTINUE
      IFIM=IUNN-IFIN-K2AV+3
      IF(IFIM.LE.0)IFIM=1
      PP(1    ,3    ,IFIM)=PP(1    ,3    ,IFIM)+SCRS(IFIN,1)*CNN*ED
13078 CONTINUE
13079 CONTINUE
C COMPLETES ALGORITHM TWO PARTICLE KE REMOVAL
C
13070 CONTINUE
      IF(PROBP.LE.0.D0)GO TO 13090
C
C  STORE ONE P OUT CS
C
      IPNLY=IDINT((BE(2,1,1)-ED/2.D0)/ED+1.0D0)
      IPNLY=MIN0(IPNLY,IUP)
      ROBP=0.D0
      IF(IPNLY.LT.1)GO TO 61308
      DO 43031 IUL=1,IPNLY
      KE=IUP+1-IUL
43031 ROBP=ROBP+SCRS(KE,2)
      LOW=IPNLY+1
      DO 73031 INN=1,IPNLY
      KE=IUP+1-INN
73031 PP(2,1,INN)=PP(2,1,INN)+SCRS(KE,2)*ED
C
      CHP=CSP/ED
      IF(ROBP.GE.PROBP.OR.ROBP.GE.CHP)GO TO 61308
      CP=(CSP/ED-ROBP)/(PROBP-ROBP)
      DO 1308 INN=LOW,IUP
      KE=IUP+1-INN
1308  PP(2,1,INN)=PP(2,1,INN)+SCRS(KE,2)*CP*ED
61308 CONTINUE
C
C
C  STORE 2P OUT CS
C
      IF(PROBPP.LE.0.D0)GO TO 13090
      CPP=0.5D0*CSPP/(PROBPP*ED)
C
C  MODIFY FOR KE DECREMENT FOR BOTH PRECOMPOUND PARTICLES
C  IUPP IS MAX KE INDEX FOR 2 PROTS OUT
```

```
C  K2AV IS THE AVERAGE KE OF THE SECOND PARTICLE FOR A GIVEN KE PARTICLE
C
      DO 13091 INN=1,IUPP
13091 SMSCR(INN)=0.D0
      SMSCR(1)=SCRS(1,2)
      DO 13092 INN=2,IUPP
13092 SMSCR(INN)=SCRS(INN,2)+SMSCR(INN-1)
      IUPPF=IUPP-1
      DO 13099 IFIN=1,IUPPF
      IFNN=IUPP-IFIN
      STEST=SMSCR(IFNN)/2.D0
      DO 13095 INN=1,IFNN
      K2AV=INN
      IF(SMSCR(INN).GE.STEST)GO TO 13096
13095 CONTINUE
13096 CONTINUE
      IFIM=IUPP-IFIN-K2AV+3
      IF(IFIM.LE.0)IFIM=1
      IF(K2AV.GT.IVV)
     #PP(3,1,IFIM)=PP(3 ,1 ,IFIM)+SCRS(IFIN,2)*CPP*ED
13097 CONTINUE
13099 CONTINUE
C
C COMPLETES ALGORITHM TWO PARTICLE KE REMOVAL
13090 CONTINUE
      IF(PRBPNN.LE.0.D0)GO TO 13100
      IF(PRBPNP.LE.0.D0)GO TO 13100
C
C  STORE P&N COINCIDENCE OUT CS
C
      CPNN=0.5D0*CSPN/(PRBPNN*ED)
      CPNP=0.5D0*CSPN/(PRBPNP*ED)
C
C  MODIFY FOR KE DECREMENT FOR BOTH PRECOMPOUND PARTICLES
C  IUPN IS MAX KE INDEX FOR 1NEUT/1PROT COINC.  OUT
C  K2AV IS THE AVERAGE KE OF THE SECOND PARTICLE FOR A GIVEN KE PARTICLE
C
C   FIRST CALC AVERAGE NEUT ENERGY FOR PROTON OF KE OUT
C
      DO 13081 INN=1,IUPN
13081 SMSCR(INN)=0.D0
      SMSCR(1)=SCRS(1,1)
      DO 13082 INN=2,IUPN
13082 SMSCR(INN)=SCRS(INN,1)            +SMSCR(INN-1)
      IUPNF=IUPN-1
      DO 13089 IFIN=1,IUPNF
      IFNN=IUPN-IFIN
      STEST=SMSCR(IFNN)/2.D0
      DO 13085 INN=1,IFNN
      K2AV=INN
      IF(SMSCR(INN).GE.STEST)GO TO 13086
13085 CONTINUE
13086 CONTINUE
      IFIM=IUPN-IFIN-K2AV+3
      IF(IFIM.LE.0)IFIM=1
      PP(2 ,2,IFIM)=PP(2 ,2 ,IFIM)+SCRS(IFIN,2)*CPNP*ED
13087 CONTINUE
13089 CONTINUE
C
```

```
C  CALC AVE PROTON ENERGY FOR NEUT OF KE AND STORE NEUT C.S.
      DO 16081 INN=1,IUPN
16081 SMSCR(INN)=0.D0
      SMSCR(1)=SCRS(1,2)
      DO 16082 INN=2,IUPN
16082 SMSCR(INN)=SCRS(INN,2)     +SMSCR(INN-1)
      IUPNF=IUPN-1
      DO 16089 IFIN=1,IUPNF
      IFNN=IUPN-IFIN
      STEST=SMSCR(IFNN)/2.D0
      DO 16085 INN=1,IFNN
      K2AV=INN
      IF(SMSCR(INN).GE.STEST)GO TO 16086
16085 CONTINUE
16086 CONTINUE
      IFIM=IUPN-IFIN-K2AV+3
      IF(IFIM.LE.0)IFIM=1
      IF(K2AV.GT.IVV)
     #PP(2 ,2 ,IFIM)=PP(2 ,2 ,IFIM)+SCRS(IFIN,1)*CPNN*ED
16087 CONTINUE
16089 CONTINUE
C COMPLETES ALGORITHM TWO PARTICLE KE REMOVAL
13100 CONTINUE
C
      Write(7,13101)CSN,CSP,CSNN,CSPP,CSPN
      IF(ITYP.EQ.0)CNCS=COR*DEP(2)
      IF(ITYP.EQ.1)CNCS=CRES
      IF(ITYP.EQ.2)CNCS=CNCS*DEP(2)
      IF (CNCS.LT.0.D0) CNCS=0.D0
       Write(7,3333)ITYP,CNCS
3333  FORMAT('ITYP=',I3,'CNCS HYB ROUTINE=',F8.2)
      Write(7,9898)JCAL
9898  FORMAT(50X,' JCAL=',I5)
C
                  SUMAPR=SMA+SMNA+SMPA+SMAA
                  SUMDER=SMD+SMND+SMPD+SMAD
C
C REDEFINE CNCS ACCORDING TO ALPHA & D PRECOMP EMISSION
      CNCS=CNCS-SMA-SMD
      IF (CNCS.LT.0.D0) CNCS=0.D0
      Write(7,3333)ITYP,CNCS
      RETURN
C
13101 FORMAT(//' CSN=',E10.3,'CSP=',E10.3,'CSNN=',E10.3,'CSPP=',E10.3,
     1'CSPN=',E10.3)
 2801 FORMAT(/41X,'TRANSITION RATES ARE FROM NUCLEON-NUCLEON SCATTERING'
     1)
  415 FORMAT(' KINETIC ENERGY// DS/DE= NEUTRONS    PROTONS  (PRECOMPOUND
     1 DISTRIBUTION)')
  440 FORMAT(/' TOTAL PRECOMPOUND NEUTRON CROSS SECTION = ',E10.3,
     1 ', TOTAL PRECOMPOUND PROTON CROSS SECTION = ',E10.3/
     2 ' IWAMOTO-HARADA TOTAL PRE SINGLE  ALPHA CROSS SECTION = ',E10.3/
     3 ' IWAMOTO-HARADA TOTAL PRE NEUTRON,ALPHA CROSS SECTION = ',E10.3/
     4 ' IWAMOTO-HARADA TOTAL PRE PROTON, ALPHA CROSS SECTION = ',E10.3/
     5 ' IWAMOTO-HARADA TOTAL PRE ALPHA,  ALPHA CROSS SECTION = ',E10.3/
     6 '          TOTAL PRECOMPOUND ALPHA CROSS SECTION (SUM) = ',E10.3/
     7 ' IWAMOTO-HARADA TOTAL PRECOMPOUND ',A5,' CROSS SECTION = ',E10.3
     8 )
 4401 FORMAT(/' TOTAL PRECOMPOUND NEUTRON CROSS SECTION = ',E10.3,
```

```
     1 ', TOTAL PRECOMPOUND PROTON CROSS SECTION = ',E10.3/
     2 ' TOTAL PRECOMPOUND ALPHA-PARTICLE CROSS SECTION  = ',E10.3/
     3 ' PRECOMPOUND SINGLE DEUTERON CROSS SECTION       = ',E10.3/
     4 ' PRECOMPOUND PRE NEUTRON, DEUTERON CROSS SECTION = ',E10.3/
     5 ' PRECOMPOUND PRE PROTON, DEUTERON CROSS SECTION  = ',E10.3/
     6 '                                                 = ',E10.3/
     7 '  TOTAL PRECOMPOUND DEUTERON CROSS SECTION (SUM) = ',E10.3)
10010 FORMAT(//30X,' PRECOMPOUND PARAMETERS HAVE BEEN SELECTED INTERNALL
     1Y'/)
 2700 FORMAT(/20X,' THE FOLLOWING PARAMETER VALUES WERE SELECTED FOR THE
     1 PRECOMPOUND CALCULATION')
 2750 FORMAT(/40X,' MEAN FREE PATH MULTIPLIER IS = ',F10.3,/)
 2800 FORMAT(' INTRANUCLEAR TRANSITION RATES WERE CALCULATED USING THE I
     1MAGINARY OPTICAL POTENTIAL')
 2851 FORMAT(' WARNING=THE IMAGINARY OPTICAL POTENTIAL PARAMETER SET MAY
     1 BE INVALID ABOVE 55 MEV CHANNEL ENERGY.')
 2900 FORMAT(' TD= ',F5.2,' EX1= ',F5.2,' EX2= ',F5.2,' TMX= ',F5.2,' AV
     1= ',F5.2,' GAV= ',F5.2,' COST= ',F5.2,' GDO= ',F5.2,' IJ= ',I5)
 3200 FORMAT(/41X,' HYBRID CALCULATION HAS BEEN SELECTED ')
 3350 FORMAT(/41X,' GEOMETRY DEPENDENT HYBRID MODEL SELECTED')
 3351 FORMAT(/38X,' CORRECTION FOR (P,N) OR (N,P) SPECTRA PERFORMED')
  345 FORMAT(/41X,' HYBRID FOLLOWING GDH SELECTED')
  310 FORMAT (/' PRECOMPOUND CROSS SECTIONS FOR PARTIAL WAVE L=',
     1 F3.0,' ONLY')
  315 FORMAT(23X,10(F8.3,2X))
  320 FORMAT(1X,F7.2,1X,'DS/DE NEUTRONS',5(1X,E9.3),2X,5(1X,E9.3))
  325 FORMAT(13X,'  PROTONS ',5(1X,1E9.3),2X,5(1X,1E9.3)/)
  326 FORMAT(13X,'1ST ALPHAS',5(1X,1PE9.3),2X,5(1X,1PE9.3)/)
  327 FORMAT(13X,'1',A9,      5(1X,1PE9.3),2X,5(1X,1PE9.3)/)
  328 FORMAT(13X,'NEUT-ALPH ',5(1X,1PE9.3),2X,5(1X,1PE9.3)/)
  329 FORMAT(13X,'PROT-ALPH ',5(1X,1PE9.3),2X,5(1X,1PE9.3)/)
  330 FORMAT(13X,'ALPH-ALPH ',5(1X,1PE9.3),2X,5(1X,1PE9.3)/)
 3281 FORMAT(13X,'NEUT-DEUT ',5(1X,1PE9.3),2X,5(1X,1PE9.3)/)
 3291 FORMAT(13X,'PROT-DEUT ',5(1X,1PE9.3),2X,5(1X,1PE9.3)/)
 9779 FORMAT(1X,100('#')/13X,'ATTENTION ! JCAL IS NOT EQUAL 1 AND '
     1' COMPLEX PARTICLE PRECOMPOUND EMISSION WILL NOT BE TREATED'
     2 /1X,100('#'))
 9777 FORMAT(1X,'MULTIPLE PRECOMPOUND SPECTRA ARE CORRECTED, ',
     14X,' V =',I5)
      END
*
*********************************************************************
*
      Subroutine IWAMOA(IALPHA)
*     ------------------------
*
C ALPHA-PARTICLES
C IWAMOTO,HARADA COALESCENCE PICK-UP MODEL, PHYS.REV.1982,V.26,P.1821
C
C FLM(KE,L), KE is kinetic energy, L is number of particles above Fermi
C
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/SHFT/QVAL,AP,AT,ZP,ZT,CLD,MC,MP,INVER,IKE,IPCH,BARFAC
      COMMON/IWAALP/FLM(300,4),WIMAG
      COMMON/INCR/ED
      COMMON/FLMIH1/FLMIH0(28,4)
      COMMON/WOO/WBREAK
      DIMENSION FLMIH(28,4),EA(28)
      DE=11.3207547
```

```
C
C COEFFICIENT FOR NORMALIZATION OF IWAMOTO-HARADA PICK-UP FACTORS
C
      RNORMA=0.30
C
      ZRES=ZT+ZP-2.
      ARES=AT+AP-4.
C HUIZENGO-IGO
         WIMAG1=10.+0.345*(ARES-2.*ZRES)
C TROMBIK
C     WIMAG1=8.4
C
      WBREAK = (45./197.)*AT
      WIMAG=    WIMAG1
      WRITE(7,33300)WIMAG1,WIMAG,ZRES,ARES
           DO 2 I=1,300
           DO 2 J=1,4
2          FLM(I,J)=0.
      EE=-DE
      DO 10 I=1,28
      EE=EE+DE
      EA(I)=EE
C FLM ARE TAKEN FROM I-H GRAPH (36.5 IS LENGTH (MM) OF 1.0)
         DO 5 L=1,3
5        FLMIH(I,L)=FLMIH0(I,L)/36.5
      RR=1.-FLMIH(I,1)-FLMIH(I,2)-FLMIH(I,3)
      IF(RR.GT.1.)RR=1.
      IF(RR.LT.0.)RR=0.
      IF(I.EQ.1)RR=0.
10    FLMIH(I,4)=RR
      EA(1)=0.
      DO 1000 IK=1,300
      X=DFLOAT(IK)*ED-ED/2.
           DO 500 I=1,28
           IF(X.LT.EA(I))GOTO 600
500        CONTINUE
           GOTO 11111
600   IF(I.EQ.1)GOTO 22222
           X2=EA(I)
           X1=EA(I-1)
      DO 900 L=1,4
           Y2=FLMIH(I,L)
           Y1=FLMIH(I-1,L)
      Y=(((Y2-Y1)/(X2-X1))*(X-X1))+Y1
      IF(Y2.LT.1.E-05.AND.Y1.LT.1.E-05) Y=0.
      Y=DABS(Y)
      FLM(IK,L) = RNORMA * Y
900   CONTINUE
1000  CONTINUE
C
      IALPHA=IALPHA+10
      IF(IALPHA.GE.10) RETURN
C
C TEST
        WRITE(7,5000)
5000    FORMAT(1X,' IWAMOTO-HARADA FLM (NORM.ON "1"):'/1X,80('_')/
     "  1X,'   E    ',3X,'(1,3)',3X,'(2,2)',3X,'(3,1)',3X,'(4,0)')
5001    FORMAT(1X,5F8.2)
      DO 6000 IK=1,300
```

```
      X=DFLOAT(IK)*ED-ED/2.
      DO 5999 L=1,4
5999  FLM(IK,L) = FLM(IK,L)/RNORMA
      WRITE(7,5001)X,(FLM(IK,L),L=1,4)
6000  CONTINUE
      STOP
C ERRORS
11111   WRITE(7,11112)X,EA
        WRITE(8,11112)X,EA
11112   FORMAT(1X,'SUBR.IWAMOA:  X=',G12.5/1X,' EA:'/1X,4(G12.5))
        STOP
22222   WRITE(7,22223)X
        WRITE(8,22223)X
22223   FORMAT(1X,'SUBR.IWAMOA: X =',G12.5,' < 0.')
33300   FORMAT(1X,'WIMAG (CENTER) =',F7.2,'  WIMAG (ALPHA) =',F7.2,
     $  ' ZRES =',F6.1,' ARES =',F6.1)
        STOP
        END

*
*********************************************************************
*
      Subroutine IWAMOD(IALPHA,WIMAG)
*     ------------------------------
*
C DEUTERONS
C IWAMOTO,HARADA COALESCENCE PICK-UP MODEL, PHYS.REV.1982,V.26,P.1821
C + SATO ET AL.
C
C FLM(KE,L) KE IS ENERGY, L IS NUMBER OF PARTICLES ABOVE FERMI LEVEL
C
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/SHFT/QVAL,AP,AT,ZP,ZT,CLD,MC,MP,INVER,IKE,IPCH,BARFAC
      COMMON/PAR3/EQ,SIGML999(300),ACRS999(300)
      COMMON/IWADEU/FLM(300,2)
      COMMON/INCR/ED
      COMMON/EFD/EFERMI,GH
      COMMON/ADDKD/FID,EDEUMIN,EDEUEXP
C
C PICK-UP  NORMALIZATION
      RNORMD= 0.3
C
C PROBABILITY FOR DEUTERON KNOCK-OUT
C
* for nucleon "x" incident
* Fd  = fi*XS_xd/[ (Z/A)*XS_xp + (N/A)*XS_xn ]
*     = fi* 2. * XS_xd/[ XS_xp + XS_xn ]
* XS_.. relates to nuclear matter
* For EF=32:
* Fd (approx) = 2.* 0.512*EXP(-9.81E-03*T)
* Constant 1.82857 is taken "historically".
* The realistic value of fi = FIDCORR *1.828572 /(2*0.512) (*1.79)
*
* Change FIDCORR for individual probability
*
       FID=1.82857*DEXP(-9.81E-03*EQ)*FIDCORR(ZP,AP,ZT,AT)
C
C EFFECTIVE VALUE OF EFERMI
       EFermi=5.
```

```
C
C
C EFFECTIVE IMAGINARY PART OF OPTICAL POTENTIAL FOR DEUTERONS
      WIMAG1=32.
*
      WIMAG=WIMAG1
        c1=-1.37d-03*AT-0.213
        If(EQ.le.62.)  WIMAG= c1  *(62.-EQ) + WIMAG1
        If(EQ.gt.62.)  WIMAG=-0.45*(EQ-62.) + WIMAG1
        If(EQ.gt.90.)  WIMAG=-0.45*(90.-62.) + WIMAG1
        if(wimag.le.0.0) wimag=0.001
*
* Additional tuning of potential
      EDEUMIN=20.
      EDEUEXP=0.1027*DEXP(-11.45*(AT-2.*ZT)/AT)
*
      ZRES=ZT+ZP-1.
      ARES=AT+AP-2.
      WRITE(7,33300)WIMAG1,WIMAG,ZRES,ARES
C
C HOLE SINGLE LEVEL DENSITY
      GH=(AT+AP)/EFermi
C
           DO 2 I=1,300
           DO 2 J=1,2
2          FLM(I,J)=0.
      DO 1000 IK=1,300
      T=DFLOAT(IK)*ED-ED/2.
C
C CALC. ACCORDING TO APPROX OF SATO DATA (FIG.3, PHYS.REV)
      If(t.le.30.) then
                   FLM11=-1.409E-02*T+0.6
                   else
                   FLM11=1.377E-04*(T**2)-1.807E-02*T+0.5946
                   endif
      If(t.gt.65.) FLM11=0.0
C NORM ON 1, BECAUSE MAX VALUE OF SATO =0.6
      FLM(IK,1)= FLM11/0.6
      FLM(IK,2)= 1. - FLM(IK,1)
      DO 900 L=1,2
900   FLM(IK,L) = RNORMD * FLM(IK,L)
1000  CONTINUE
      IALPHA=IALPHA+10
      IF(IALPHA.GE.20) RETURN
C
C TEST
      WRITE(7,5000)
5000  FORMAT(///1X,'                              DEUTERONS '/
     1         1X,' IWAMOTO-HARADA FLM (NORM.ON "1"):'/1X,80('_')/
     1  1X,'   E    ',3X,'(1,1)',3X,'(2,0)')
5001    FORMAT(1X,5F8.2)
      DO 6000 IK=1,300
      X=DFLOAT(IK)*ED-ED/2.
      DO 5999 L=1,2
5999  FLM(IK,L) = FLM(IK,L)/RNORMD
      WRITE(7,5001)X,(FLM(IK,L),L=1,2)
6000  CONTINUE
      STOP
33300 FORMAT(1X,'WIMAG (CENTER) =',F7.2,'  WIMAG (DEUTR) =',F7.2,
```

```
     $' ZRES =',F6.1,' ARES =',F6.1)
      END
*
*********************************************************************
*
      Subroutine IWAMOH(IALPHA,WIMAG)
*     ------------------------------
*
C HE-3 (temporarily as for tritons)
C IWAMOTO,HARADA COALESCENCE PICK-UP MODEL, PHYS.REV.1982,V.26,P.1821
C + SATO ET AL.
C
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/SHFT/QVAL,AP,AT,ZP,ZT,CLD,MC,MP,INVER,IKE,IPCH,BARFAC
      COMMON/IWAHE3/FLM(300,3)
      COMMON/INCR/ED
      COMMON/FLMIH3/FLMIH0(42,3)
      DIMENSION FLMIH(42,3),EA(42)
      DE=400./53.7
C
C COEFFICIENT FOR NORMALIZATION (IWAMOTO-HARADA -- 0.33)
      RNORMA=1.00
C
      ZRES=ZT+ZP-1.
      ARES=AT+AP-3.
C BECHETTI
      WIMAG1=55.-110.*(ARES-2.*ZRES )/ARES
C
      WIMAG=    WIMAG1
      WRITE(7,33300)WIMAG1,WIMAG,ZRES,ARES
           DO 2 I=1,300
           DO 2 J=1,3
2          FLM(I,J)=0.
      EE=-DE
      DO 10 I=1,42
      EE=EE+DE
      EA(I)=EE
C 34.25 IS LENGTH (MM) OF 1.0 ON I-H GRAPHIC
         DO 5 L=1,2
5        FLMIH(I,L)=FLMIH0(I,L)/34.25
      RR=1.-FLMIH(I,1)-FLMIH(I,2)
      IF(RR.GT.1.)RR=1.
      IF(RR.LT.0.)RR=0.
      IF(I.EQ.1)RR=0.
10    FLMIH(I,3)=RR
      EA(1)=0.
      DO 1000 IK=1,300
      X=FLOAT(IK)*ED-ED/2.
           DO 500 I=1,42
           IF(X.LT.EA(I))GOTO 600
500        CONTINUE
           GOTO 11111
600   IF(I.EQ.1)GOTO 22222
           X2=EA(I)
           X1=EA(I-1)
      DO 900 L=1,3
           Y2=FLMIH(I,L)
           Y1=FLMIH(I-1,L)
      Y=(((Y2-Y1)/(X2-X1))*(X-X1))+Y1
```

```
      IF(Y2.LT.1.E-05.AND.Y1.LT.1.E-05) Y=0.
      Y=ABS(Y)
900   FLM(IK,L) = RNORMA * Y
1000  CONTINUE
      IALPHA=IALPHA+10
      IF(IALPHA.GE.20) RETURN
C
C TEST
      WRITE(7,5000)
5000  FORMAT(1X,' IWAMOTO-HARADA FLM FOR HE-3 (NORM.ON "1"):
     1'/1X,60('_')/
     11X,'   E    ',3X,'(1,2)',3X,'(2,1)',3X,'(3,0)')
5001  FORMAT(1X,4F8.2)
      DO 6000 IK=1,300
      X=FLOAT(IK)*ED-ED/2.
      DO 5999 L=1,3
5999  FLM(IK,L) = FLM(IK,L)/RNORMA
      WRITE(7,5001)X,(FLM(IK,L),L=1,3)
6000  CONTINUE
      STOP
C ERRORS
11111 WRITE(7,11112)X,EA
      WRITE(8,11112)X,EA
11112 FORMAT(1X,'SUBR.IWAMOH:  X=',G12.5/1X,' EA:'/1X,4(G12.5))
      STOP
22222 WRITE(7,22223)X
      WRITE(8,22223)X
22223 FORMAT(1X,'SUBR.IWAMOH: X =',G12.5,' < 0.')
33300 FORMAT(1X,'WIMAG (CENTER) =',F7.2,'  WIMAG (HE-3) =',F7.2,
     $' ZRES =',F6.1,' ARES =',F6.1)
      STOP
      END
*
*********************************************************************
*
      Subroutine IWAMOT(IALPHA,WIMAG)
*     ------------------------------
*
C TRITONS
C IWAMOTO,HARADA COALESCENCE PICK-UP MODEL, PHYS.REV.1982,V.26,P.1821
C + SATO ET AL.
C
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/SHFT/QVAL,AP,AT,ZP,ZT,CLD,MC,MP,INVER,IKE,IPCH,BARFAC
      COMMON/IWATRI/FLM(300,3)
      COMMON/INCR/ED
      COMMON/FLMIH2/FLMIH0(42,3)
      DIMENSION FLMIH(42,3),EA(42)
      DE=400./53.7
C
C COEFFICIENT FOR NORMALIZATION (IWAMOTO-HARADA -- 0.33)
      RNORMA=1.00
C
      ZRES=ZT+ZP-1.
      ARES=AT+AP-3.
C BECHETTI
      WIMAG1=55.-110.*(ARES-2.*ZRES )/ARES
C
      WIMAG=    WIMAG1
```

```
      WRITE(7,33300)WIMAG1,WIMAG,ZRES,ARES
           DO 2 I=1,300
           DO 2 J=1,3
2          FLM(I,J)=0.
      EE=-DE
      DO 10 I=1,42
      EE=EE+DE
      EA(I)=EE
C 34.25 IS LENGTH (MM) OF 1.0 ON I-H GRAPHIC
         DO 5 L=1,2
5        FLMIH(I,L)=FLMIH0(I,L)/34.25
      RR=1.-FLMIH(I,1)-FLMIH(I,2)
      IF(RR.GT.1.)RR=1.
      IF(RR.LT.0.)RR=0.
      IF(I.EQ.1)RR=0.
10    FLMIH(I,3)=RR

      EA(1)=0.
      DO 1000 IK=1,300
      X=FLOAT(IK)*ED-ED/2.
           DO 500 I=1,42
           IF(X.LT.EA(I))GOTO 600
500        CONTINUE
           GOTO 11111
600   IF(I.EQ.1)GOTO 22222
           X2=EA(I)
           X1=EA(I-1)
      DO 900 L=1,3
           Y2=FLMIH(I,L)
           Y1=FLMIH(I-1,L)
      Y=(((Y2-Y1)/(X2-X1))*(X-X1))+Y1
      IF(Y2.LT.1.E-05.AND.Y1.LT.1.E-05) Y=0.
      Y=ABS(Y)
900   FLM(IK,L) = RNORMA * Y
1000  CONTINUE
      IALPHA=IALPHA+10
      IF(IALPHA.GE.20) RETURN
C
C TEST
      WRITE(7,5000)
5000  FORMAT(1X,' IWAMOTO-HARADA FLM FOR TRITONS (NORM.ON "1"):
     1'/1X,60('_')/
     1 1X,'   E    ',3X,'(1,2)',3X,'(2,1)',3X,'(3,0)')
5001  FORMAT(1X,4F8.2)
      DO 6000 IK=1,300
      X=FLOAT(IK)*ED-ED/2.
      DO 5999 L=1,3
5999  FLM(IK,L) = FLM(IK,L)/RNORMA
      WRITE(7,5001)X,(FLM(IK,L),L=1,3)
6000  CONTINUE
      STOP
C ERRORS
11111 WRITE(7,11112)X,EA
      WRITE(8,11112)X,EA
11112 FORMAT(1X,'SUBR.IWAMOT:  X=',G12.5/1X,' EA:'/1X,4(G12.5))
      STOP
22222 WRITE(7,22223)X
      WRITE(8,22223)X
22223 FORMAT(1X,'SUBR.IWAMOT: X =',G12.5,' < 0.')
```

```
33300 FORMAT(1X,'WIMAG (CENTER) =',F7.2,'  WIMAG (TRITON) =',F7.2,
     $' ZRES =',F6.1,' ARES =',F6.1)
      STOP
      END
*
**********************************************************************
*
      Subroutine KALBACH(III,RKALB,AKE0,AVECOS)
*     ----------------------------------------
*
* prepared basing on ANGEL subroutine
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/PARO/PQ,CROSS
      COMMON/SHFT/QVAL,AP,AT,ZP,ZT,CLD,MC,MP,INVER,IKE,IPCH,BARFAC
      CHARACTER*4 SYMB,SYMBP,SYMBS
      COMMON/LYM1/BE(11,24,4),SYMB(11,24),PAIR(11,24),SYMBP(11,24),
     1SYMBS(11,24),XMAS(11,24),DELSHL(11,24),AMAS(11,24)
      DIMENSION SIGMA(73),XCOS(73)
                DO 100 I=1,10
  100           SIGMA(I)=0.D0
      DO 102 I=1,73
      THETA=DFLOAT(I-1)*2.5
  102 XCOS(I)=DCOS(THETA*3.1415926/180.)
*  iii=n,p,a,d,t,h
      If(iii.eq.1) XMB=0.5
      If(iii.eq.2) XMB=1.
      If(iii.eq.3) XMB=2.
      If(iii.eq.4) XMB=1.
      If(iii.eq.5) XMB=1.
      If(iii.eq.6) XMB=1.
         IZP=idint(ZP+0.0001d0)
         IZA=idint(AP+0.0001d0)
                                XMA=1.
      If(IZP.eq.2.and.IZA.eq.4) XMA=0.
      JIN=IZA
      ESYS=PQ+QVAL
      If(iii.le.4) BIN=BE(1,1,iii)
      If(iii.gt.4) BIN=BE(1,1,4)
      E1=130.*DFLOAT(JIN)
      IF(ESYS.LT.E1)E1=ESYS
      E3=0.
      IF(JIN.LE.2) E3=DMIN1(ESYS,4.1D1)
      EPS=AKE0
      FMSD=RKALB
      IF(FMSD.LE.0.)FMSD=1.D0
      EPSCM=EPS+BIN
      Y=EPSCM*E1/ESYS
      A=0.04*Y+1.8D-06*Y*Y*Y
      IF(JIN.GT.2)GO TO 22
      Y=EPSCM*E3/ESYS
      A=A+6.7D-07*Y*Y*Y*Y*XMB*XMA
   22 XNORM=1. ! For norm purp only,  A*TOTAL/(12.5664*DSINH(A))
          DO I=1,73
          ARG=A*XCOS(I)
          SIGMA(I)=( FMSD*DSINH(ARG)+DCOSH(ARG) )*XNORM
          EnddO
* get mean cos(T)
      sum1=0.
      s1=0.
```

```
      Do i=2,73
      sum1=sum1+xcos(i)*sigma(i)*(xcos(i)-xcos(i-1))
      s1=s1+sigma(i)*(xcos(i)-xcos(i-1))
      Enddo
      sum2=0.
      s2=0.
      Do i=1,72
      sum2=sum2+xcos(i)*sigma(i)*(xcos(i+1)-xcos(i))
      s2=s2+sigma(i)*(xcos(i+1)-xcos(i))
      Enddo
      avecos=0.0
      If((s1+s2).eq.0.0) Return
      avecos=(sum1+sum2)/(s1+s2)
      if(avecos.gt.1.)avecos=1.
      Return
      END
*
*********************************************************************
*
      Subroutine LDCALC(A,EXCIT,KJZ,KJA,K,EPAIR,SOR)
*     ----------------------------------------------
*
C Gamma width calculation included (Jan,1997)
      IMPLICIT REAL*8 (A-H,O-Z)
      CHARACTER*4 SYMB,SYMBP,SYMBS
      COMMON/LAB10/POW(4,3000),GAM(3000)
      COMMON/PL3/EB(70),RCSP(70),ZEE,AMASS,PLEX,NEPR
      COMMON/LYM1/BE(11,24,4),SYMB(11,24),PAIR(11,24),SYMBP(11,24),
     1SYMBS(11,24),XMAS(11,24),DELSHL(11,24),AMAS(11,24)
      COMMON/QQ/GOW(3000)
      INTEGER HILIM
      PI=3.1415926D0
      PISQ=9.8696D0
      SRTPI=1.7725D0/12.D0
      TPI=6.283D0
      CON=1./(12.D0*DSQRT(2.D0))
      GF=6./PISQ
      A3=A**0.333333333
      A23=A3*A3
      BOFN=BE(KJZ,KJA,1)
      BOFP=BE(KJZ,KJA,2)
        IF(BOFN.EQ.0.D0.OR.BOFP.EQ.0.D0) THEN
        ALDM=A/9.D0
        ELSE
        ALDM=0.11035*A-0.25132*A23+1.4*A23/BOFN + 0.4*A23/BOFP
        END IF
C Arbitrary instructions (4 Jan 1997)
      If(ALDM.le.0.0D+0) ALDM=A/9.D0
      If(ALDM.gt.1.5D0*A/9.0) then
      Print *,'! (LDCALC)  Bad calculation :  ALDM=',ALDM
      ALDM=A/9.D0
                              endif
      W=0.185*A3
      PIW=PI*W
      EM2BAR=0.240*A23
      CONMUL=PI/(12.*DSQRT(12.D0*EM2BAR))
      UMIN=2.5+150.D0/A
      UD=UMIN-(EPAIR+DELSHL(KJZ,KJA))-0.1
      IF(UD.LT.0.1D0)UMIN=-(EPAIR+DELSHL(KJZ,KJA))+0.1
```

```
      IF(UMIN.GT.2.D0)UMIN=2.D0
      IF(UMIN.LT.1.D0)UMIN=1.D0
      ILOW=IDINT(10.*UMIN)
      IF(EXCIT.GT.300.D0)EXCIT=300.D0
      HILIM=IDINT(10.*EXCIT)
      IF(HILIM.LT.1)GO TO 900
      U=EXCIT-EPAIR+0.100
      DELS=DELSHL(KJZ,KJA)
      IF(HILIM.LT.ILOW)HILIM=ILOW
      IF((HILIM+ILOW-1).GT.3000)HILIM=HILIM-ILOW
      DO 850 IIE=ILOW,HILIM
      IE=HILIM+ILOW-IIE
      U=U-0.100
      IF(U.LT.0.1D0)GO TO 850
      TP=DSQRT(U/ALDM)
   10 T=TP
      T1=T
      T2=T+0.005
      U1=ALDM*T1*T1-DELS
      U2=ALDM*T2*T2 -DELS
      XX1=PIW*T1
      IF(XX1.GT.15.)GO TO 700
      XX2=PIW*T2
      U1=U1+DELS*(XX1*XX1*DCOSH(XX1)/(DSINH(XX1))**2)
      U2=U2+DELS*(XX2*XX2*DCOSH(XX2)/(DSINH(XX2))**2)
  700 CONTINUE
      TP=T1+(U-U1)*((T2-T1)/(U2-U1))
      IF(DABS(T-TP).GT.0.005D0)GO TO 10
      T=TP
      S=2.*ALDM*T
      XXX=PIW*T
      IF(XXX.GT.15.D0)GO TO 99
      S=S+(DELS/T)*(XXX*XXX*DCOSH(XXX)/((DSINH(XXX))**2)-
     1 XXX/DSINH(XXX))
   99 AEFF=S/2./T
C Arbitrary instructions (4 Jan 1997)
      If(AEFF.le.0.D+0) then
      DENS=0.0D+0
      Print *,'! (LDCALC)  Bad calculation -  AEFF=',AEFF
                        endif
      If(AEFF.gt.0.D+0) DENS=DEXP(S-SOR)*CONMUL/((AEFF**0.75)*DSQRT(T)*
     1 (U**1.25+T))
      IF(k.ne.0) POW(K,IE)=DENS
      IF(k.eq.0) GOW(IE)  =DENS
  850 CONTINUE
      CNORM=DENS/DEXP(U/T)
C  NOW ADD CONSTANT TEMPERATURE PART OF LEVEL DENSITY
      DO 860 IIE=1,ILOW
      IE=ILOW+1-IIE
      IF(k.ne.0) POW(K,IE)=CNORM*DEXP(U/T)
      IF(k.eq.0) GOW(IE)  =CNORM*DEXP(U/T)
      U=U-0.1D0
  860 CONTINUE
  900 CONTINUE
      RETURN
      END
*
*********************************************************************
*
```

```
      Subroutine LDIST
*     ----------------
*
C Level density according to Ignatyuk, Smirenkin, Tishin,
(Sov.J.Nucl.Phys.,1975)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/SS/SOR,RR /LAB10/POW(4,3000),GAM(3000)
      COMMON/QQ/GOW(3000) /UG/IZ,IA  /SF/M3,KPLT
      COMMON/SFT5/EXC(10,24),XMAX
      CHARACTER*4 SYMB,SYMBP,SYMBS
      COMMON/LYM1/BE(11,24,4),SYMB(11,24),PAIR(11,24),SYMBP(11,24),
     1SYMBS(11,24),XMAS(11,24),DELSHL(11,24),AMAS(11,24)
      COMMON/PL3/EB(70),RCSP(70),ZEE,AMASS,PLEX,NEPR
      COMMON/GR/RINT(500) /INCR/ED
      COMMON/GIANI/PRE, SIGT(500),SIGAM(500),SIGPRE(500),GSP(500),
     2 EQGAM(500),IGAM /HOT/KPG,MPG
      DO 1 IE=1,3000
      GOW(IE)=0.D0
      DO 1 JK=1,3
      POW(JK,IE)=0.D0
   1  CONTINUE
C
C Loop for ejectile
C
      DO 9000 JK=1,5
      If(M3.lt.JK  .and. JK.ne.5) goto 9000
      IF(JK.EQ.1) N=0
      IF(JK.EQ.1) M=1
          IF(JK.EQ.2) N=1
          IF(JK.EQ.2) M=0
      IF(JK.EQ.3) N=2
      IF(JK.EQ.3) M=2
      IF(JK.EQ.4 .and. KPG.EQ.0) N=1
      IF(JK.EQ.4 .and. KPG.EQ.0) M=1
          IF(JK.EQ.4 .and. KPG.EQ.1) N=1
          IF(JK.EQ.4 .and. KPG.EQ.1) M=2
      IF(JK.EQ.4 .and. KPG.EQ.2) N=2
      IF(JK.EQ.4 .and. KPG.EQ.2) M=1
      IF(JK.EQ.5) N=0
      IF(JK.EQ.5) M=0
C
      ITZ=IZ+N
      ITA=IA+M
      EXCIT=EXC(ITZ,ITA)
      IF(EXCIT.GT.300.D0)EXCIT=300.D0
      ILIM=IDINT(10.*EXCIT)
      IF(ILIM.LT.1)GO TO 9000
      IF(ILIM.GT.3000)ILIM=3000
      A=AMASS+ 2. -DFLOAT(ITA)-DFLOAT(ITZ)
      Z=ZEE  + 1. -DFLOAT(ITZ)
         IAOZ=IDINT(A+0.001D+0)
         IZOZ=IDINT(Z+0.001D+0)
         INOZ=IAOZ-IZOZ
            MZOZ=MOD(IZOZ,2)
            MNOZ=MOD(INOZ,2)
C Define parity correction
C A odd
                                       EPAIR=12./DSQRT(A)
C Even-even
```

```
         If(MZOZ.eq.0 .and. MNOZ.eq.0) EPAIR=24./DSQRT(A)
C Odd-odd
         If(MZOZ.ne.0 .and. MNOZ.ne.0) EPAIR=0.D+00
      L=JK
         DW=DELSHL(ITZ,ITA)
         AASS=A*(0.154 - 6.3D-05*A)
      DO 1000 IB=1,ILIM
      BJ=DFLOAT(IB)/10.D0-.05D0
      U=BJ
         If(U.le.EPAIR) goto 1000
         FU=1.-DEXP(-0.054*U)
         ADENS=AASS*(1.D+00+DW*FU/U)
         UEFF=U-EPAIR
      SQ=2.D0*DSQRT(ADENS*UEFF)-SOR
       If(JK.ne.5)  POW(L,IB)=
     #   (   1.D0/ ((ADENS**0.25)*(1.D0+UEFF**1.25))   )*DEXP(SQ)
      If(JK.eq.5)  GOW(IB)=
     #   (   1.D0/ ((ADENS**0.25)*(1.D0+UEFF**1.25))   )*DEXP(SQ)
 1000 CONTINUE
C Now arbitrary energy for jointing two level densities
      EX=2.D0
         FU=1.-DEXP(-0.054*EX)
         ADENS=AASS*(1.D+00+DW*FU/EX)
      TEN=10.D0*EX+0.05D0
      IT=IDINT(TEN)
      IF=IT-1
      TEMP=DSQRT(EX/ADENS)
      D=DEXP((EX)/TEMP)
       If(JK.ne.5) CQ1=POW(L,IT)/D
       If(JK.eq.5) CQ1=GOW(IT)/D
      DO 2000 IB=1,IF
      E=0.10D0*DFLOAT(IB)-0.05D0
      If(JK.ne.5) POW(L,IB)=CQ1*DEXP((E)/TEMP)
      If(JK.eq.5) GOW(IB)  =CQ1*DEXP((E)/TEMP)
2000  CONTINUE
9000  CONTINUE
C
            DO 71581 II3=1,500
71581       RINT(II3)=0.D0
       KX3=IDINT(40.D0/ED)
       IF(KX3.GT.500)KX3=500
       RINT(1)=1.D-10
       DO 61441 IT3=2,KX3
       DO 61431 IF3=2,IT3
       JF3=IF3-1
       EG3=DFLOAT(JF3)*ED
       AIB3=(DFLOAT(IT3)*ED-EG3)*10.D0+0.05D0
       IB3=IDINT(AIB3)
       RTEM3=SIGT(JF3)*GOW(IB3)
       RINT(IT3)=RINT(IT3)+RTEM3
61431  CONTINUE
C NOTE THAT SIGT(I) IS E*E*SIG(E) FROM SUBROUTINE GAMMA
61441 CONTINUE
      DO 61451 IT3=2,KX3
      RINT(IT3)=5.36766D-4*RINT(IT3)*ED
61451 CONTINUE
      RETURN
      END
*
```

```
************************************************************************
*
      Subroutine LDLOAD
*     -----------------
*
C Gamma width calculation included (Jan,1997)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/SS/SOR,RR /LAB10/POW(4,3000),GAM(3000)
      COMMON/QQ/GOW(3000) /UG/IZ,IA /SF/M3,KPLT
      COMMON/SFT5/EXC(10,24),XMAX
      CHARACTER*4 SYMB,SYMBP,SYMBS
      COMMON/LYM1/BE(11,24,4),SYMB(11,24),PAIR(11,24),SYMBP(11,24),
     1SYMBS(11,24),XMAS(11,24),DELSHL(11,24),AMAS(11,24)
      COMMON/PL3/EB(70),RCSP(70),ZEE,AMASS,PLEX,NEPR
      COMMON/GR/RINT(500) /INCR/ED
      COMMON/GIANI/PRE, SIGT(500),SIGAM(500),SIGPRE(500),GSP(500),
     2 EQGAM(500),IGAM /HOT/KPG,MPG
      DO 30 IE=1,3000
      GOW(IE)=0.D0
      DO 30 JK=1,3
      POW(JK,IE)=0.D0
   30 CONTINUE
      DO 10 JK=1,M3
      IF(JK.EQ.1) N=0
      IF(JK.EQ.1) M=1
          IF(JK.EQ.2) N=1
          IF(JK.EQ.2) M=0
      IF(JK.EQ.3) N=2
      IF(JK.EQ.3) M=2
      IF(JK.EQ.4 .and. KPG.EQ.0) N=1
      IF(JK.EQ.4 .and. KPG.EQ.0) M=1
          IF(JK.EQ.4 .and. KPG.EQ.1) N=1
          IF(JK.EQ.4 .and. KPG.EQ.1) M=2
      IF(JK.EQ.4 .and. KPG.EQ.2) N=2
      IF(JK.EQ.4 .and. KPG.EQ.2) M=1
      ITZ=IZ+N
      ITA=IA+M
      EXCIT=EXC(ITZ,ITA)
      A=AMASS+ 2. -DFLOAT(ITA)-DFLOAT(ITZ)
      EPAIR=PAIR(ITZ,ITA)/10.
      CALL LDCALC(A,EXCIT,ITZ,ITA,JK,EPAIR,SOR)
   10 CONTINUE
C
C Gamma
      JK=0
          N=0
          M=0
      ITZ=IZ+N
      ITA=IA+M
      EXCIT=EXC(ITZ,ITA)
      A=AMASS+ 2. -DFLOAT(ITA)-DFLOAT(ITZ)
      EPAIR=PAIR(ITZ,ITA)/10.
      CALL LDCALC(A,EXCIT,ITZ,ITA,JK,EPAIR,SOR)
             DO 71581 II3=1,500
71581        RINT(II3)=0.D0
       KX3=IDINT(40.D0/ED)
       IF(KX3.GT.500)KX3=500
       RINT(1)=1.D-10
       DO 61441 IT3=2,KX3
```

```
       DO 61431 IF3=2,IT3
       JF3=IF3-1
       EG3=DFLOAT(JF3)*ED
       AIB3=(DFLOAT(IT3)*ED-EG3)*10.D0+0.05D0
       IB3=IDINT(AIB3)
       RTEM3=SIGT(JF3)*GOW(IB3)
       RINT(IT3)=RINT(IT3)+RTEM3
61431  CONTINUE
C   NOTE THAT SIGT(I) IS E*E*SIG(E) FROM SUBROUTINE GAMMA
61441 CONTINUE
      DO 61451 IT3=2,KX3
      RINT(IT3)=5.36766D-4*RINT(IT3)*ED
61451 CONTINUE
      RETURN
      END
*
*********************************************************************
*
      Subroutine LPOLY(X,N,PL)
*     ------------------------
*
C    THIS SUBROUTINE CALCULATES THE ORDINARY LEGENDRE POLYNOMIALS OF
C    ORDER 0 TO N-1 OF ARGUMENT  X  AND STORES THEM IN THE VECTOR
C    PL.  THEY ARE CALCULATED BY RECURSION RELATION FROM THE FIRST TWO
C    POLYNOMIALS.
C
C    WRITTEN BY A. J. SIERK   LANL  T-9  FEBRUARY, 1984
C
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION PL(20)
      PL(1) = 1.D0
      PL(2) = X
      DO 10 I = 3,N
        PL(I) = (DFLOAT(2*I-3)*X*PL(I-1)-DFLOAT(I-2)*PL(I-2))/
     1DFLOAT(I-1)
 10     CONTINUE
      RETURN
      END
*
*********************************************************************
*
      Subroutine LYMASS(ZEE,AMASS,NZ,NA,MC,MP,AP,AT,ZP,ZT,QVAL,LDOPT)
*     ---------------------------------------------------------------
*
C  SIGMA for light nuclei is changed becuse max value = 1.D+299 (WATCOM
C  Fortran)
      IMPLICIT REAL*8 (A-H,O-Z)
      Character*8  Partix(3)
      DIMENSION EM(10),XK(10),Y(2),F(2),XMS(24,11), EMP(10)
      DIMENSION XQ(30)
      CHARACTER*4 BLANK,TAB,FOR,RINP,ABE,SYMB(11,24),SYMBP(11,24),
     1SYMBS(11,24),AAA,AAB
      COMMON/LYM1/BE(11,24,4),SYMB,PAIR(11,24),SYMBP,SYMBS,XMAS(11,24),
     1DELSHL(11,24), AMAS(11,24)
      COMMON/SF/M3,KPLT /CSHEL/SHEL(11,24,2)
      COMMON/DEFOR/DEF(24,11) /HOT/KPG,MPG
      DATA BLANK,TAB,FOR,RINP,ABE/4H    ,4H TAB,4H MSL,4H INP,4H ABE/
      DATA PARTIX/8HDEUTERON,8HTRITON  ,8HHE-3    /
      DO 1 I=1,11
```

```
      DO 1 K=1,24
      SYMBP(I,K)=BLANK
      SYMB(I,K)=BLANK
      SYMBS(I,K)=BLANK
      XMAS(I,K)=0.D0
      AMAS(I,K)=0.D0
      DELSHL(I,K)=0.D0
      PAIR(I,K)=0.D0
      DEF(K,I)=0.D0
      DO 1 L=1,4
      BE(I,K,L)=0.D0
    1 CONTINUE
      DEL=0.D0
      IF(MP.EQ.0.)DEL=2.D0
      IF(MP.EQ.3.)DEL=1.D0
C
C      ABOVE STATEMENTS DEFINE PAIRING TREATMENT
C
      IBIND=0
      IF(MC.LT.10) GO TO 6
      IBIND = 1
      MC=MC-10
    6 EM(1)=0.0D0
      EM(2)=2.0D0
      EM(3)=8.0D0
      EM(4)=14.0D0
      EM(5)=28.0D0
      EM(6)=50.0D0
      EM(7)=82.0D0
      EM(8)=126.0D0
      EM(9)=184.0D0
      EM(10)=258.0D0
      CAY1=1.15303D0
      CAY3=200.0D0
      CAY4=11.0D0
      CAY5=8.07144D0
      CAY6=7.28899D0
      GAMMA=1.7826D0
      A1=15.4941D0
      A2=17.9439D0
      A3=0.7053D0
      D=0.444D0
      C=5.8D0
      SMALC=0.325D0
      PVAL=0.D0
      DO 15 I=1,10
      EMP(I)=EM(I)**1.66666666
   15 CONTINUE
      DO 20 I=1,9
      XK(I)=0.6*(EMP(I+1)-EMP(I))/(EM(I+1)-EM(I))
   20 CONTINUE
      RZ=.863987/A3
      L=0
      Z=1.0D0
   25 KZ=IDINT(ZEE)
      KA=IDINT(AMASS)
      IF(QVAL.EQ.0.D0.AND.PVAL.EQ.0.D0)GO TO 30
      GO TO 35
   30 NNZ=3
```

```
    NNA=1
    GO TO 90
 35 NNZ=NZ+2
    NNA=NA+2
    WRITE(7,36)
 36 FORMAT (1H1,53X,'MASS OPTIONS'/)
    IF (MC.EQ.1.AND.MP.NE.0) MC=0
    IF(IBIND.EQ.1)Write(7,86)
 86 FORMAT(20X,' EXPERIMENTAL MASSES ARE USED WHERE TABUL'
   1,'ATED; LIQUID DROP VALUES OTHERWISE.')
    IF(MC.EQ.0) Write(7,70)
    IF(MC.EQ.1) Write(7,65)
    IF (MC.EQ.2) WRITE(7,70)
 50 IF(MP.EQ.0)Write(7,75)
     IF(MP.EQ.1)Write(7,80)
    IF(MP.EQ.3)Write(7,81)
 81 FORMAT(' NORMAL PAIRING SHIFT WITH ODD-EVEN REFERENCE POINT')
 65 FORMAT(40X,'LIQUID DROP WITHOUT SHELL CORRECTION TERM')
 70 FORMAT(41X,'LIQUID DROP WITH SHELL CORRECTION TERM')
 75 FORMAT(21X,'WITHOUT PAIRING, I.E. LEVEL DENSITY PAIRING ',
   1 'SHIFT ABSORBED IN BINDING ENERGIES')
 80 FORMAT(10X,'WITH PAIRING, LEVEL DENSITY PAIRING SHIFT',
   1 ' CALC. FROM MSL FORMULA AND APPLIED IN BACKSHIFTED',
   2 ' CONVENTION')
    IF (MP.EQ.2) Write(7,85)
 85 FORMAT (20X,'MSL SHELL CORRECTION TERM INCLUDED IN LEVEL ',
   1 'DENSITY GROUND STATE SHIFT')
 90 DO 215 JZ=1,NNZ
    DO 215 JA=1,NNA
    IF(QVAL.EQ.0.D0.AND.PVAL.EQ.0.D0)GO TO 95
    GO TO 115
 95 IF(JZ-2)100,105,110
100 Z=ZEE
    A=AMASS
    IA=IDINT(A)
    IZ=IDINT(Z)
    N=IA-IZ
    UN=AMASS-ZEE
    GO TO 125
105 Z=ZT
    A=AT
    IA=IDINT(A)
    IZ=IDINT(Z)
    N=IA-IZ
    UN=AT-ZT
    GO TO 125
110 Z=ZP
    A=AP
    IZ=IDINT(Z)
    IA=IDINT(A)
    N=IA-IZ
    UN=AP-ZP
    GO TO 125
115 IA=KA+2-JA-JZ
    IZ=KZ+1-JZ
    N=IA-IZ
120 Z=DFLOAT(IZ)
    UN=DFLOAT(N)
    A=DFLOAT(IA)
```

```
125 A3RT=A**.333333333
    A2RT=DSQRT(A)
    A3RT2=A3RT**2
    ZSQ=Z**2
    SYM=((UN-Z)/A)**2
    ACOR=1.0D0-GAMMA*SYM
    PARMAS=CAY5*UN+CAY6*Z
    VOLNUC=-1.0D0*A1*ACOR*A
    SUFNUC=A2*ACOR*A3RT2
    COULMB=A3*ZSQ/A3RT
    FUZSUR=-1.0D0*CAY1*ZSQ/A
    ODDEV=-1.0D0*(1.0+2.0*DFLOAT(N/2)-UN+2.*DFLOAT(IZ/2)-Z)/
   1 DSQRT(A)*CAY4
    DEF(JA,JZ)=0.D0
    PAIR(JZ,JA)=-ODDEV
    SYMBP(JZ,JA)=FOR
    IF(MP.EQ.0)ODDEV=0.D0
    IF(MP.EQ.0)GO TO 11
 10 PAIR(JZ,JA)=(2.0*DFLOAT(N/2)-UN+2.0*DFLOAT(IZ/2)-Z+DEL)/
   1 DSQRT(A)*CAY4
    SYMBP(JZ,JA) = FOR
 11 CONTINUE
    IF(SYM.GT.0.4D0)WTERM=0.D0
130 WTERM=0.D0
    WOTNUC=PARMAS+COULMB+FUZSUR+ODDEV+WTERM
    SMASS=WOTNUC+VOLNUC+SUFNUC
    XMS(JA,JZ)=SMASS
    XQ(JZ)=SMASS
135 CONTINUE
    C2=(SUFNUC+WTERM)/(A**.66666666)
    X=COULMB/(2.0D0*(SUFNUC+WTERM))
140 BARR=0.0D0
145 Y(1)=UN
    Y(2)=Z
    DO 165 J=1,2
    DO 150 I=1,9
    IF (Y(J)-EM(I+1)) 160,160,150
150 CONTINUE
155 STOP
160 F(J)=XK(I)*(Y(J)-EM(I))-.6*(Y(J)**(1.666666666)-EMP(I))
165 CONTINUE
    S=(2.0/A)**(.6666666666)*(F(1)+F(2))-SMALC*A**(.3333333333)
    EE=2.*C2*D**2*(1.0D0-X)
    FF=.42591771*C2*D**3*(1.+2.D0*X)/A3RT
    SSHELL=C*S
    V=SSHELL/EE
    EPS=1.5*FF/EE
    IF(EE*(1.-3.*V).LE.0.D0) GO TO 170
    QCALC=0.0D0
    THETA=0.0D0
    SHLL=SSHELL
    DEF(JA,JZ)=0.D0
    GO TO 210
170 TO=1.0D0
175 DO 180 IPQ=1,30
    T=TO-(1.-EPS*TO-V*(3.-2.*TO**2)*DEXP(-TO**2))/(-EPS+V*(10.*TO-4.
   1 *TO**3)*DEXP(-TO**2))
    IF (T.LE.0.D0) GO TO 190
    IF (DABS(T-TO).LT.0.1D-5) GO TO 185
```

```
    TO=T
180 CONTINUE
    GO TO 200
185 TRAC=2.D0*EE*(1.-2.*EPS*T-V*(3.-12.*T**2+4.*T**4)*DEXP(-T**2))
    IF(TRAC.GT.0.D0)GOTO 205
190 DO 195 I=1,20
    TO=DFLOAT(I)/10.D0
    GL=EE*(1.-EPS*TO-V*(3.-2.*TO**2)*DEXP(-TO**2))
    IF (GL.GE.0.D0) GO TO 175
195 CONTINUE
200 CONTINUE
205 THETA=T
    ALPHA0=D*DSQRT(5.D0)/A**.33333333
    ALPHA=ALPHA0*THETA
    SIGMA=ALPHA*(1.D0+ALPHA/14.D0)
    If((2.*SIGMA).gt.688.d+00) then
                               Print *,'BAD calculations in LYMASS'
                               SIGMA=688.D+00/2.d+00
                               endif
    QCALC=.004*Z*(RZ*A3RT)**2*(DEXP(2.*SIGMA)-DEXP(-SIGMA))
    SHLL=EE*T**2-FF*T**3+SSHELL*(1.-2.*T**2)*DEXP(-T**2)
    DEF(JA,JZ)=ALPHA*DSQRT(4.D0*3.141592653589793/5.D0)
210 IF(MC.NE.1.OR.MP.NE.0) GO TO 211
    PAIR(JZ,JA)=PAIR(JZ,JA)-SHLL
    SHLL = 0.D0
211 CMASS=SMASS+SHLL
    XMS(JA,JZ)=CMASS
    AMAS(JZ,JA)=SMASS
    XMAS(JZ,JA)=CMASS
    SYMBS(JZ,JA)=FOR
    DELSHL(JZ,JA)=SHLL
    SHEL(JZ,JA,2)=SHLL
    IF(MP.EQ.2) PAIR(JZ,JA)=PAIR(JZ,JA)-SHLL
    XQ(JZ)=CMASS
215 CONTINUE
    IF(QVAL.EQ.0.D0.AND.PVAL.EQ.0.D0)GO TO 220
    GO TO 240
220 IF(ZP-20.D0)225,225,230
225 CONTINUE
    IZE=IDINT(ZP)
    INE=IDINT(AP-ZP)
    CALL MASS(IZE,INE,XQ(3),ER,IRET)
230 PVAL=XQ(2)+XQ(3)-XQ(1)
    Write(7,235)PVAL
235 FORMAT(/41X,' QVAL FROM MYERS SWIATECKI MASS FORMULA = ',F8.3)
    GO TO 25
240 DO 245 JZ=1,NZ
    DO 245 JA=1,NA
    SYMB(JZ,JA) = FOR
    BE(JZ,JA,1)=8.07+XMS(JA+1,JZ)-XMS(JA,JZ)
    BE(JZ,JA,2)=7.29+XMS(JA,JZ+1)-XMS(JA,JZ)
    BE(JZ,JA,4)=13.3+XMS(JA+1,JZ+1)-XMS(JA,JZ)
245 BE(JZ,JA,3)=2.42+XMS(JA+2,JZ+2)-XMS(JA,JZ)
    IF(IBIND.EQ.1) CALL BINDEN(ZEE,AMASS,NZ,NA,AP,AT,ZP,ZT,
   1   QVAL,M3,MP,MC,LDOPT)
     IF(QVAL.EQ.0.D0)Write(7,235)PVAL
    IF(QVAL.EQ.0.D0)QVAL=PVAL
    IF(MC.NE.2) GO TO 260
250 DO 255 IZ=1,NZ
```

```
      DO 255 IA=1,NA
      READ(5,*)BE1,BE2,BE3,BE4,PDEL
      IF(BE1.EQ.0.D0) GO TO 400
      BE(IZ,IA,1)=BE1
      BE(IZ,IA,2)=BE2
      BE(IZ,IA,3)=BE3
      BE(IZ,IA,4)=BE4
      SYMB(IZ,IA)=RINP
  400 IF(PDEL.EQ.0.D0) GO TO 255
      PAIR(IZ,IA)=PDEL
      SYMBP(IZ,IA)=RINP
  255 CONTINUE
      WRITE(7,275)
  260 Write(7,280)PARTIX(KPG+1)
13346 FORMAT(10X,'FORTH')
      DO 266 I1=1,NZ
      MZ=IDINT(ZEE)+1-I1
      DO 265 I2=1,NA
       MA=IDINT(AMASS)+2-I2-I1
      Write(7,285)MZ,MA,(BE(I1,I2,K),K=1,4),SYMB(I1,I2),
     1 PAIR(I1,I2),SYMBP(I1,I2),DELSHL(I1,I2),SYMBS(I1,I2)
     2,DEF(I2,I1)
      IF(MP.LE.0)PAIR(I1,I2)=0.D0
      PAIR(I1,I2)=10.*PAIR(I1,I2)
  265 CONTINUE
  266 CONTINUE
      WRITE(7,268)
      AAA=TAB
      AAB=ABE
  268 FORMAT (1H1)
      RETURN
  275 FORMAT (20X,'SOME BINDING ENERGIES OR LEVEL DENSITY GROUND ',
     1 'STATE SHIFTS PROVIDED BY USER')
  280 FORMAT (/30X,'BINDING ENERGIES AND LEVEL DENSITY GROUND ',
     1 'STATE SHIFTS USED'//22X,' IZ = Z-INDEX OF NUCLEUS,',
     2 ' IA = A-INDEX OF NUCLEUS IN PROGRAM ISOTOPE TABLE'/32X,
     3 'MSL = CALCULATED BY MYERS SWIATECKI LYSEKILL MASS FORMULA'/
     4 32X,'TAB = TAKEN FROM 1971 MASS TABLE'/32X,'INP = PROVIDED',
     5 ' BY USER'/32X,'ABE = ABSORBED IN BINDING ENERGY'//
     6 10X,'  IZ  IA     NEUTRON      PROTON      ALPHA     ',
     7 A8,'    SOURCE    GS SHIFT  SOURCE SHELL CORR   SOURCE',
     8  'DEFORMATION'/)
  285 FORMAT(10X,2I4,2X,4(F10.5,2X),3X,A4,2(3X,F10.5,3X,A4),2X,F8.3)
      END
*
*********************************************************************
*
      Subroutine MASS(MZ,N,EXCES,ERRR,IRET)
*     ------------------------------------
*
C     USING INDEX(Z*1000+N) FINDS MASS EXCESS(MEV) AND ITS ERROR(KEV)
C     FROM 1983 WAPSTRA ADJUSTMENTS AS PRESENTED IN THE ENSDF
C     DATA BASE AND RENDERED HERE BY W.P. TROWER 10FEB89.
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION ITABLE(2300),AMASS(2300),ERR(2300),
     * I1 (100),I2 (100),I3 (100),I4 (100),I5 (100),I6 (100),I7 (100),
     * I8 (100),I9 (100),I10(100),I11(100),I12(100),I13(100),I14(100),
     * I15(100),I16(100),I17(100),I18(100),I19(100),I20(100),I21(100),
     * I22(100),I23(100),
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* A1 (100),A2 (100),A3 (100),A4 (100),A5 (100),A6 (100),A7 (100),
* A8 (100),A9 (100),A10(100),A11(100),A12(100),A13(100),A14(100),
* A15(100),A16(100),A17(100),A18(100),A19(100),A20(100),A21(100),
* A22(100),A23(100),
* E1 (100),E2 (100),E3 (100),E4 (100),E5 (100),E6 (100),E7 (100),
* E8 (100),E9 (100),E10(100),E11(100),E12(100),E13(100),E14(100),
* E15(100),E16(100),E17(100),E18(100),E19(100),E20(100),E21(100),
* E22(100),E23(100)
 EQUIVALENCE          (I1 (1),ITABLE(   1)),(I2 (1),ITABLE( 101)),
*(I3 (1),ITABLE(201 )),(I4 (1),ITABLE( 301)),(I5 (1),ITABLE( 401)),
*(I6 (1),ITABLE( 501)),(I7 (1),ITABLE( 601)),(I8 (1),ITABLE( 701)),
*(I9 (1),ITABLE( 801)),(I10(1),ITABLE( 901)),(I11(1),ITABLE(1001)),
*(I12(1),ITABLE(1101)),(I13(1),ITABLE(1201)),(I14(1),ITABLE(1301)),
*(I15(1),ITABLE(1401)),(I16(1),ITABLE(1501)),(I17(1),ITABLE(1601)),
*(I18(1),ITABLE(1701)),(I19(1),ITABLE(1801)),(I20(1),ITABLE(1901)),
*(I21(1),ITABLE(2001)),(I22(1),ITABLE(2101)),(I23(1),ITABLE(2201))
 EQUIVALENCE          (A1 (1),AMASS(   1)),(A2 (1),AMASS( 101)),
*(A3 (1),AMASS( 201)),(A4 (1),AMASS( 301)),(A5 (1),AMASS( 401)),
*(A6 (1),AMASS( 501)),(A7 (1),AMASS( 601)),(A8 (1),AMASS( 701)),
*(A9 (1),AMASS( 801)),(A10(1),AMASS( 901)),(A11(1),AMASS(1001)),
*(A12(1),AMASS(1101)),(A13(1),AMASS(1201)),(A14(1),AMASS(1301)),
*(A15(1),AMASS(1401)),(A16(1),AMASS(1501)),(A17(1),AMASS(1601)),
*(A18(1),AMASS(1701)),(A19(1),AMASS(1801)),(A20(1),AMASS(1901)),
*(A21(1),AMASS(2001)),(A22(1),AMASS(2101)),(A23(1),AMASS(2201))
 EQUIVALENCE        (E1 (1),ERR(   1)),(E2 (1),ERR( 101)),
*(E3 (1),ERR( 201)),(E4 (1),ERR( 301)),(E5 (1),ERR( 401)),
*(E6 (1),ERR( 501)),(E7 (1),ERR( 601)),(E8 (1),ERR( 701)),
*(E9 (1),ERR( 801)),(E10(1),ERR( 901)),(E11(1),ERR(1001)),
*(E12(1),ERR(1101)),(E13(1),ERR(1201)),(E14(1),ERR(1301)),
*(E15(1),ERR(1401)),(E16(1),ERR(1501)),(E17(1),ERR(1601)),
*(E18(1),ERR(1701)),(E19(1),ERR(1801)),(E20(1),ERR(1901)),
*(E21(1),ERR(2001)),(E22(1),ERR(2101)),(E23(1),ERR(2201))
 DATA NT/2213/
 DATA I1/
*      -999,         0,       999,         1,         4,      1000,
*      1001,      1002,      1003,      2001,      2002,      2003,
*      2004,      2005,      2006,      2007,      3001,      3002,
*      3003,      3004,      3005,      3006,      3007,      3008,
*      4002,      4003,      4004,      4005,      4006,      4007,
*      4008,      4009,      4010,      5002,      5003,      5004,
*      5005,      5006,      5007,      5008,      5009,      5010,
*      5011,      5012,      6002,      6003,      6004,      6005,
*      6006,      6007,      6008,      6009,      6010,      6011,
*      6012,      6013,      6014,      7003,      7004,      7005,
*      7006,      7007,      7008,      7009,      7010,      7011,
*      7012,      7013,      7014,      8004,      8005,      8006,
*      8007,      8008,      8009,      8010,      8011,      8012,
*      8013,      8014,      8015,      9005,      9006,      9007,
*      9008,      9009,      9010,      9011,      9012,      9013,
*      9014,      9015,      9016,     10006,     10007,     10008,
*     10009,     10010,     10011,     10012/
 DATA I2/
*     10013,     10014,     10015,     10016,     10017,     11007,
*     11008,     11009,     11010,     11011,     11012,     11013,
*     11014,     11015,     11016,     11017,     11018,     11019,
*     11020,     11021,     11022,     11023,     12008,     12009,
*     12010,     12011,     12012,     12013,     12014,     12015,
*     12016,     12017,     12018,     12019,     12020,     12021,
*     12022,     12023,     13009,     13010,     13011,     13012,
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*     13013,     13014,     13015,     13016,     13017,     13018,
*     13019,     13020,     13021,     13022,     13023,     14010,
*     14011,     14012,     14013,     14014,     14015,     14016,
*     14017,     14018,     14019,     14020,     14021,     14022,
*     14023,     14024,     15011,     15012,     15013,     15014,
*     15015,     15016,     15017,     15018,     15019,     15020,
*     15021,     15022,     15023,     15024,     15025,     16012,
*     16013,     16014,     16015,     16016,     16017,     16018,
*     16019,     16020,     16021,     16022,     16023,     16024,
*     16025,     16026,     17013,     17014/
 DATA I3/
*     17015,     17016,     17017,     17018,     17019,     17020,
*     17021,     17022,     17023,     17024,     17025,     17026,
*     17027,     18014,     18015,     18016,     18017,     18018,
*     18019,     18020,     18021,     18022,     18023,     18024,
*     18025,     18026,     18027,     18028,     19015,     19016,
*     19017,     19018,     19019,     19020,     19021,     19022,
*     19023,     19024,     19025,     19026,     19027,     19028,
*     19029,     19030,     20016,     20017,     20018,     20019,
*     20020,     20021,     20022,     20023,     20024,     20025,
*     20026,     20027,     20028,     20029,     20030,     20031,
*     21017,     21018,     21019,     21020,     21021,     21022,
*     21023,     21024,     21025,     21026,     21027,     21028,
*     21029,     21030,     21031,     22018,     22019,     22020,

*     22021,     22022,     22023,     22024,     22025,     22026,
*     22027,     22028,     22029,     22030,     22031,     22032,
*     23019,     23020,     23021,     23022,     23023,     23024,
*     23025,     23026,     23027,     23028/
 DATA I4/
*     23029,     23030,     23031,     23032,     23033,     24020,
*     24021,     24022,     24023,     24024,     24025,     24026,
*     24027,     24028,     24029,     24030,     24031,     24032,

*     24033,     24034,     25021,     25022,     25023,     25024,
*     25025,     25026,     25027,     25028,     25029,     25030,
*     25031,     25032,     25033,     25034,     25035,     26023,
*     26024,     26025,     26026,     26027,     26028,     26029,
*     26030,     26031,     26032,     26033,     26034,     26035,
*     26036,     26037,     27024,     27025,     27026,     27027,
*     27028,     27029,     27030,     27031,     27032,     27033,
*     27034,     27035,     27036,     27037,     27038,     28025,
*     28026,     28027,     28028,     28029,     28030,     28031,
*     28032,     28033,     28034,     28035,     28036,     28037,
*     28038,     28039,     28040,     28041,     29026,     29027,
*     29028,     29029,     29030,     29031,     29032,     29033,
*     29034,     29035,     29036,     29037,     29038,     29039,
*     29040,     29041,     29042,     30027/
 DATA I5/
*     30028,     30029,     30030,     30031,     30032,     30033,
*     30034,     30035,     30036,     30037,     30038,     30039,
*     30040,     30041,     30042,     30043,     30044,     30045,
*     30046,     30047,     30048,     31030,     31031,     31032,
*     31033,     31034,     31035,     31036,     31037,     31038,
*     31039,     31040,     31041,     31042,     31043,     31044,
*     31045,     31046,     31047,     31048,     31049,     31050,
*     32031,     32032,     32033,     32034,     32035,     32036,
*     32037,     32038,     32039,     32040,     32041,     32042,
*     32043,     32044,     32045,     32046,     32047,     32048,
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*     32049,     32050,     32051,     33032,     33033,     33034,
*     33035,     33036,     33037,     33038,     33039,     33040,
*     33041,     33042,     33043,     33044,     33045,     33046,
*     33047,     33048,     33049,     33050,     33051,     33052,
*     34033,     34034,     34035,     34036,     34037,     34038,
*     34039,     34040,     34041,     34042,     34043,     34044,
*     34045,     34046,     34047,     34048/
 DATA I6/
*     34049,     34050,     34051,     34052,     34053,     35034,
*     35035,     35036,     35037,     35038,     35039,     35040,
*     35041,     35042,     35043,     35044,     35045,     35046,
*     35047,     35048,     35049,     35050,     35051,     35052,
*     35053,     35054,     35055,     36035,     36036,     36037,
*     36038,     36039,     36040,     36041,     36042,     36043,
*     36044,     36045,     36046,     36047,     36048,     36049,
*     36050,     36051,     36052,     36053,     36054,     36055,
*     36056,     36057,     37036,     37037,     37038,     37039,
*     37040,     37041,     37042,     37043,     37044,     37045,
*     37046,     37047,     37048,     37049,     37050,     37051,
*     37052,     37053,     37054,     37055,     37056,     37057,
*     37058,     37059,     37060,     37061,     37062,     38039,
*     38040,     38041,     38042,     38043,     38044,     38045,
*     38046,     38047,     38048,     38049,     38050,     38051,
*     38052,     38053,     38054,     38055,     38056,     38057,
*     38058,     38059,     38060,     38061/
 DATA I7/
*     38062,     39040,     39041,     39042,     39043,     39044,
*     39045,     39046,     39047,     39048,     39049,     39050,
*     39051,     39052,     39053,     39054,     39055,     39056,
*     39057,     39058,     39059,     39060,     39061,     39062,
*     40041,     40042,     40043,     40044,     40045,     40046,
*     40047,     40048,     40049,     40050,     40051,     40052,
*     40053,     40054,     40055,     40056,     40057,     40058,
*     40059,     40060,     40061,     40062,     40063,     41044,
*     41045,     41046,     41047,     41048,     41049,     41050,
*     41051,     41052,     41053,     41054,     41055,     41056,
*     41057,     41058,     41059,     41060,     41061,     41062,
*     41063,     41064,     42045,     42046,     42047,     42048,
*     42049,     42050,     42051,     42052,     42053,     42054,
*     42055,     42056,     42057,     42058,     42059,     42060,
*     42061,     42062,     42063,     42064,     42065,     43046,
*     43047,     43048,     43049,     43050,     43051,     43052,
*     43053,     43054,     43055,     43056/
 DATA I8/
*     43057,     43058,     43059,     43060,     43061,     43062,
*     43063,     43064,     43065,     43066,     44047,     44048,
*     44049,     44050,     44051,     44052,     44053,     44054,
*     44055,     44056,     44057,     44058,     44059,     44060,
*     44061,     44062,     44063,     44064,     44065,     44066,
*     44067,     45048,     45049,     45050,     45051,     45052,
*     45053,     45054,     45055,     45056,     45057,     45058,
*     45059,     45060,     45061,     45062,     45063,     45064,
*     45065,     45066,     45067,     45068,     46049,     46050,
*     46051,     46052,     46053,     46054,     46055,     46056,
*     46057,     46058,     46059,     46060,     46061,     46062,
*     46063,     46064,     46065,     46066,     46067,     46068,
*     46069,     46070,     47050,     47051,     47052,     47053,
*     47054,     47055,     47056,     47057,     47058,     47059,
*     47060,     47061,     47062,     47063,     47064,     47065,
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*     47066,     47067,     47068,     47069,     47070,     47071,
*     47072,     47073,     47074,     48051/
 DATA I9/
*     48052,     48053,     48054,     48055,     48056,     48057,
*     48058,     48059,     48060,     48061,     48062,     48063,
*     48064,     48065,     48066,     48067,     48068,     48069,
*     48070,     48071,     48072,     48073,     48074,     48075,
*     49052,     49053,     49054,     49055,     49056,     49057,
*     49058,     49059,     49060,     49061,     49062,     49063,
*     49064,     49065,     49066,     49067,     49068,     49069,
*     49070,     49071,     49072,     49073,     49074,     49075,
*     49076,     49077,     49078,     49079,     49080,     49081,
*     49082,     50052,     50053,     50054,     50055,     50056,
*     50057,     50058,     50059,     50060,     50061,     50062,
*     50063,     50064,     50065,     50066,     50067,     50068,
*     50069,     50070,     50071,     50072,     50073,     50074,
*     50075,     50076,     50077,     50078,     50079,     50080,
*     50081,     50082,     50083,     51053,     51054,     51055,
*     51056,     51057,     51058,     51059,     51060,     51061,
*     51062,     51063,     51064,     51065/
 DATA I10/
*     51066,     51067,     51068,     51069,     51070,     51071,
*     51072,     51073,     51074,     51075,     51076,     51077,
*     51078,     51079,     51080,     51081,     51082,     51083,
*     51084,     52054,     52055,     52056,     52057,     52058,
*     52059,     52060,     52061,     52062,     52063,     52064,
*     52065,     52066,     52067,     52068,     52069,     52070,
*     52071,     52072,     52073,     52074,     52075,     52076,
*     52077,     52078,     52079,     52080,     52081,     52082,
*     52083,     52084,     52085,     53055,     53056,     53057,
*     53058,     53059,     53060,     53061,     53062,     53063,
*     53064,     53065,     53066,     53067,     53068,     53069,
*     53070,     53071,     53072,     53073,     53074,     53075,
*     53076,     53077,     53078,     53079,     53080,     53081,
*     53082,     53083,     53084,     53085,     53086,     54056,
*     54057,     54058,     54059,     54060,     54061,     54062,
*     54063,     54064,     54065,     54066,     54067,     54068,
*     54069,     54070,     54071,     54072/
 DATA I11/
*     54073,     54074,     54075,     54076,     54077,     54078,
*     54079,     54080,     54081,     54082,     54083,     54084,
*     54085,     54086,     54087,     54088,     55058,     55059,
*     55060,     55061,     55062,     55063,     55064,     55065,
*     55066,     55067,     55068,     55069,     55070,     55071,
*     55072,     55073,     55074,     55075,     55076,     55077,
*     55078,     55079,     55080,     55081,     55082,     55083,
*     55084,     55085,     55086,     55087,     55088,     55089,
*     55090,     55091,     55092,     55093,     56061,     56062,
*     56063,     56064,     56065,     56066,     56067,     56068,
*     56069,     56070,     56071,     56072,     56073,     56074,
*     56075,     56076,     56077,     56078,     56079,     56080,
*     56081,     56082,     56083,     56084,     56085,     56086,
*     56087,     56088,     56089,     56090,     56091,     56092,
*     56093,     57070,     57071,     57072,     57073,     57074,
*     57075,     57076,     57077,     57078,     57079,     57080,

*     57081,     57082,     57083,     57084/
 DATA I12/
*     57085,     57086,     57087,     57088,     57089,     57090,
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*     57091,     57092,     57093,     58072,     58073,     58074,
*     58075,     58076,     58077,     58078,     58079,     58080,
*     58081,     58082,     58083,     58084,     58085,     58086,
*     58087,     58088,     58089,     58090,     58091,     58092,
*     58093,     59073,     59074,     59075,     59076,     59077,
*     59078,     59079,     59080,     59081,     59082,     59083,
*     59084,     59085,     59086,     59087,     59088,     59089,
*     59090,     59091,     59092,     59093,     60074,     60075,
*     60076,     60077,     60078,     60079,     60080,     60081,
*     60082,     60083,     60084,     60085,     60086,     60087,
*     60088,     60089,     60090,     60091,     60092,     60093,
*     60094,     61075,     61076,     61077,     61078,     61079,
*     61080,     61081,     61082,     61083,     61084,     61085,
*     61086,     61087,     61088,     61089,     61090,     61091,
*     61092,     61093,     61094,     61095,     62076,     62077,
*     62078,     62079,     62080,     62081/
 DATA I13/
*     62082,     62083,     62084,     62085,     62086,     62087,
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*-39.21    ,-45.33    ,-53.902   ,-56.0774  ,-60.2251  ,-61.1536  ,
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*-77.499   ,-79.011   ,-77.778   ,-78.607   ,-75.64    ,-73.88    ,
*-70.72    ,-68.42    ,-64.26    ,-46.49    ,-53.97    ,-56.89    ,
*-62.14    ,-64.246   ,-68.969   ,-70.227   ,-74.151   ,-74.442   ,
*-77.892   ,-77.697   ,-80.591   ,-79.983   ,-82.431   ,-81.477   ,
*-83.262   ,-80.706   ,-79.687   ,-76.72    ,-74.96    ,-71.37    ,
*-68.68    ,-64.15    ,-46.59    ,-51.75    ,-57.28    ,-60.58    ,

*-64.95    ,-66.98    ,-70.837   ,-72.173   ,-75.461   ,-76.202   ,
*-79.044   ,-79.746   ,-82.1644  ,-82.7434  ,-84.5923  ,-82.6     ,
*-81.713   ,-79.353   ,-77.794   ,-74.836   ,-72.679   ,-68.529   ,
*-65.808   ,-61.14    ,-58.28    ,-54.06    ,-50.86    ,-57.89    ,
*-63.65    ,-65.34    ,-70.19    ,-71.47    ,-75.997   ,-76.788   ,
*-80.64    ,-81.099   ,-84.5177  ,-84.8746  ,-87.9162  ,-86.21    ,
*-85.942   ,-83.661   ,-82.956   ,-80.121   ,-78.836   ,-75.09    ,
*-72.89    ,-68.8     ,-66.49    ,-62.18/
 DATA A7/
*-60.02    ,-58.24    ,-61.19    ,-65.95    ,-68.18    ,-72.38    ,
*-74.23    ,-77.839   ,-79.278   ,-83.0136  ,-84.294   ,-87.7022  ,
*-86.4881  ,-86.347   ,-84.844   ,-84.235   ,-82.348   ,-81.214   ,
*-78.3     ,-76.27    ,-72.37    ,-70.13    ,-66.72    ,-64.38    ,
*-58.79    ,-64.18    ,-66.36    ,-71.43    ,-73.15    ,-77.98    ,
*-79.348   ,-83.626   ,-84.869   ,-88.7697  ,-87.8928  ,-88.4566  ,
*-87.1193  ,-87.2679  ,-85.6593  ,-85.442   ,-82.95    ,-81.288   ,
*-77.74    ,-76.62    ,-73.1     ,-71.76    ,-67.61    ,-66.74    ,
*-69.58    ,-74.18    ,-76.43    ,-80.622   ,-82.659   ,-86.638   ,
*-86.4507  ,-87.2098  ,-86.3679  ,-86.7836  ,-85.605   ,-85.6083  ,
*-83.528   ,-82.327   ,-79.95    ,-78.88    ,-76.35    ,-75.11    ,
*-71.78    ,-70.14    ,-67.44    ,-72.83    ,-75.004   ,-80.172   ,
*-82.2     ,-86.808   ,-86.804   ,-88.4132  ,-87.7092  ,-88.7921  ,
*-87.5421  ,-88.1132  ,-85.9674  ,-86.186   ,-83.513   ,-83.559   ,
*-80.61    ,-80.48    ,-77.14    ,-76.43    ,-72.51    ,-68.      ,
*-70.97    ,-75.98    ,-78.938   ,-83.606   ,-84.157   ,-86.018   ,
*-85.819   ,-87.222   ,-86.429   ,-87.3244/
 DATA A8/
*-86.0174  ,-86.325   ,-84.573   ,-84.606   ,-82.48    ,-82.14    ,
*-79.63    ,-78.96    ,-75.99    ,-74.91    ,-68.4     ,-74.41    ,
*-77.27    ,-82.567   ,-83.449   ,-86.071   ,-86.111   ,-88.225   ,
*-87.618   ,-89.2199  ,-87.9506  ,-89.0995  ,-87.2606  ,-88.098   ,
*-85.937   ,-86.33    ,-83.71    ,-83.7     ,-80.81    ,-80.34    ,
*-76.92    ,-69.11    ,-72.97    ,-78.34    ,-79.63    ,-82.6     ,
*-83.168   ,-85.519   ,-85.59    ,-87.413   ,-86.803   ,-88.027   ,
*-86.954   ,-87.853   ,-86.37    ,-86.862   ,-85.09    ,-85.014   ,
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*-82.94    ,-82.32    ,-79.73    ,-78.84    ,-70.15    ,-76.37    ,
*-77.8     ,-81.299   ,-82.192   ,-85.207   ,-85.431   ,-87.902   ,
*-87.455   ,-89.397   ,-88.419   ,-89.91    ,-88.374   ,-89.522   ,
*-87.604   ,-88.337   ,-86.02    ,-86.329   ,-83.68    ,-83.54    ,
*-80.49    ,-80.11    ,-70.9     ,-73.07    ,-76.76    ,-78.12    ,
*-81.22    ,-82.02    ,-84.78    ,-85.118   ,-87.076   ,-86.944   ,
*-88.407   ,-87.605   ,-88.72    ,-87.458   ,-88.218   ,-86.623   ,
*-87.041   ,-84.99    ,-84.95    ,-82.72    ,-82.25    ,-79.58    ,
*-78.59    ,-75.77    ,-74.55    ,-69.99/
 DATA A9/
*-74.31    ,-75.69    ,-79.7     ,-80.62    ,-83.974   ,-84.339   ,
*-87.132   ,-86.99    ,-89.26    ,-88.536   ,-90.351   ,-89.255   ,
*-90.5823  ,-89.0511  ,-90.0229  ,-88.0924  ,-88.721   ,-86.417   ,
*-86.71    ,-83.94    ,-83.973   ,-80.95    ,-80.58    ,-77.32    ,
*-68.41    ,-70.42    ,-74.42    ,-75.97    ,-79.589   ,-80.59    ,
*-83.57    ,-84.135   ,-86.505   ,-86.41    ,-88.391   ,-87.994   ,
*-89.367   ,-88.57    ,-89.534   ,-88.247   ,-88.943   ,-87.45    ,
*-87.73    ,-85.8     ,-85.84    ,-83.58    ,-83.42    ,-81.06    ,
*-80.42    ,-77.81    ,-77.01    ,-74.      ,-73.03    ,-69.99    ,
*-68.55    ,-64.8     ,-66.92    ,-71.47    ,-73.27    ,-77.29    ,
*-78.37    ,-82.09    ,-82.63    ,-85.83    ,-85.939   ,-88.654   ,
*-88.328   ,-90.557   ,-90.032   ,-91.523   ,-90.3964  ,-91.6516  ,
*-90.0657  ,-91.1017  ,-89.2018  ,-89.9454  ,-87.8202  ,-88.2371  ,
*-85.8982  ,-86.021   ,-83.504   ,-83.31    ,-80.63    ,-80.19    ,
*-77.37    ,-76.61    ,-69.99    ,-59.27    ,-64.09    ,-66.49    ,
*-70.67    ,-72.53    ,-76.25    ,-77.53    ,-80.84    ,-81.589   ,
*-84.421   ,-84.67    ,-87.002   ,-86.816/
 DATA A10/
*-88.641   ,-87.995   ,-89.472   ,-88.421   ,-89.5907  ,-88.3259  ,
*-89.2229  ,-87.619   ,-88.258   ,-86.4     ,-86.705   ,-84.6     ,
*-84.631   ,-82.36    ,-82.02    ,-79.73    ,-79.04    ,-74.      ,
*-70.31    ,-58.05    ,-60.51    ,-65.62    ,-67.65    ,-72.14    ,
*-73.47    ,-77.3     ,-78.32    ,-81.76    ,-82.25    ,-85.28    ,
*-85.11    ,-87.647   ,-87.178   ,-89.38    ,-88.542   ,-90.309   ,
*-89.1717  ,-90.5252  ,-89.025   ,-90.0673  ,-88.286   ,-88.993   ,
*-87.008   ,-87.348   ,-85.206   ,-85.217   ,-82.99    ,-82.41    ,
*-77.85    ,-74.41    ,-69.48    ,-52.55    ,-57.76    ,-60.49    ,
*-64.97    ,-67.12    ,-71.12    ,-72.86    ,-76.3     ,-77.52    ,
*-80.61    ,-81.25    ,-83.81    ,-83.98    ,-86.263   ,-86.075   ,
*-87.939   ,-87.368   ,-88.8468  ,-87.912   ,-88.984   ,-87.738   ,
*-88.506   ,-86.897   ,-87.455   ,-85.71    ,-85.91    ,-83.97    ,
*-83.813   ,-79.51    ,-76.5     ,-72.31    ,-68.88    ,-51.75    ,
*-54.38    ,-59.88    ,-62.13    ,-66.91    ,-68.67    ,-73.02    ,
*-74.29    ,-78.05    ,-78.82    ,-82.03    ,-82.49    ,-85.54    ,
*-85.261   ,-87.6596  ,-87.1915  ,-89.162/
 DATA A11/
*-88.323   ,-89.8608  ,-88.6974  ,-89.8811  ,-88.426   ,-89.29    ,
*-87.665   ,-88.125   ,-86.509   ,-86.431   ,-82.385   ,-80.13    ,
*-75.7     ,-73.02    ,-68.36    ,-65.55    ,-51.61    ,-54.71    ,
*-59.55    ,-62.3     ,-66.23    ,-68.24    ,-72.2     ,-73.77    ,
*-77.09    ,-78.16    ,-81.05    ,-81.72    ,-84.092   ,-84.334   ,
*-86.231   ,-85.926   ,-87.536   ,-86.859   ,-88.079   ,-87.16    ,
*-88.093   ,-86.913   ,-87.668   ,-86.361   ,-86.561   ,-82.9     ,
*-80.715   ,-77.076   ,-74.515   ,-70.59    ,-67.79    ,-63.41    ,
*-60.24    ,-55.69    ,-52.38    ,-47.59    ,-56.93    ,-61.95    ,
*-63.96    ,-68.47    ,-70.14    ,-74.36    ,-75.26    ,-78.82    ,
*-79.51    ,-82.66    ,-82.78    ,-85.478   ,-85.1     ,-87.299   ,
*-86.721   ,-88.453   ,-87.572   ,-88.972   ,-87.873   ,-88.909   ,
*-87.736   ,-88.276   ,-84.928   ,-83.294   ,-79.771   ,-77.91    ,
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*-74.07    ,-71.87    ,-68.04    ,-65.1     ,-61.26    ,-58.51    ,
*-53.39    ,-77.98    ,-78.88    ,-81.38    ,-81.6     ,-83.76    ,
*-83.74    ,-85.57    ,-85.27    ,-86.673   ,-86.04    ,-87.13    ,
*-86.531   ,-87.238   ,-84.328   ,-83./
 DATA A12/
*-80.025   ,-78.32    ,-74.85    ,-72.99    ,-69.37    ,-66.97    ,
*-63.91    ,-61.19    ,-57.89    ,-79.4     ,-79.86    ,-82.44    ,
*-82.57    ,-84.87    ,-84.657   ,-86.5     ,-85.91    ,-87.575   ,
*-86.973   ,-88.089   ,-85.446   ,-84.542   ,-81.615   ,-80.442   ,
*-77.1     ,-75.76    ,-72.16    ,-70.41    ,-67.29    ,-65.51    ,
*-62.26    ,-75.34    ,-78.07    ,-78.77    ,-80.91    ,-81.38    ,
*-83.2     ,-83.138   ,-84.844   ,-84.701   ,-86.027   ,-83.799   ,
*-83.077   ,-80.76    ,-79.636   ,-76.78    ,-75.47    ,-72.46    ,
*-70.988   ,-68.59    ,-67.16    ,-64.56    ,-75.57    ,-76.21    ,
*-79.17    ,-79.4     ,-82.14    ,-82.04    ,-84.481   ,-84.213   ,
*-85.959   ,-84.012   ,-83.757   ,-81.441   ,-80.935   ,-78.156   ,
*-77.418   ,-74.385   ,-73.694   ,-70.957   ,-70.16    ,-67.37    ,
*-65.77    ,-71.28    ,-74.1     ,-75.14    ,-77.52    ,-78.41    ,
*-80.48    ,-81.07    ,-82.969   ,-81.424   ,-81.28    ,-79.45    ,
*-79.052   ,-76.874   ,-76.074   ,-73.607   ,-73.4     ,-71.27    ,
*-70.669   ,-68.47    ,-67.1     ,-64.48    ,-71.34    ,-72.09    ,
*-75.41    ,-75.942   ,-78.986   ,-79.526/
 DATA A13/
*-81.974   ,-80.66    ,-80.992   ,-79.276   ,-79.346   ,-77.147   ,
*-77.061   ,-74.587   ,-74.773   ,-72.569   ,-72.466   ,-70.202   ,
*-69.38    ,-66.87    ,-65.2     ,-67.21    ,-69.98    ,-71.59    ,
*-74.38    ,-75.645   ,-77.998   ,-77.114   ,-77.555   ,-76.266   ,
*-76.452   ,-74.798   ,-74.663   ,-72.897   ,-73.379   ,-71.749   ,
*-71.829   ,-70.094   ,-69.473   ,-67.25    ,-66.059   ,-63.45    ,
*-67.19    ,-68.48    ,-71.94    ,-72.95    ,-76.1     ,-75.505   ,
*-76.278   ,-75.131   ,-75.766   ,-74.198   ,-74.719   ,-72.895   ,
*-73.718   ,-72.082   ,-72.547   ,-70.835   ,-70.702   ,-68.573   ,
*-67.954   ,-65.518   ,-64.26    ,-62.94    ,-66.2     ,-67.86    ,
*-70.96    ,-70.67    ,-71.495   ,-71.102   ,-71.632   ,-70.869   ,
*-71.316   ,-70.16    ,-71.26    ,-70.103   ,-70.773   ,-69.48    ,
*-69.544   ,-67.848   ,-67.473   ,-65.66    ,-64.69    ,-62.12    ,
*-62.86    ,-64.57    ,-67.98    ,-67.89    ,-69.325   ,-68.902   ,
*-70.127   ,-69.146   ,-70.395   ,-69.166   ,-70.536   ,-69.434   ,
*-70.419   ,-69.178   ,-69.683   ,-68.065   ,-68.19    ,-66.39    ,
*-65.977   ,-63.622   ,-62.594   ,-59.94/
 DATA A14/
*-58.37    ,-61.85    ,-62.22    ,-63.803   ,-63.74    ,-65.023   ,
*-64.637   ,-66.064   ,-65.54    ,-66.89    ,-66.2     ,-67.342   ,
*-66.397   ,-67.208   ,-66.051   ,-66.387   ,-64.939   ,-64.908   ,
*-63.081   ,-62.292   ,-60.28    ,-58.806   ,-56.25    ,-58.02    ,
*-58.5     ,-60.62    ,-60.67    ,-62.623   ,-62.36    ,-64.      ,
*-63.42    ,-65.2     ,-64.573   ,-66.063   ,-65.209   ,-66.347   ,
*-65.177   ,-65.952   ,-64.531   ,-64.935   ,-63.299   ,-62.999   ,
*-60.931   ,-60.118   ,-57.728   ,-56.493   ,-53.77    ,-51.      ,
*-51.74    ,-54.18    ,-54.63    ,-56.81    ,-56.97    ,-58.79    ,
*-58.7     ,-60.57    ,-60.46    ,-62.01    ,-61.56    ,-62.738   ,
*-61.99    ,-62.939   ,-61.888   ,-62.552   ,-61.321   ,-61.282   ,
*-59.804   ,-59.219   ,-57.383   ,-56.267   ,-53.86    ,-52.3     ,
*-49.6     ,-46.32    ,-47.27    ,-50.12    ,-50.74    ,-53.38    ,
*-53.62    ,-56.023   ,-55.93    ,-58.06    ,-57.81    ,-59.75    ,
*-59.37    ,-60.99    ,-60.176   ,-61.595   ,-60.598   ,-61.578   ,
*-60.374   ,-60.772   ,-59.315   ,-59.264   ,-57.56    ,-56.953   ,
*-54.704   ,-53.502   ,-50.997   ,-49.706/
 DATA A15/
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*-38.38    ,-39.63    ,-42.77    ,-43.72    ,-46.63    ,-47.24    ,
*-49.85    ,-50.26    ,-52.51    ,-52.66    ,-54.74    ,-54.69    ,
*-56.38    ,-56.12    ,-57.47    ,-57.11    ,-58.081   ,-57.332   ,
*-57.836   ,-56.743   ,-56.887   ,-55.577   ,-55.173   ,-53.3946  ,
*-52.3954  ,-50.336   ,-49.13    ,-46.69    ,-32.82    ,-34.44    ,
*-37.86    ,-38.96    ,-42.3     ,-43.09    ,-46.06    ,-46.48    ,
*-49.179   ,-49.39    ,-51.79    ,-51.65    ,-53.79    ,-53.47    ,
*-55.21    ,-54.73    ,-56.13    ,-55.44    ,-56.39    ,-55.29    ,
*-55.849   ,-54.486   ,-54.581   ,-52.8932  ,-52.4474  ,-50.476   ,
*-49.7928  ,-47.4171  ,-46.063   ,-43.29    ,-41.5     ,-25.92    ,
*-29.58    ,-31.      ,-34.6     ,-35.74    ,-38.92    ,-39.91    ,
*-42.69    ,-43.44    ,-45.88    ,-46.31    ,-48.37    ,-48.61    ,
*-50.28    ,-50.33    ,-51.54    ,-51.47    ,-52.49    ,-51.85    ,
*-52.49    ,-51.48    ,-51.735   ,-50.54    ,-50.366   ,-48.94    ,
*-48.445   ,-46.437   ,-45.299   ,-42.844   ,-41.403   ,-38.62    ,
*-23.78    ,-25.55    ,-29.36    ,-30.61    ,-34.2     ,-35.15    ,
*-38.36    ,-39.02    ,-41.899   ,-42.37/
 DATA A16/
*-44.91    ,-45.02    ,-47.24    ,-47.24    ,-48.97    ,-48.71    ,
*-50.15    ,-49.59    ,-50.68    ,-49.73    ,-50.45    ,-49.307   ,
*-49.648   ,-48.259   ,-48.25    ,-46.37    ,-45.71    ,-43.393   ,
*-42.517   ,-39.912   ,-38.676   ,-35.49    ,-34.27    ,-20.71    ,
*-22.3     ,-26.11    ,-27.39    ,-30.84    ,-31.91    ,-34.85    ,
*-35.82    ,-38.45    ,-39.09    ,-41.34    ,-41.68    ,-43.56    ,
*-43.61    ,-45.24    ,-45.18    ,-46.23    ,-45.79    ,-46.62    ,
*-45.85    ,-46.56    ,-45.45    ,-45.814   ,-44.218   ,-43.826   ,
*-41.933   ,-41.224   ,-39.025   ,-37.987   ,-35.54    ,-34.361   ,
*-31.79    ,-16.45    ,-20.46    ,-21.87    ,-25.64    ,-26.74    ,
*-30.11    ,-30.88    ,-33.934   ,-34.57    ,-37.26    ,-37.54    ,
*-39.95    ,-40.07    ,-42.03    ,-41.93    ,-43.55    ,-43.01    ,
*-44.35    ,-43.53    ,-44.6     ,-43.51    ,-44.257   ,-42.811   ,
*-43.007   ,-41.227   ,-41.145   ,-38.995   ,-38.717   ,-36.403   ,
*-35.893   ,-33.406   ,-32.441   ,-29.7     ,-28.3     ,-13.17    ,
*-17.14    ,-18.56    ,-22.14    ,-23.32    ,-26.36    ,-27.43    ,
*-30.22    ,-31.06    ,-33.4     ,-34.02/
 DATA A17/
*-36.      ,-36.29    ,-38.02    ,-37.95    ,-39.46    ,-39.15    ,
*-40.32    ,-39.54    ,-40.31    ,-39.176   ,-39.73    ,-38.35    ,
*-38.46    ,-36.72    ,-36.716   ,-34.857   ,-34.543   ,-32.538   ,
*-31.702   ,-29.46    ,-28.29    ,-25.93    ,-11.15    ,-12.6     ,
*-16.51    ,-17.71    ,-21.22    ,-22.1     ,-25.326   ,-25.96    ,
*-28.94    ,-29.47    ,-31.95    ,-32.35    ,-34.35    ,-34.38    ,
*-36.18    ,-35.74    ,-37.33    ,-36.61    ,-37.85    ,-36.83    ,
*-37.832   ,-36.499   ,-37.338   ,-35.71    ,-36.311   ,-34.487   ,
*-34.787   ,-32.821   ,-32.671   ,-30.446   ,-29.93    ,-27.43    ,
*-26.625   ,-23.75    ,-12.84    ,-14.21    ,-17.34    ,-18.57    ,
*-21.5     ,-22.58    ,-24.99    ,-25.8     ,-27.83    ,-28.33    ,
*-30.13    ,-30.24    ,-31.85    ,-31.58    ,-33.11    ,-32.53    ,
*-33.8     ,-32.896   ,-33.88    ,-32.796   ,-33.49    ,-32.278   ,
*-32.591   ,-31.165   ,-31.165   ,-29.606   ,-29.119   ,-27.32    ,
*-26.413   ,-24.37    ,-23.153   ,-20.22    , -8.27    ,-11.89    ,
*-12.94    ,-16.323   ,-17.11    ,-20.26    ,-20.76    ,-23.52    ,
*-23.89    ,-26.26    ,-26.17    ,-28.55/
 DATA A18/
*-28.17    ,-30.2     ,-29.6     ,-31.3     ,-30.54    ,-32.      ,
*-31.15    ,-32.238   ,-31.07    ,-31.851   ,-30.565   ,-30.979   ,
*-29.571   ,-29.529   ,-27.687   ,-27.37    ,-25.292   ,-24.716   ,
*-22.312   ,-20.969   ,-16.27    , -7.92    , -9.35    ,-12.32    ,
*-13.55    ,-16.17    ,-17.07    ,-19.4     ,-20.02    ,-22.13    ,
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*-22.47    ,-24.4     ,-24.7     ,-26.24    ,-25.97    ,-27.46    ,
*-27.09    ,-28.29    ,-27.52    ,-28.42    ,-27.52    ,-28.07    ,
*-27.075   ,-27.205   ,-26.003   ,-25.784   ,-24.369   ,-23.846   ,
*-22.278   ,-21.048   ,-16.778   ,-13.662   , -9.263   , -7.73    ,
*-11.06    ,-11.65    ,-14.63    ,-15.06    ,-17.72    ,-17.9     ,
*-20.43    ,-20.34    ,-22.55    ,-22.25    ,-24.24    ,-23.77    ,
*-25.45    ,-24.82    ,-26.12    ,-25.27    ,-26.27    ,-25.3     ,
*-25.957   ,-24.811   ,-25.132   ,-23.792   ,-23.809   ,-22.476   ,
*-21.772   ,-17.638   ,-14.752   ,-10.493   , -7.572   , -3.25    ,
* -0.1879  , -7.38    , -9.71    ,-10.73    ,-12.94    ,-13.6     ,
*-15.66    ,-16.26    ,-17.98    ,-17.99    ,-19.67    ,-19.57    ,
*-20.94    ,-20.41    ,-21.49    ,-20.81/
 DATA A19/
*-21.59    ,-20.74    ,-21.085   ,-20.048   ,-20.078   ,-18.894   ,
*-18.282   ,-14.815   ,-11.872   , -8.146   , -5.254   , -1.219   ,
*  1.71    ,  5.96    , -7.98    , -8.37    ,-11.01    ,-11.17    ,
*-13.47    ,-13.41    ,-15.5     ,-15.27    ,-17.04    ,-16.59    ,
*-17.99    ,-17.35    ,-18.36    ,-17.56    ,-18.206   ,-17.168   ,
*-17.492   ,-16.391   ,-15.977   ,-12.457   ,-10.394   , -6.676   ,
* -4.494   , -0.542   ,  1.759   ,  5.83    ,  8.3517  , -0.81    ,
* -3.11    , -3.97    , -6.14    , -6.94    , -8.77    , -8.97    ,
*-10.77    ,-10.79    ,-12.31    ,-11.92    ,-13.05    ,-12.5     ,
*-13.29    ,-12.56    ,-12.902   ,-11.992   ,-11.672   , -8.64    ,
* -6.603   , -3.403   , -1.269   ,  2.226   ,  4.373   ,  8.089   ,
* 10.52    , 14.29    , -1.61    , -4.      , -4.12    , -6.31    ,
* -6.22    , -8.07    , -7.78    , -9.18    , -8.67    , -9.68    ,
* -8.97    , -9.623   , -8.779   , -8.682   , -5.723   , -4.342   ,
* -1.192   ,  0.232   ,  3.634   ,  5.198   ,  8.829   , 10.589   ,
* 14.41    , 16.367   ,  3.83    ,  3.08    ,  0.93    ,  0.63    ,
* -1.29    , -1.44    , -2.98    , -2.72/
 DATA A20/
* -3.84    , -3.41    , -4.2     , -3.61    , -3.573   , -0.98    ,
*  0.289   ,  2.96    ,  4.293   ,  7.036   ,  8.609   , 11.451   ,
* 13.255   , 16.36    , 18.381   , 21.63    , 23.84    , 27.2     ,
* 29.59    , 33.14    ,  6.02    ,  5.8     ,  3.54    ,  3.48    ,
*  1.63    ,  1.79    ,  0.4     ,  0.8     , -0.22    ,  0.31    ,
*  0.074   ,  2.51    ,  3.269   ,  5.863   ,  6.63    ,  9.365   ,
* 10.25    , 12.938   , 14.301   , 17.234   , 18.803   , 21.987   ,
* 23.6626  , 27.1726  , 28.936   , 32.48    , 34.46    ,  8.87    ,
*  8.59    ,  7.07    ,  7.23    ,  6.09    ,  6.37    ,  5.97    ,
*  8.06    ,  8.684   , 10.82    , 11.54    , 13.73    , 14.5     ,
* 16.603   , 17.818   , 20.2     , 21.615   , 24.298   , 25.849   ,
* 28.89    , 30.72    , 33.76    , 35.91    , 39.24    , 12.      ,
* 12.06    , 10.65    , 10.89    , 10.27    , 12.16    , 12.346   ,
* 14.45    , 14.646   , 16.916   , 17.183   , 19.243   , 19.98    ,
* 22.283   , 23.18    , 25.805   , 26.748   , 29.58    , 30.8586  ,
* 33.8121  , 35.4444  , 38.7294  , 40.607   , 44.25    , 17.66    ,
* 17.66    , 17.      , 18.59    , 18.49/
 DATA A21/
* 20.18    , 20.31    , 21.94    , 22.31    , 23.78    , 24.31    ,
* 26.015   , 26.825   , 28.852   , 29.876   , 32.162   , 33.4222  ,
* 35.923   , 37.4859  , 40.337   , 42.32    , 45.54    , 47.64    ,
* 51.27    , 27.17    , 28.87    , 29.208   , 31.181   , 31.598   ,
* 33.78    , 34.586   , 36.914   , 38.142   , 40.9155  , 42.4417  ,
* 45.3872  , 47.306   , 50.5709  , 52.711   , 33.74    , 35.22    ,
* 35.62    , 37.28    , 38.      , 39.95    , 41.0387  , 43.37    ,
* 44.8683  , 47.4516  , 49.3069  , 52.21    , 54.26    , 57.41    ,
* 59.921   , 38.39    , 38.349   , 40.02    , 40.333   , 42.16    ,
* 42.879   , 45.086   , 46.1602  , 48.5849  , 50.1224  , 52.952   ,
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     * 54.7139  , 57.751   , 59.801   , 63.174   , 65.365   , 43.17    ,
     * 44.34    , 44.64    , 46.      , 46.63    , 48.42    , 49.385   ,
     * 51.491   , 52.9312  , 55.4632  , 57.171   , 59.8763  , 61.893   ,
     * 64.991   , 67.23    , 70.59    , 48.02    , 47.87    , 49.15    ,
     * 49.39    , 51.09    , 51.701   , 53.696   , 54.8007  , 57.1773  ,
     * 58.449   , 60.998   , 62.6133  , 65.528   , 67.388   , 70.746   ,
     * 72.985   , 76.65    , 53.19    , 54.17/
      DATA A22/
     * 54.27    , 55.6     , 56.1     , 57.7     , 58.682   , 60.69    ,
     * 61.812   , 64.01    , 65.485   , 68.099   , 69.8436  , 72.948   ,
     * 75.23    , 78.53    , 58.24    , 58.02    , 59.17    , 59.33    ,
     * 60.91    , 61.459   , 63.377   , 64.0873  , 66.15    , 67.239   ,
     * 69.7179  , 71.167   , 74.128   , 76.03    , 79.296   , 81.337   ,
     * 63.82    , 64.69    , 64.72    , 65.96    , 66.38    , 67.93    ,
     * 68.55    , 70.27    , 71.11    , 73.27    , 74.507   , 77.263   ,
     * 79.0077  , 81.99    , 84.09    , 87.16    , 69.36    , 69.04    ,
     * 70.1     , 70.13    , 71.54    , 71.885   , 73.5     , 74.063   ,
     * 76.      , 76.817   , 79.339   , 80.897   , 83.787   , 85.482   ,
     * 88.585   , 76.04    , 77.08    , 77.26    , 78.6     , 79.02    ,
     * 80.54    , 81.24    , 83.49    , 84.842   , 87.522   , 89.03    ,
     * 91.82    , 82.78    , 82.856   , 84.33    , 84.723   , 86.87    ,
     * 87.796   , 90.22    , 91.42    , 94.018   , 88.64    , 89.73    ,
     * 90.05    , 91.74    , 92.67    , 94.75    , 95.85    , 98.1     ,
     * 94.31    , 94.28    , 95.89    , 96.35    , 98.3     , 99.02    ,
     *101.24    ,100.39    ,101.55    ,102.07/
      DATA A23/
     *103.44    ,104.16    ,105.97    ,106.91    ,108.22    ,108.47    ,
     *110.12    ,114.51    ,114.8     ,115.96    ,120.13    ,121.24    ,
     *128.21    ,  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,
     *  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,
     *  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,
     *  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,
     *  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,
     *  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,
     *  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,
     *  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,
     *  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,
     *  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,
     *  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,
     *  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,
     *  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,
     *  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,  0.      ,
     *  0.      ,  0.      ,  0.      ,  0./
      DATA E1/
     *     0.33 ,     2.5  ,     0.33 ,     0.013,     0.052,     0.011,
     *     0.022,     0.03 ,   380.   ,     0.03 ,     0.05 ,    50.   ,
     *     1.   ,    30.   ,     7.   ,   120.   ,   300.   ,    50.   ,
     *     0.7  ,     0.8  ,     0.8  ,     2.   ,   250.   ,   110.   ,
     *     5.   ,     0.8  ,     0.11 ,     0.4  ,     0.4  ,     6.   ,
     *    15.   ,   500.   ,   300.   ,    70.   ,     1.2  ,     1.   ,
     *     0.3  ,     0.4  ,     1.3  ,     1.1  ,    21.   ,    22.   ,
     *   500.   ,   700.   ,    24.   ,     2.2  ,     0.5  ,     0.9  ,
     *     0.   ,     0.016,     0.025,     0.8  ,     4.   ,    40.   ,
     *   130.   ,   240.   ,   910.   ,   400.   ,   150.   ,     1.   ,
     *     0.27 ,     0.024,     0.04 ,     2.3  ,    15.   ,    20.   ,
     *    19.   ,   400.   ,   600.   ,    40.   ,    10.   ,     0.08 ,
     *     0.5  ,     0.05 ,     0.4  ,     0.9  ,     2.8  ,     2.1  ,
     *    50.   ,    90.   ,   620.   ,   400.   ,   130.   ,     8.   ,
     *     0.24 ,     0.7  ,     0.14 ,     0.2  ,     8.   ,    30.   ,
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*   170.   ,   400.   ,   500.   ,    20.   ,    50.   ,     5.   ,
*     0.6,     2.   ,     2.   ,    1.6/
 DATA E2/
*     2.6  ,    10.   ,   100.   ,    70.   ,   400.   ,   400.   ,
*    12.   ,     7.   ,     2.1  ,     1.7  ,     0.9  ,     0.9  ,
*     6.   ,    16.   ,    40.   ,   140.   ,   150.   ,   250.   ,
*   580.   ,   740.   ,  1140.   ,  3570.   ,    27.   ,    16.   ,
*     1.5  ,     1.5  ,     0.7  ,     0.7  ,     0.8  ,     0.9  ,
*     2.1  ,    30.   ,   210.   ,   410.   ,  1580.   ,   500.   ,
*   760.   ,   650.   ,    90.   ,    25.   ,     4.   ,     1.1  ,
*     0.8  ,     0.7  ,     0.7  ,     5.   ,    40.   ,    70.   ,
*   300.   ,   400.   ,   500.   ,   510.   ,   600.   ,    19.   ,
*    10.   ,     3.   ,     0.7  ,     0.6  ,     0.6  ,     0.6  ,
*     0.7  ,     2.4  ,    50.   ,   300.   ,   410.   ,   400.   ,
*   500.   ,   600.   ,   300.   ,    40.   ,     4.   ,     1.8  ,
*     1.7  ,     0.6  ,     0.6  ,     1.5  ,     1.2  ,    80.   ,
*    60.   ,   300.   ,   400.   ,   400.   ,   500.   ,   160.   ,
*    50.   ,     3.   ,     1.5  ,     0.24 ,     0.21 ,     0.21 ,
*     0.21 ,     0.25 ,     0.26 ,    12.   ,   200.   ,    40.   ,
*   300.   ,   400.   ,   300.   ,    50./
 DATA E3/
*     8.   ,     0.7  ,     0.27 ,     0.07 ,     0.07 ,     0.1  ,
*     0.14 ,    19.   ,   500.   ,   160.   ,   200.   ,    60.   ,
*   300.   ,    50.   ,    30.   ,     3.   ,     1.3  ,     0.27 ,
*     0.6  ,     0.8  ,     5.   ,     1.3  ,     1.4  ,    40.   ,
*    70.   ,    20.   ,    60.   ,    40.   ,   300.   ,    20.   ,
*     8.   ,     1.4  ,     0.9  ,     1.1  ,     1.1  ,     1.1  ,
*     1.5  ,    10.   ,    40.   ,    11.   ,    16.   ,     8.   ,
*    24.   ,   400.   ,    40.   ,    22.   ,     5.   ,     2.1  ,
*     1.2  ,     1.2  ,     1.2  ,     1.2  ,     1.3  ,     1.3  ,
*     4.   ,     4.   ,     4.   ,     4.   ,     8.   ,    50.   ,
*   300.   ,   200.   ,     4.   ,     1.5  ,     1.3  ,     2.3  ,
*     2.2  ,     1.3  ,     1.3  ,     2.2  ,     5.   ,     4.   ,
*    16.   ,    20.   ,   300.   ,    11.   ,    40.   ,     6.   ,
*     7.   ,     1.4  ,     2.8  ,     1.3  ,     1.1  ,     1.1  ,
*     1.1  ,     1.1  ,     1.4  ,     7.   ,   100.   ,   300.   ,
*   300.   ,   200.   ,   100.   ,    17.   ,     1.4  ,     1.3  ,
*     3.   ,     1.3  ,     1.5  ,     1.5/
 DATA E4/
*     1.8  ,     3.   ,    15.   ,   100.   ,   300.   ,   180.   ,
*   150.   ,    20.   ,    14.   ,     7.   ,     2.7  ,     1.6  ,
*     1.6  ,     1.6  ,     1.6  ,     1.6  ,     1.6  ,    10.   ,
*   200.   ,   300.   ,   400.   ,   200.   ,   100.   ,    24.   ,
*     1.6  ,     1.5  ,     2.4  ,     1.6  ,     1.8  ,     1.5  ,
*     1.5  ,     3.   ,    30.   ,    29.   ,   100.   ,   160.   ,
*    60.   ,    15.   ,    12.   ,     2.2  ,     1.4  ,     1.4  ,
*     1.5  ,     1.5  ,     1.5  ,     1.5  ,     4.   ,    20.   ,
*    15.   ,    60.   ,   200.   ,   100.   ,    18.   ,     1.5  ,
*     1.5  ,     2.5  ,     1.5  ,     1.8  ,     1.5  ,     1.5  ,
*     1.7  ,    19.   ,    20.   ,    20.   ,    50.   ,   180.   ,
*    50.   ,    11.   ,    11.   ,     3.   ,     1.5  ,     1.5  ,
*     1.5  ,     1.5  ,     1.5  ,     1.5  ,     1.6  ,     1.6  ,
*    16.   ,    19.   ,    18.   ,   200.   ,   300.   ,   200.   ,
*   300.   ,     2.5  ,     2.1  ,     2.6  ,     1.8  ,     5.   ,
*     1.5  ,     1.5  ,     1.8  ,     1.9  ,     8.   ,    50.   ,
*     8.   ,    20.   ,   300.   ,   130./
 DATA E5/
*   100.   ,    40.   ,    11.   ,    16.   ,    10.   ,     2.2  ,
*     1.7  ,     1.8  ,     1.6  ,     1.6  ,     1.7  ,     1.8  ,
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*     3.   ,    11.   ,     6.   ,    40.   ,    19.   ,   150.   ,
*   190.   ,   280.   ,   280.   ,   400.   ,    28.   ,   100.   ,
*     4.   ,     2.   ,     3.   ,     1.7  ,     2.1  ,     2.9  ,
*     3.   ,     2.3  ,     2.5  ,     6.   ,    70.   ,     7.   ,
*   150.   ,   200.   ,   200.   ,   130.   ,   300.   ,   190.   ,
*   320.   ,   250.   ,   100.   ,    13.   ,     5.   ,     6.   ,
*     4.   ,     1.5  ,     1.8  ,     1.5  ,     1.5  ,     1.4  ,
*     2.1  ,     1.6  ,     1.9  ,     4.   ,   100.   ,    30.   ,
*   120.   ,   140.   ,   400.   ,   410.   ,    50.   ,   100.   ,
*   100.   ,    30.   ,    20.   ,     4.   ,     4.   ,     4.   ,
*     2.2  ,     1.6  ,     1.8  ,     2.2  ,    10.   ,     6.   ,
*    24.   ,     6.   ,    25.   ,   220.   ,   300.   ,   400.   ,
*   400.   ,   300.   ,    40.   ,   200.   ,   200.   ,    12.   ,
*    11.   ,     1.5  ,     1.5  ,     1.5  ,     1.5  ,     1.5  ,
*     1.6  ,     1.8  ,     1.9  ,     2.1/
 DATA E6/
*     4.   ,    15.   ,   100.   ,   130.   ,   400.   ,   500.   ,
*   360.   ,   300.   ,   200.   ,   250.   ,    15.   ,    20.   ,
*    11.   ,     3.   ,     4.   ,     2.4  ,     2.4  ,     5.   ,
*     5.   ,     5.   ,    26.   ,    19.   ,    60.   ,   120.   ,
*   130.   ,   400.   ,   400.   ,   420.   ,   240.   ,   140.   ,
*    60.   ,    20.   ,    12.   ,    29.   ,     8.   ,     6.   ,
*     8.   ,     6.   ,     5.   ,     3.   ,     3.   ,     3.   ,
*     5.   ,     5.   ,    14.   ,    50.   ,    30.   ,    80.   ,
*    80.   ,   120.   ,   620.   ,   470.   ,   110.   ,    70.   ,
*    40.   ,    30.   ,    27.   ,    19.   ,    23.   ,    17.   ,
*    21.   ,     4.   ,     3.   ,     2.9  ,     2.9  ,     5.   ,
*     8.   ,    13.   ,     8.   ,    14.   ,    15.   ,    26.   ,
*    28.   ,    30.   ,    50.   ,    60.   ,   120.   ,   150.   ,
*   300.   ,   200.   ,    30.   ,    40.   ,     9.   ,    21.   ,
*     4.   ,     4.   ,     2.6  ,     2.6  ,     2.6  ,     4.   ,
*     3.   ,     5.   ,    12.   ,    12.   ,     7.   ,    60.   ,
*    40.   ,    70.   ,    80.   ,   130./
 DATA E7/
*   610.   ,   500.   ,   400.   ,    70.   ,    90.   ,    60.   ,
*   170.   ,    11.   ,    20.   ,     2.9  ,     3.   ,     2.8  ,
*     2.8  ,     3.   ,    10.   ,    11.   ,     6.   ,     6.   ,
*    40.   ,    60.   ,    60.   ,   100.   ,   410.   ,   510.   ,
*   300.   ,   510.   ,   100.   ,   350.   ,   100.   ,   200.   ,
*     8.   ,    10.   ,     4.   ,     2.4  ,     2.4  ,     2.4  ,
*     2.4  ,     2.6  ,     2.6  ,     3.   ,     3.   ,    20.   ,
*    70.   ,    80.   ,   140.   ,   400.   ,   540.   ,   400.   ,
*   300.   ,    60.   ,   200.   ,    19.   ,     5.   ,     3.   ,
*     2.8  ,     2.5  ,     2.5  ,     2.1  ,     4.   ,     2.7  ,
*     6.   ,    13.   ,    30.   ,    70.   ,    70.   ,   230.   ,
*   410.   ,   500.   ,   310.   ,   300.   ,    16.   ,     6.   ,
*    13.   ,     4.   ,     4.   ,     2.4  ,     2.1  ,     2.   ,
*     2.   ,     2.   ,     2.1  ,     6.   ,     6.   ,    21.   ,
*   200.   ,   310.   ,   300.   ,   400.   ,   580.   ,   400.   ,
*   300.   ,   200.   ,    26.   ,     4.   ,     5.   ,     6.   ,
*     6.   ,     5.   ,     4.   ,     2.1/
 DATA E8/
*     2.3  ,    24.   ,    10.   ,    11.   ,    70.   ,   200.   ,
*   300.   ,   300.   ,   400.   ,   500.   ,   400.   ,   300.   ,
*    90.   ,    13.   ,    12.   ,     8.   ,     8.   ,     6.   ,
*     2.2  ,     2.2  ,     2.2  ,     2.3  ,     2.4  ,     5.   ,
*     5.   ,    10.   ,   300.   ,   610.   ,   300.   ,   300.   ,
*   400.   ,   400.   ,   300.   ,   150.   ,    13.   ,    30.   ,
*    12.   ,    10.   ,    20.   ,    17.   ,    21.   ,     3.   ,
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*     3.   ,     5.   ,    10.   ,    18.   ,    50.   ,    22.   ,
*   100.   ,   210.   ,   300.   ,   400.   ,   400.   ,   300.   ,
*   300.   ,    21.   ,    16.   ,    12.   ,    18.   ,     4.   ,
*     4.   ,     5.   ,     5.   ,     5.   ,     6.   ,     4.   ,
*     4.   ,    18.   ,    50.   ,    25.   ,   150.   ,   150.   ,
*   300.   ,   160.   ,   400.   ,   300.   ,   150.   ,    90.   ,
*   120.   ,   110.   ,    50.   ,     7.   ,     9.   ,     6.   ,
*     5.   ,     5.   ,     3.   ,     3.   ,     4.   ,    28.   ,
*    20.   ,   110.   ,    70.   ,   120.   ,    50.   ,   100.   ,
*    70.   ,   100.   ,   190.   ,   500./
 DATA E9/
*   300.   ,   180.   ,   200.   ,    18.   ,    11.   ,    10.   ,
*     6.   ,     7.   ,     6.   ,     4.   ,     3.   ,     3.   ,
*     2.9  ,     2.9  ,     2.9  ,     2.9  ,     3.   ,    13.   ,
*    20.   ,    60.   ,    19.   ,   150.   ,   210.   ,   300.   ,
*   540.   ,   420.   ,   300.   ,   200.   ,    18.   ,    30.   ,
*     8.   ,    11.   ,     7.   ,    30.   ,     6.   ,     5.   ,
*     4.   ,     4.   ,     4.   ,     4.   ,     5.   ,   300.   ,
*    18.   ,   170.   ,    28.   ,    50.   ,    30.   ,    50.   ,
*    80.   ,    80.   ,    70.   ,   170.   ,   170.   ,   320.   ,
*   240.   ,   630.   ,   500.   ,   400.   ,    80.   ,   200.   ,
*   100.   ,    30.   ,    10.   ,    16.   ,     7.   ,     5.   ,
*     4.   ,     3.   ,     3.   ,     3.   ,     2.9  ,     2.9  ,
*     2.9  ,     2.7  ,     2.7  ,     2.7  ,     2.7  ,     1.6  ,
*     2.1  ,    11.   ,    25.   ,    40.   ,   120.   ,   120.   ,
*   140.   ,    80.   ,   210.   ,   630.   ,   500.   ,   500.   ,
*   400.   ,   300.   ,    19.   ,   200.   ,   200.   ,    25.   ,
*    24.   ,   200.   ,    20.   ,     6./
 DATA E10/
*     9.   ,     4.   ,     8.   ,     8.   ,     2.7  ,     2.7  ,
*     2.3  ,     2.3  ,     3.   ,    30.   ,     6.   ,    40.   ,
*    22.   ,   100.   ,    70.   ,    80.   ,   210.   ,   150.   ,

*   200.   ,   630.   ,   500.   ,   400.   ,    70.   ,   200.   ,
*    70.   ,   160.   ,   200.   ,   200.   ,   200.   ,   100.   ,
*    30.   ,    23.   ,     8.   ,    19.   ,    25.   ,     3.   ,
*     2.   ,     1.7  ,     2.4  ,     2.4  ,     4.   ,     3.   ,
*     4.   ,     4.   ,     4.   ,    21.   ,    80.   ,   110.   ,
*   100.   ,   100.   ,   300.   ,   660.   ,   540.   ,   500.   ,
*   400.   ,   300.   ,    50.   ,   280.   ,   200.   ,   160.   ,
*   200.   ,   200.   ,   100.   ,   200.   ,    19.   ,     6.   ,
*     5.   ,     4.   ,     2.6  ,     5.   ,     4.   ,     4.   ,
*     4.   ,    10.   ,     4.   ,    20.   ,    30.   ,    60.   ,
*    22.   ,    50.   ,    80.   ,    80.   ,   120.   ,   630.   ,
*   510.   ,   400.   ,    80.   ,   290.   ,   280.   ,   260.   ,
*   320.   ,   280.   ,   160.   ,   280.   ,    60.   ,   410.   ,
*    16.   ,     2.1  ,     2.1  ,     7./
 DATA E11/
*     6.   ,     1.6  ,     1.9  ,     1.5  ,     4.   ,     4.   ,
*     7.   ,     7.   ,    11.   ,     7.   ,     7.   ,    50.   ,
*    60.   ,    60.   ,    90.   ,   100.   ,   410.   ,   510.   ,
*   500.   ,   310.   ,   180.   ,   130.   ,   100.   ,    80.   ,
*    60.   ,    70.   ,    40.   ,    40.   ,    17.   ,    24.   ,
*     8.   ,     6.   ,    14.   ,     8.   ,     6.   ,    12.   ,
*     6.   ,     6.   ,     8.   ,     6.   ,     6.   ,    23.   ,
*     7.   ,    16.   ,    22.   ,    30.   ,    40.   ,    60.   ,
*    70.   ,   100.   ,   130.   ,   370.   ,   560.   ,   490.   ,
*   410.   ,   410.   ,   350.   ,   310.   ,   300.   ,   300.   ,
*   250.   ,   200.   ,   100.   ,    18.   ,    14.   ,     8.   ,
```

```
*     8.   ,     8.   ,     7.   ,     6.   ,     6.   ,     6.   ,
*     6.   ,     6.   ,     6.   ,    10.   ,    24.   ,    40.   ,
*    50.   ,    80.   ,   130.   ,   110.   ,   510.   ,   620.   ,
*   580.   ,   220.   ,   400.   ,    50.   ,   200.   ,   100.   ,
*    50.   ,   100.   ,    30.   ,    12.   ,    70.   ,    50.   ,
*     5.   ,     4.   ,     4.   ,    25./
 DATA E12/
*     7.   ,    50.   ,   110.   ,   100.   ,    90.   ,   300.   ,
*   330.   ,   500.   ,   630.   ,   300.   ,   220.   ,   210.   ,
*   200.   ,   110.   ,    18.   ,    50.   ,    50.   ,    11.   ,
*     7.   ,     4.   ,     4.   ,     4.   ,     4.   ,     5.   ,
*    50.   ,    80.   ,    80.   ,   140.   ,   300.   ,   220.   ,
*   500.   ,   300.   ,   220.   ,   200.   ,   200.   ,    50.   ,
*    50.   ,    15.   ,     7.   ,     7.   ,     4.   ,     4.   ,
*     4.   ,     5.   ,     8.   ,    70.   ,    40.   ,   100.   ,
*    11.   ,   200.   ,   300.   ,   300.   ,   320.   ,   360.   ,
*    60.   ,    60.   ,   200.   ,    50.   ,    19.   ,     9.   ,
*     3.   ,     3.   ,     3.   ,     3.   ,     3.   ,     3.   ,
*     4.   ,     4.   ,     4.   ,     4.   ,    30.   ,   200.   ,
*   300.   ,   400.   ,   310.   ,   280.   ,    60.   ,    40.   ,
*    30.   ,    50.   ,     4.   ,     4.   ,     4.   ,     7.   ,
*     3.   ,    15.   ,     5.   ,    20.   ,     6.   ,    80.   ,
*    16.   ,   100.   ,   200.   ,   300.   ,   450.   ,   160.   ,
*   300.   ,    13.   ,    16.   ,    11./
 DATA E13/
*     4.   ,     4.   ,     6.   ,     3.   ,     3.   ,     3.   ,
*     3.   ,     3.   ,     3.   ,     3.   ,     3.   ,     3.   ,
*    14.   ,   200.   ,   200.   ,   400.   ,    40.   ,   100.   ,
*    40.   ,    21.   ,     5.   ,    10.   ,     4.   ,    21.   ,
*     6.   ,     8.   ,     3.   ,     3.   ,     4.   ,     4.   ,
*     4.   ,    10.   ,     7.   ,    80.   ,     9.   ,   200.   ,
*   400.   ,   300.   ,   300.   ,    50.   ,    11.   ,    23.   ,
*     4.   ,     5.   ,     8.   ,     4.   ,     3.   ,     3.   ,
*     3.   ,     3.   ,     3.   ,     3.   ,     3.   ,     4.   ,
*     3.   ,     4.   ,   120.   ,   400.   ,   300.   ,   150.   ,
*    29.   ,    40.   ,     6.   ,    11.   ,     5.   ,    15.   ,
*     5.   ,    50.   ,    13.   ,     5.   ,     4.   ,     4.   ,
*     4.   ,     4.   ,     4.   ,    60.   ,    50.   ,   150.   ,
*   250.   ,    70.   ,    60.   ,   200.   ,    11.   ,    23.   ,
*     6.   ,     5.   ,     9.   ,    12.   ,     7.   ,     7.   ,
*     5.   ,     4.   ,     4.   ,     3.   ,     3.   ,     3.   ,
*     3.   ,     3.   ,     3.   ,    60./
 DATA E14/
*   300.   ,   210.   ,   200.   ,    29.   ,    60.   ,    10.   ,
*    12.   ,    24.   ,   200.   ,    50.   ,    30.   ,     7.   ,
*    15.   ,     4.   ,     5.   ,     4.   ,     4.   ,     3.   ,
*     3.   ,     6.   ,   100.   ,    20.   ,    50.   ,   280.   ,
*   300.   ,    60.   ,   210.   ,    12.   ,    60.   ,   200.   ,
*    90.   ,   110.   ,    12.   ,    28.   ,    11.   ,     4.   ,
*     6.   ,     4.   ,     4.   ,     3.   ,     3.   ,     3.   ,
*     3.   ,     4.   ,     4.   ,     5.   ,   200.   ,   430.   ,
*   410.   ,   210.   ,   210.   ,    30.   ,    80.   ,   210.   ,
*   200.   ,   200.   ,   100.   ,   100.   ,    60.   ,     6.   ,
*    20.   ,     4.   ,    12.   ,     4.   ,     4.   ,     3.   ,
*     3.   ,     3.   ,     6.   ,     5.   ,    50.   ,    50.   ,
*   200.   ,   500.   ,   450.   ,   280.   ,   310.   ,    60.   ,
*   210.   ,    16.   ,   210.   ,   200.   ,   220.   ,   200.   ,
*   100.   ,   100.   ,    20.   ,     8.   ,     5.   ,     5.   ,
```

```
*     5.   ,     3.   ,     3.   ,     3.   ,     3.   ,     3.   ,
*     3.   ,     3.   ,     4.   ,    11./
 DATA E15/
*   540.   ,   540.   ,   430.   ,   410.   ,   220.   ,    70.   ,
*    60.   ,   320.   ,   220.   ,   210.   ,   300.   ,   200.   ,
*   200.   ,   160.   ,   100.   ,    80.   ,     6.   ,    20.   ,
*     4.   ,     4.   ,     4.   ,     4.   ,     3.   ,     3.   ,
*     3.   ,    25.   ,    40.   ,    70.   ,   580.   ,   590.   ,
*   500.   ,   450.   ,   280.   ,   310.   ,    60.   ,   220.   ,
*    17.   ,   420.   ,   230.   ,   400.   ,   300.   ,   220.   ,
*   130.   ,   100.   ,   200.   ,   200.   ,    50.   ,   100.   ,
*     4.   ,     4.   ,     3.   ,     2.8  ,     2.8  ,     2.7  ,
*     2.8  ,     2.8  ,     7.   ,    30.   ,    60.   ,   650.   ,
*   550.   ,   540.   ,   430.   ,   410.   ,   220.   ,   210.   ,
*   210.   ,   380.   ,   280.   ,   340.   ,   320.   ,   310.   ,
*   200.   ,   200.   ,   200.   ,   190.   ,   220.   ,   100.   ,
*   100.   ,   100.   ,     6.   ,   100.   ,     6.   ,     3.   ,
*     3.   ,     3.   ,     3.   ,    26.   ,    14.   ,    60.   ,
*   580.   ,   590.   ,   500.   ,   460.   ,   280.   ,   310.   ,
*    60.   ,   220.   ,    18.   ,   370./
 DATA E16/
*   240.   ,   350.   ,   300.   ,   280.   ,   270.   ,   220.   ,
*   300.   ,   200.   ,   200.   ,   100.   ,   100.   ,    16.   ,
*     5.   ,     7.   ,     3.   ,     3.   ,     3.   ,     3.   ,
*     3.   ,     3.   ,     4.   ,   200.   ,   210.   ,   550.   ,
*   550.   ,   430.   ,   410.   ,   230.   ,   220.   ,   210.   ,
*   380.   ,   350.   ,   400.   ,   370.   ,   370.   ,   280.   ,
*   350.   ,   360.   ,   280.   ,   200.   ,   210.   ,    50.   ,
*    30.   ,   100.   ,   100.   ,     9.   ,     5.   ,     3.   ,
*     3.   ,     3.   ,     3.   ,    10.   ,   200.   ,    11.   ,
*   200.   ,   590.   ,   500.   ,   460.   ,   280.   ,   320.   ,
*    60.   ,   230.   ,    18.   ,   380.   ,   240.   ,   350.   ,
*   300.   ,   310.   ,   280.   ,   320.   ,   220.   ,   200.   ,
*   200.   ,   220.   ,   100.   ,   100.   ,     3.   ,     3.   ,
*     3.   ,     3.   ,     3.   ,     3.   ,     3.   ,     4.   ,
*     4.   ,     4.   ,     5.   ,   500.   ,    40.   ,   550.   ,
*   440.   ,   420.   ,   240.   ,   220.   ,   220.   ,   380.   ,
*   350.   ,   400.   ,   380.   ,   370./
 DATA E17/
*   290.   ,   290.   ,   310.   ,   300.   ,   320.   ,   230.   ,
*   140.   ,   250.   ,   200.   ,    20.   ,   100.   ,    11.   ,
*    14.   ,   200.   ,     4.   ,     5.   ,     4.   ,     4.   ,
*    13.   ,    60.   ,    21.   ,   200.   ,   500.   ,   460.   ,
*   280.   ,   320.   ,    60.   ,   240.   ,    19.   ,   380.   ,
*   240.   ,   350.   ,   300.   ,   300.   ,   280.   ,   320.   ,
*   230.   ,   210.   ,   200.   ,   200.   ,   110.   ,   200.   ,
*     7.   ,    12.   ,     7.   ,     8.   ,     5.   ,     4.   ,
*     4.   ,     4.   ,     4.   ,     4.   ,     6.   ,    19.   ,
*    21.   ,    50.   ,   240.   ,   230.   ,   230.   ,   390.   ,
*   350.   ,   400.   ,   380.   ,   420.   ,   290.   ,   290.   ,
*   310.   ,   310.   ,   320.   ,   300.   ,   150.   ,   300.   ,
*   200.   ,    16.   ,    50.   ,    17.   ,   100.   ,    16.   ,
*     4.   ,     5.   ,     4.   ,     4.   ,     4.   ,    50.   ,
*    16.   ,   200.   ,    16.   ,   300.   ,   330.   ,    60.   ,
*   240.   ,    19.   ,   380.   ,   240.   ,   350.   ,   300.   ,
*   300.   ,   280.   ,   320.   ,   230./
 DATA E18/
*   210.   ,   200.   ,   280.   ,   100.   ,    70.   ,   200.   ,
*   100.   ,    25.   ,    50.   ,     5.   ,     5.   ,     4.   ,
```

```
*     4.   ,     4.   ,     4.   ,     4.   ,     5.   ,     4.   ,
*     7.   ,    21.   ,   150.   ,   380.   ,   490.   ,   460.   ,
*   500.   ,   430.   ,   430.   ,   350.   ,   290.   ,   370.   ,
*   370.   ,   360.   ,   320.   ,   310.   ,   710.   ,   210.   ,
*   190.   ,   150.   ,   140.   ,    60.   ,    80.   ,   220.   ,
*     9.   ,    16.   ,    17.   ,     4.   ,     4.   ,     4.   ,
*     4.   ,     6.   ,     5.   ,    12.   ,    13.   ,   380.   ,
*   240.   ,   350.   ,   300.   ,   300.   ,   280.   ,   320.   ,
*   230.   ,   220.   ,   200.   ,   320.   ,   300.   ,   300.   ,
*   200.   ,   210.   ,   130.   ,    80.   ,   100.   ,    40.   ,
*    11.   ,     9.   ,     4.   ,     4.   ,     4.   ,     4.   ,
*     4.   ,     4.   ,     4.   ,     4.   ,     6.   ,   100.   ,
*     2.8  ,   440.   ,   350.   ,   310.   ,   370.   ,   380.   ,
*   370.   ,   330.   ,   320.   ,   700.   ,   180.   ,   160.   ,
*   120.   ,   100.   ,    60.   ,    70./
 DATA E19/
*    40.   ,    40.   ,     8.   ,    11.   ,     5.   ,     5.   ,
*     4.   ,     4.   ,     6.   ,     5.   ,    11.   ,    12.   ,
*   100.   ,   100.   ,   280.   ,   330.   ,   230.   ,   220.   ,
*   200.   ,   320.   ,   300.   ,   300.   ,   200.   ,   210.   ,
*   130.   ,    80.   ,   100.   ,    30.   ,    11.   ,     9.   ,
*     5.   ,     5.   ,     4.   ,     4.   ,     4.   ,     5.   ,
*     4.   ,     4.   ,     6.   ,   100.   ,     2.8  ,   300.   ,
*   420.   ,   380.   ,   380.   ,   340.   ,   330.   ,   700.   ,
*   180.   ,   160.   ,   120.   ,    90.   ,    60.   ,    70.   ,
*    40.   ,    40.   ,     8.   ,    11.   ,     5.   ,     5.   ,
*    13.   ,     6.   ,     7.   ,     6.   ,    11.   ,    13.   ,
*    80.   ,   100.   ,   230.   ,   200.   ,   330.   ,   300.   ,
*   300.   ,   200.   ,   220.   ,   130.   ,    80.   ,   100.   ,
*    30.   ,    11.   ,    10.   ,     6.   ,     9.   ,    11.   ,
*     9.   ,    11.   ,     6.   ,     5.   ,     4.   ,     6.   ,
*   100.   ,     2.8  ,   380.   ,   350.   ,   330.   ,   690.   ,
*   170.   ,   160.   ,   110.   ,    70./
 DATA E20/
*    60.   ,    50.   ,    40.   ,    40.   ,     9.   ,    12.   ,
*    10.   ,    13.   ,    15.   ,     6.   ,     8.   ,     7.   ,
*    11.   ,    50.   ,     4.   ,    50.   ,    90.   ,   140.   ,
*    90.   ,   200.   ,   280.   ,   340.   ,   300.   ,   310.   ,
*   200.   ,   220.   ,   130.   ,    80.   ,   100.   ,    30.   ,
*    12.   ,    11.   ,    10.   ,    12.   ,    14.   ,    14.   ,
*    15.   ,     8.   ,     6.   ,     4.   ,     6.   ,     3.   ,
*     2.8  ,     2.8  ,     4.   ,   160.   ,   280.   ,   180.   ,
*   170.   ,   120.   ,    90.   ,    80.   ,    70.   ,    60.   ,
*    40.   ,    13.   ,    50.   ,    50.   ,    50.   ,    50.   ,
*     7.   ,     8.   ,     7.   ,    11.   ,     3.   ,     3.   ,
*     4.   ,   150.   ,   200.   ,   100.   ,   200.   ,   200.   ,
*   230.   ,   130.   ,   100.   ,   100.   ,    40.   ,    16.   ,
*    50.   ,    23.   ,    13.   ,    16.   ,    17.   ,    18.   ,
*     9.   ,     6.   ,     4.   ,     6.   ,     3.   ,     2.4  ,
*     2.4  ,     2.1  ,     2.1  ,     6.   ,    50.   ,   130.   ,
*   100.   ,    90.   ,    90.   ,   210./
 DATA E21/
*   210.   ,   200.   ,    70.   ,    70.   ,    70.   ,    70.   ,
*    12.   ,    10.   ,     7.   ,    12.   ,     3.   ,     2.8  ,
*    11.   ,     2.4  ,     8.   ,   100.   ,   200.   ,    50.   ,
*   300.   ,    30.   ,   100.   ,    21.   ,    10.   ,     6.   ,

*    50.   ,     6.   ,     3.   ,     2.2  ,     2.2  ,     2.1  ,
*     2.2  ,     2.1  ,     2.1  ,     5.   ,    90.   ,    50.   ,
```

```
     *    50.    ,   100.    ,   100.    ,     9.    ,     2.4   ,    50.    ,
     *     2.1   ,     2.1   ,     3.    ,    60.    ,   100.    ,   200.    ,
     *    11.    ,   140.    ,    23.    ,    50.    ,     8.    ,    60.    ,
     *     6.    ,     6.    ,     2.2   ,     2.2   ,     2.1   ,     2.1   ,
     *     2.1   ,     3.    ,     5.    ,    14.    ,    19.    ,   220.    ,
     *   210.    ,   210.    ,   140.    ,   140.    ,    50.    ,     5.    ,
     *    12.    ,     2.1   ,     2.2   ,     3.    ,     2.3   ,     3.    ,
     *    22.    ,   100.    ,   200.    ,   250.    ,   200.    ,   210.    ,
     *    30.    ,   100.    ,     6.    ,     6.    ,     2.2   ,     2.4   ,
     *     2.1   ,     2.2   ,     2.8   ,     5.    ,     5.    ,     5.    ,
     *    11.    ,   200.    ,   300.    ,   290./
      DATA E22/
     *   290.    ,   200.    ,   200.    ,   200.    ,     6.    ,    50.    ,
     *     5.    ,   100.    ,     6.    ,    21.    ,     3.    ,     7.    ,
     *   200.    ,   200.    ,   320.    ,   200.    ,   290.    ,    30.    ,
     *   140.    ,     6.    ,     6.    ,     2.5   ,   100.    ,     6.    ,
     *     2.3   ,     2.9   ,     5.    ,     5.    ,     7.    ,    12.    ,
     *   360.    ,   350.    ,   290.    ,   200.    ,   210.    ,   220.    ,
     *    50.    ,   110.    ,    50.    ,   100.    ,     7.    ,    21.    ,
     *     3.    ,     8.    ,   200.    ,   220.    ,   320.    ,   280.    ,
     *   350.    ,    40.    ,   170.    ,    21.    ,   100.    ,    20.    ,
     *   100.    ,    21.    ,     5.    ,     6.    ,     5.    ,     7.    ,
     *     7.    ,   350.    ,   280.    ,   290.    ,   300.    ,   210.    ,
     *   230.    ,   210.    ,   140.    ,     8.    ,    29.    ,   200.    ,
     *   200.    ,   180.    ,    26.    ,   220.    ,    26.    ,   100.    ,
     *    26.    ,    30.    ,   200.    ,    11.    ,   290.    ,   360.    ,
     *   290.    ,   240.    ,   210.    ,   140.    ,    50.    ,    60.    ,
     *   270.    ,   200.    ,   230.    ,   200.    ,   110.    ,   200.    ,
     *   200.    ,   300.    ,   410.    ,   350./
      DATA E23/
     *   240.    ,   220.    ,   150.    ,   450.    ,   460.    ,   360.    ,
     *   120.    ,   420.    ,   610.    ,   560.    ,   920.    ,   920.    ,
     *   420.    ,     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,
     *     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,
     *     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,
     *     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,
     *     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,
     *     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,
     *     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,
     *     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,
     *     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,
     *     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,
     *     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,
     *     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,
     *     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,
     *     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,     0.    ,
     *     0.    ,     0.    ,     0.    ,     0./
      NZNO=MZ*1000+N
      NL=((MZ/10)*2-4)*100
      IF(NL.LE.0) NL=1
      DO 11 J=NL,NT
      IF(ITABLE(J).EQ.NZNO) GO TO 12
   11 CONTINUE
      IRET=IRET+1
      RETURN
   12 EXCES=AMASS(J)
      ERRR=ERR(J)
      RETURN
      END
```

```
*
*********************************************************************
*
      Subroutine MFP
*     --------------
*
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/HYBSUB/RS(2,420),C,POT,IAV,R1
      COMMON/PL3/EB(70),RCSP(70),Z,A,PLEX,NEPR
      COMMON/INCR/ED
      RAD=A**.33333333
      CONV=4040./C
      IAV=1
      ANUT=A-Z
      SYM=(ANUT-Z)/A
      RWP=1.32*RAD
      RWN=1.26*RAD
      ALIL=0.51+0.7*SYM
      SWNW=1./(1.+DEXP((R1-RWN)/0.58))
      SWPW=1./(1.+DEXP((R1-RWP)/ALIL))
      RSWNW=1./SWNW
      RSWPW=1./SWPW
      DO 60 IE=1,420
      E=DFLOAT(IE)*ED-ED/2.
      VP=0.22*E-2.7
      IF(VP)5,5,10
    5 VP=0.D0
   10 SFP=11.8-0.25*E+12.*SYM
      IF(SFP)15,15,20
   15 SFP=0.
   20 WPV=VP*SWPW
      WPSF=SFP*4.*DEXP((R1-RWP)/ALIL)*SWPW**2
      VN=0.22*E-1.56
      IF(VN)25,25,30
   25 VN=0.
   30 SFN=13.-0.25*E-12.*SYM
      IF(SFN)35,35,40
   35 SFN=0.D0
   40 WNV=VN*SWNW
      WNSF=SFN*4.*DEXP((R1-RWN)/.58)*SWNW**2
      RRN=2.9+RWN
      IF(R1-RRN)45,45,55
   45 IF(IAV)55,55,50
   50 RRP=5.*ALIL+RWP
      FAP=.0268*ALIL
      WPSF=SFP*(4.*ALIL*SWPW-FAP)/(R1-RRP)*(-1.)
      WNSF=SFN*(2.32*SWNW-.0155)/(R1-RRN)*(-1.)
      R2N=1.+DEXP((RRN-RWN)/0.58)
      R2P=1.+DEXP((RRP-RWP)/ALIL)
       WPV    =VP*(1.+(ALIL/(RRP-R1))*(DLOG(RSWPW)-DLOG(R2P)))
      WNV    =VN *(1.+(0.58/(RRN-R1))*(DLOG(RSWNW)-DLOG(R2N)))
   55  CONTINUE
      WN=WNV+WNSF

      WP=WPV+WPSF
      RS(1,IE)=WN*CONV
   60 RS(2,IE)=WP*CONV
      RETURN
      END
```

```
*
**********************************************************************
*
      Subroutine NUCMFP
*     ----------------
*
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/PL3/EB(70),RCSP(70),Z,A,PLEX,NEPR
      COMMON/HYBSUB/RS(2,420),C,POT,IAV,R1
      COMMON/INCR/ED
      AN=A-Z
      DEN=1.D0/C
      DC=312.5*DEN
      DO 20 KE=1,420
      EK=DFLOAT(KE)*ED-ED/2.
      E1=POT+EK
      SS=DSQRT(E1)
       BTA=0.0463*SS
      DCN=DC*SS
      AA=(10.63/BTA**2-29.92/BTA+42.9)/A
      BB=(34.1/BTA**2-82.2/BTA+82.2)/A
      SIG1=AN*AA+Z*BB
      SIG2=Z*AA+AN*BB
      RE=POT/E1
      IF(RE-.5)5,5,10
    5 PA=1.-1.4*RE
      GO TO 15
   10 PA=1.-1.4*RE+.4*RE*(2.-1./RE)**2.5
   15 RS(1,KE)=DCN*SIG1*PA
   20 RS(2,KE)=DCN*SIG2*PA
      RETURN
      END
*
**********************************************************************
*
      Subroutine OBNINS(IZ,IA)
*     ------------------------
*
C Written by A.V.Ignatyuk
C
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/LAB10/POW(4,3000),GAM(3000)
      CHARACTER*4 SYMB,SYMBP,SYMBS
      COMMON/LYM1/BE(11,24,4),SYMB(11,24),PAIR(11,24),SYMBP(11,24),
     1SYMBS(11,24),XMAS(11,24),DELSHL(11,24),AMAS(11,24)
      COMMON/CSHEL/SHEL(11,24,2) /INCR/ED /SF/M3,KPLT
      COMMON/SHFT/QVAL,AP,AT,ZP,ZT,CLD,MC,MP,INVER,IKE,IPCH,BARFAC
      COMMON/DEFOR/DEF(24,11) /OBN2/MAXOBN /HOT/KPG,MPG
      COMMON/QQ/GOW(3000)
          DIMENSION PAR(10),RES(7),AM(5)
      NIA=IDINT(AP+AT)
      ANIA=DFLOAT(NIA)
      IIP=IDINT(ZP+ZT)
      AM(1)=28.D0
      AM(2)=50.D0
      AM(3)=82.D0
      AM(4)=126.D0
      AM(5)=184.D0
C SCALING FACTOR FOR LEVEL DESITY
```

```
            SQ11=-DSQRT(ANIA*100./9.D+0)
      FLOU=DEXP(SQ11)
      DO 7050 L=1,5
               WRITE(*,5603)IZ,IA,L
5603  FORMAT(' NUCLEAR LEVEL DENSITY according to ',
     $'IGNATYUK for ',2i4,' L=',i2)
               If(L.ne.5.  and. L.gt.M3) goto 7050
      GO TO(350,355,360,365, 367),L
  350 JZ=1
C                  NEUTRON CHANNEL
      KZ=IZ
      JA=IA+1
      GO TO 370
  355 JZ=2
C                 PROTON CHANNEL
      KZ=IZ+1
      JA=IA
      GO TO 370
  360 JZ=3
C                 ALPHA CHANNEL
      KZ=IZ+2
      JA=IA+2
      GO TO 370
C                 OTHER COMPLEX PARTICLE CHANNEL
  365 IF(KPG.eq.0) JZ=2
      IF(KPG.eq.0) KZ=IZ+1
      IF(KPG.eq.0) JA=IA+1
           IF(KPG.eq.1) JZ=2
           IF(KPG.eq.1) KZ=IZ+1
           IF(KPG.eq.1) JA=IA+2
      IF(KPG.eq.2) JZ=3
      IF(KPG.eq.2) KZ=IZ+2
      IF(KPG.eq.2) JA=IA+1
      GO TO 370
  367 JZ=1
C             Gamma and fission channel
      KZ=IZ
      JA=IA
  370 CONTINUE
C                MOTHER NUCLEUS
         IAOZ=NIA-KZ-JA+2
         IZOZ=IIP-KZ+1
      A=DFLOAT(NIA-KZ-JA+2)
      Z=DFLOAT(IIP-KZ+1)
       X=Z
       INX=0
       IND=0
   8   IZ1=0
       DO 6 I=1,5
       X1=DABS(X-AM(I))
       IF(X1.EQ.0.D0)IZ1=3
       IF(X1.EQ.1.D0)IZ1=2
   6   CONTINUE
       IND=IND+IZ1
       INX=INX+1
       X=A-Z
       IF(INX.LT.2)GOTO 8
       AKP=1.D0
       IF(IND.EQ.6)AKP=0.4D0
```

```
       IF(IND.EQ.5)AKP=0.6D0
       IF(IND.EQ.4)AKP=0.8D0
C
C   FOR DOUBLE MAGIC NUCLEI ZM&NM DEL0= 0.4*DEL00
C   FOR NONMAGIC NUCLEI
C        NM+1 OR NM-1 AND ZM  DEL0=0.6*DEL00
C        NM+1 OR NM-1 AND ZM+1 ORZM-1  DEL0=0.8*DEL00
C
      PAR(1)=Z
       PAR(2)=A
        PAR(3)=.073*A+.115*A**.66666666
         PAR(4)=.4/A**.333333333
          PAR(5)=DELSHL(KZ,JA)
           PAR(6)=AKP*12.0/DSQRT(A)
            PAR(7)=.4*AKP
             PAR(8)=30./A**.66666666
               PAR(9)=DEF(JA,KZ)
C FOR DOUBLE MAGIC NUCLEUS 208-PB-82
C     POSITION OF FIRST 2+ LEVEL
C
              IF(Z.EQ.82.D0.AND.A.EQ.208.D0)PAR(8)=4.1D0
        GAM(1)=0.D+00
      DO 7049 IB=2,MAXOBN
C ENERGY BIN FOR LEVEL DENSITY CALCULATION = 0.1 MEV
      BJ=DFLOAT(IB)
      BJ=BJ/10.-.05
      RES(1)=BJ
      CALL BCS(PAR,RES)
       SQ12=RES(2)
C FLOU - SCALING FACTOR
        If(L.ne.5) POW(L,IB)=DEXP(SQ12)*FLOU
C Gamma channel
        If(L.eq.5) GOW(IB)=DEXP(SQ12)*FLOU
C Fission channel
        If(L.eq.5) GAM(IB)=33.D+00*DEXP(SQ12)*FLOU+GAM(IB-1)
        IF(IB.GT.500)GOTO 7049
        IF(IB.NE.(IB/5)*5)GOTO 7049
 7049 CONTINUE
 7050 CONTINUE
             POW(1,1)=0.0
             POW(2,1)=0.0
             POW(3,1)=0.0
             POW(4,1)=0.0
                GOW(1)=0.0
       RETURN
1000   FORMAT(2X,7(F8.3,2X))
1001   FORMAT(2X,' ENERGIES LOG.STATES  LOG.LEVELS  SIGMA2   TEMPER

     C QVIBR  QROT')
1002  FORMAT(1X,'Z=  ',F5.1,' A= ',F6.1,4I4)
1003  FORMAT(1X,'KZ= ',I5,'JA= ', I5,'DELSHEL='
     1,F10.3,'SHEL(JZ)=',F10.3)
       END
*
*********************************************************************
*
      Subroutine OVER
*     ---------------
*
```

```
C CALCULATES THE TRANSMISSION COEFFICIENTS
C (temporarily, t = d)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/PL3/EB(70),RCSP(70),ZEE,AMASS,PLEX,NEPR
      COMMON/SF/M3,KPLT /SFT9/K5,PLD,JMAX,C(4),DELT,ALT
      COMMON/PARO/PQ,CROSS /LAB3/SIG(4,300)
      COMMON/PAR3/DQ,TL(300),ACRS(300)
      COMMON /LAB2/T(3,81),V(15),V1(3) /INCR/ED
      COMMON/HOT/KPG,MPG
      EQ=PQ
      JMIN=1
      M2=1
      AM=AMASS**.33333333
      II=IDINT(0.14*ZEE/ED)
      IK=II/2
      IF(EQ.GT.0.)M2=M3
      IF(EQ.GT.0.)JMIN=JMAX
      IF(EQ.GT.0.)GO TO 5
      DELT=0.0D0
      ALT=0.0D0
    5 DO 150 K=M2,M3
      TSUM=0.D0
      GO TO(10,15,20,25),K
   10 XJP=0.50D0
      XMP=1.00D0
      XMT=AMASS-1.D0
      ZP=0.0D0
      ZT=ZEE
      P=48.00D0
      RV=1.322-.00076*AMASS+4.0*AMASS*AMASS*1.0D-06
     1-8.0*(AMASS**3)*1.0D-09
      AV=.660D0
      W=9.00D0
      RW=1.266-.00037*AMASS+2.0*AMASS*AMASS*1.0D-06
     1-4.0*(AMASS**3)*1.0D-09
      RV=1.151+1.77*(AMASS-2.*ZEE)/(AMASS**1.3333)
      RW=RV
      AW=0.64D0
      VSO=7.00D0
      RSO=RW
      ASO=AW
      RCLMB=.001D0
      S=1.00D0
      XLM=30.0
      GO TO 30
   15 XJP=0.50D0
      RSO=1.25D0
      XMP=1.00D0
      XMT=AMASS-1.0D0
      ZP=1.0D0
      ZT=ZEE-1.0D0
      VSO=7.50D0
      ASO=.51D0
      RCLMB=1.25D0
      S=0.00D0
      XLM=30.0D0
      SYMM=(AMASS-2.*ZEE)/AMASS
      DELPD=27.*(AMASS-2.*ZEE)/AMASS+.4*ZEE/AM
      RV=1.2D0
```

```
      RW=1.55D0
      AW=.5D0
      AV=.6D0
      P=60.D0
      W=5.D0
      GO TO 30
   20 XJP=0.0D0
      XMP=4.0D0
      XMT=AMASS-4.D0
      ZP=2.00D0
      ZT=ZEE-2.D0
      P=50.2D0
      RV=1.2+1.5/AM
      AV=.564D0
      W=12.30D0
      RW=RV
      AW=.564D0
      RSO=1.D0
      VSO=.001D0
      ASO=1.0D0
      RCLMB=1.30D0
      S=0.0D0
      XLM=40.0D0
      GO TO 30
C He-3
   22 XJP=0.5
      XMP=3.0
      XMT=AMASS-3.0
      ZP=2.00
      ZT=ZEE-2.0
      P0=151.9 + 50.0* (XMT-2.0D+00*ZT)/XMT  ! See P definition below
      RV=1.2
      AV=0.72
      W0= 41.7 - 44.0* (XMT-2.0D+00*ZT)/XMT  ! See W definition below
      RW=1.4
      AW=0.88
      RSO=1.2
      VSO=2.5
      ASO=0.72
      RCLMB=1.3
      S=0.0D0
      XLM=40.0D0
      GO TO 30
   25 IF(M2.eq.M3) GOTO 251
      IF(KPG.eq.2) GOTO 22
251   XJP=1.00D0
      XMP=2.00D0
      XMT=AMASS-2.D0
      ZP=1.D0
      ZT=ZEE-1.D0
      P=79.+2.*ZEE/AM
      RV=1.15D0
      AV=.81D0
      W=16.D0
      RW=1.01D0+1.26/AM
      AW=.68D0
      RSO=.98D0
      VSO=5.6D0
      ASO=1.00D0
```

```
      RCLMB=1.30D0
      S=1.00D0
      XLM=35.D0
   30 XF=XMT**.33333333
      XM=XMT/(XMT + XMP)
      XJT=0.0D0
      LMX=IDINT(XLM)
      DO 90 JE=JMIN,JMAX
      ENGY=DFLOAT(JE)*ED-ED/2.
        IF(KPG.eq.2 .and. K.eq.4) then
                                  P = P0 -0.17*ENGY
                                  W = W0 -0.33*ENGY
                                  endif
      IF(EQ.GT.0.D0)ENGY=EQ
      E=ENGY
      IF(K.EQ.2.AND.JE.LE.IK)GO TO 65
      IF(K.EQ.4.AND.JE.LE.IK)GO TO 65
      IF(K.EQ.3.AND.JE.LE.II)GO TO 65
   35 V(1)=RV*XF
      V(2)=AV
      V(3)=RW*XF
      V(4)=AW
      V(5)=S
      V(6)=VSO
      V(9)=RCLMB*XF
      V(10)=RSO*XF
      V(11)=ASO
      V1(1)=XJP
      V1(2)=+0.0D0
      W1=0.04783258*XMP*XM
      STPLTH=0.1D0
      V1(3)=XLM
      V(7)=P
      V(8)=W
      H4=0.04783*XMP*XM*E
      H1=DSQRT(H4)
      Z=(0.03478*ZP*ZT*XMP*XM)/H1
      C6=31.42/H4
      DO 40 J=1,2
      DO 40 I=1,81
   40 T(J,I)=0.0D0
      CALL TLJ(H4,N1,J1,H1,Z,W1,STPLTH)
      TSUM=0.0D0
      INTRPO=IDINT(2.D0*XJP)
C Changed 14/11/96
      IF(INTRPO-1)55,45,1145
 1145 DO 1150 I=1,LMX
      TK=2.*DFLOAT(I-1)
      TL(I) = C6* (T(1,I)*(TK-1.d0) +T(2,I)*(TK+1.d0)+
     c t(3,i)*(tk+3.d0))/3.d0
 1150 TSUM=TSUM+TL(I)
      go to 65
   45 DO 50 I=1,LMX
      TK=DFLOAT(I-1)
      TL(I) = C6* (T(1,I)*TK +T(2,I)*(TK+1.D0))
   50 TSUM=TSUM+TL(I)
      GO TO 65
   55 DO 60 I=1,LMX
   60 TSUM = TSUM+T(1,I)*C6*(2*I-1)
```

```
   65 CONTINUE
      IF(TSUM.GT.0.01D0) GO TO 85
      GO TO(85,70,75,80),K
   70 DELT=DELT+1.0D0
      TSUM =0.0D0
      GO TO 85
   75 ALT=ALT+1.0D0
      TSUM =0.0D0
      GO TO 85
   80 TSUM=0.D0
   85 IF(EQ.EQ.0.D0)SIG(K,JE)=TSUM
      IF(EQ.GT.0.D0)CROSS=TSUM
      IF(EQ.GT.0.D0)JJ=I
   90 CONTINUE
      AJMAX=DFLOAT(JMAX)*ED-ED/2.
      IF(EQ.GT.0.D0)GO TO 160
      GO TO (95,105,115,125),K
   95 Write(7,100)
  100 FORMAT(/,38X,'OPTICAL MODEL NEUTRON INVERSE CROSS SECTIONS'/)
      GO TO 135
  105 Write(7,110)
  110 FORMAT(//38X,'OPTICAL MODEL PROTON INVERSE CROSS SECTIONS'/)
      GO TO 135
  115 Write(7,120)
  120 FORMAT(//39X,'OPTICAL MODEL ALPHA INVERSE CROSS SECTIONS'/)
      GO TO 135
  125 Write(7,130)
  130 FORMAT(//37X,'OPTICAL MODEL DEUTERON INVERSE CROSS SECTIONS'/)
  135 Write(7,140)AJMAX
  140 FORMAT( 1H0'INVERSE REACTION CROSS SECT. FOR E=1 TO',F8.3,3HMEV )
      Write(7,145) (SIG(K,JE),JE=1,JMAX)
  145 FORMAT ( 1H ,10F9.3)
      WRITE(2,146) (SIG(K,JE),JE=1,JMAX)
  146 FORMAT(7E11.4)
  150 CONTINUE
  155 RETURN
  160 Write(7,165)CROSS
      WRITE(8,165)CROSS
  165 FORMAT(' REACTION CROSS SECTION COMPUTED BY OPTICAL MODEL SUBROUTI
     1NE',F10.2,' MB')
      EQ=0.D0
      Write(7,170)
  170 FORMAT(' PARTIAL REACTION CROSS SECTIONS,L=0 TO LMAX ')
      Write(7,145)(TL(I),I=1,30)
      GO TO 155
      END
*
*********************************************************************
*
      Subroutine PARAP(MX,JCAL)
*     -------------------------
*
C     QUICK CALCULATION OF NUCLEAR CROSS SECTIONS VIA OPTICAL MODEL
C     WITH PARABOLIC BARRIER - SEE THOMAS, PHYS REV 116,703 (1959) -
C     PROGRAM BELOW BY W. G. WINN
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION CNCS(300)
      COMMON/PARFS/DELRR(300),K6
      COMMON/PAR2/CNCSS
```

```
      COMMON/PAR3/EQ,SIGML(300),ACRS(300)
      COMMON/SHFT/QVAL,AP,AT,ZP,ZT,CLD,MC,MP,INVER,IKE,IPCH,BARFAC
      EN=EQ
      DO 10 I=1,300
    5 CNCS(I)=0.D0
      ACRS(I)=0.D0
   10 SIGML(I)=0.D0
      CCS=0.D0
      LMAX=300
      LCM=0
      LMAX=LMAX+1
      COUL=(1.4393)*ZT*ZP
      IF(AP-4.)30,30,25
   25 CONTINUE
      AR=AT**0.333333+AP**0.3333333
      RA=1.22*AR
      F=67.0D0
      GO TO 35
   30 AR=AT**.3333333
       AR=AT**.3333333
      RA=1.17*AR
      F=1100.0
   35 CONTINUE
      D=0.574
      U=AT*AP/(AT+AP)
      H2=41.814
      ACN=AP+AT
      CROTL=H2/(1.16*ACN**1.666666)
      CR2=D*COUL/F
      CR3P=H2*D/(F*U)
      IF(LCM) 40,40,45
   40 E=EN*AT/(AT+AP)
      EL=EN
      GO TO 50
   45 E=EN
      EL=EN*(AT+AP)/AT
   50 Write(7,55)
   55 FORMAT(3H0  )
      PWAVE=DSQRT(2.*931.16*U*E)
      WAVEL=19.732/PWAVE
      ARWAVE=3141.59*(WAVEL**2)
      SUMAL2=0.0D0
      SUMTL=0.0D0
      SUMDXL=0.0D0
      EROTLI=0.0D0
      DO 200 K=1,LMAX
      L=K-1
      R=RA
      AL=DFLOAT(L)
      CR3=CR3P*AL*(AL+1)
   95 RB=RA-D*DLOG(CR2/R**2+CR3/R**3)
      DELTR=DABS(RB-R)
      IF(DELTR-0.001D0) 105,100,100
  100 R=RB
      GO TO 95
  105 CONTINUE
      R0=RB/AR
      VLB=COUL/RB+(H2/2./U)*(AL*(AL+1)/RB**2)-F*DEXP(-(RB-RA)/D)
      D2VLB=2.*COUL/RB**3+(H2/U)*3.*AL*(AL+1)/RB**4
```

```
   1 -(F/D**2)*DEXP(-(RB-RA)/D)
     IF(D2VLB) 110,115,120
110  SD2VLB=-1.0D0
     GO TO 125
115  SD2VLB=0.0D0
     GO TO 125
120  SD2VLB=1.0D0
125  CONTINUE
     WL2=DABS((H2/U)*D2VLB)
     WL=DSQRT(WL2)
     TL=1./(1.+DEXP(2.*3.14159*(VLB-E)/WL))
     RSIGL=TL*(2.*AL+1.)
     SIGL=ARWAVE*RSIGL
     SIGML(K)=SIGL
     IF(JCAL.LE.0.OR.JCAL.EQ.2)GO TO 130
     GO TO 135
130  EROTL=DELRR(K)
     GO TO 140
135  EROTL=CROTL*AL*(AL+1.)
     DELRR(K)=EROTL
140  SIGXL2=AL*(AL+1.)*RSIGL

     IF(EROTL-0.5-EROTLI) 145,145,155
145  SUMDXL=SUMDXL+SIGL
     IF(TL-0.0001D0  ) 155,150,150
150  CONTINUE
     GO TO 175
155  IF(L) 170,170,160
160  Write(7,165) EROTLI,SUMDXL
     LX=IDINT(EROTL+.5)
     IF(TL.LT..0001D0)LX=LX+1
     ACRS(K-1)=SUMDXL
     MX=LX
165  FORMAT(3H+  ,107X,F5.1,1X,F7.2)
170  CONTINUE
     EROTLI=EROTLI+1.D0
     SUMDXL=SIGL
175  CONTINUE
     IF(L) 185,185,195
185  IF(TL-.0001D0)190,195,195
190  Write(7,165) EROTLI,SUMDXL
195  CONTINUE
     SUMTL=SUMTL+RSIGL
     SUMAL2=SUMAL2+SIGXL2
     IF(TL-.0001D0)205,200,200
200  CONTINUE
205  SIGMA=3141.59*(WAVEL**2)*SUMTL
     AVEL2=SUMAL2/SUMTL
     AVROE=AVEL2*CROTL
     RMSL2=DSQRT(AVEL2)
220  DO 230 I=1,300
     CCS=CCS+SIGML(I)
     CNCS(I)=CCS
     IF(SIGML(I))225,225,230
225  JJ=I-1
     GO TO 235
230  JJ=I
235  CONTINUE
     CNCSS=CNCS(JJ)
```

```
  250 RETURN
      END
*
***********************************************************************
*
      Subroutine PLEXC(NZL,NEPR)
*     -------------------------
*
C     PROGRAM FOR PLOTTING EXCITATION FUNCTIONS
C     NZL = NUMBER OF PROTONS EMITTED
C     NEPR = NUMBER OF ENERGIES CALCULATED (LE.20)
C     ECM = CM-ENERGIES OF PROJECTILE
C     RSUM = CROSS SECTIONS AS USED IN BLANN PROGRAM
C
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/PL1/ECM(70)
      COMMON/PL2/SUM(22,9,20)
      DIMENSION NPRINT(11)
      DIMENSION PL(11),XPL(121)
      LOGICAL TEN
      DATA PL/1H0,1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9,1HZ/
      DATA BLANK,STAR/1H ,1H*/
      EMX=ECM(1)
      EMN=EMX
      DO 5 N=2,NEPR
      EMX=DMAX1(EMX,ECM(N))
    5 EMN=DMIN1(EMN,ECM(N))
      KMN=IDINT(EMN)
      KMX=IDINT(EMX)
      TEN=.FALSE.
      FA=0.D0
      SLO=1.D0
      SHI=1000.D0
      DO 10 N=1,NEPR
      DO 10 L=1,11
      IF(SUM(L,NZL,N).LT.1000.D0)GO TO 10
      TEN=.TRUE.
      FA=1.D0
      SLO=10.D0
      SHI=10000.D0
      GO TO 15
   10 CONTINUE
   15 CONTINUE
      Write(7,20)
   20 FORMAT(1H1/)
      IF(TEN)Write(7,25)
      IF(.NOT.TEN)Write(7,30)
   25 FORMAT(3X,'10 ',24X,'50 ',10X,'100',24X,'500',9X,'1000',23X,'5000'
     1,8X,'10000  MB')
   30 FORMAT(4X,'1 ',25X,'5 ',10X,' 10',24X,' 50',9X,' 100',23X,' 500',8
     1X,' 1000  MB')
      Write(7,35)
   35 FORMAT(4X,1H*,3(26X,1H*,12X,1H*)/4X    ,121(1H*))
      DO 40 L=1,11
   40 NPRINT(L)=0
      DO 45 K=1,121
   45 XPL(K) = BLANK
      XPL(1) = STAR
      XPL(121) = STAR
```

```
      DO 100 K=KMN,KMX
      DO 55 N=1,NEPR
      IF (DFLOAT(K)-ECM(N)) 50,50,55
   50 IF (DFLOAT(K+1)-ECM(N)) 55,55,60
   55 CONTINUE
      GO TO 70
   60 DO 65 L = 1,11
      NPRINT(L) = 0
      SU=SUM(L,NZL,N)
      IF(SU.LE.SLO.OR.SU.GE.SHI)GO TO 65
      NPRINT(L)=(DLOG10(SU)-FA)*40.+2.
      KX = NPRINT(L)
      IF (KX.GT.0) XPL(KX) = PL(L)
   65 CONTINUE
   70 IF (DFLOAT(K/10).EQ.DFLOAT(K)/10.0) GO TO 80
      WRITE(7,75) XPL
   75 FORMAT (4H    ,121A1)
C     INCLUDE OTHER CARRIAGE CONTROL CHARACTER HERE
      GO TO 90
   80 IF(XPL(41).EQ.BLANK) XPL(41) = STAR
      IF(XPL(81).EQ.BLANK) XPL(81) = STAR
      WRITE(7,85) K,XPL,K
   85 FORMAT (1H ,I3,'*',121A1,'*',I3)
C     INCLUDE OTHER CARRIAGE CONTROL CHARACTER HERE FOR NO FORM ADV.
      XPL(41) = BLANK
      XPL(81) = BLANK
   90 DO 95 L=1,11
      IF (NPRINT(L).LE.0) GO TO 95
      KX = NPRINT(L)
      NPRINT(L) = 0
      XPL(KX) = BLANK
   95 CONTINUE
      XPL(1) = STAR
      XPL(121) = STAR
  100 CONTINUE
      Write(7,105)
  105 FORMAT(2(5H    *,119X,1H*/),4X,121(1H*)/4X,1H*,3(26X,1H*,12X,1H*))
      IF(TEN)Write(7,25)
      IF(.NOT.TEN)Write(7,30)
      Write(7,110)
  110 FORMAT(4X,1H*/7H ENERGY/ 7H (MEV) )
      RETURN
      END
*
*********************************************************************
*
      Subroutine PLOTRE
*     -----------------
*
C This subroutine calculates recoil spectra at the energy  of
C incident paticles UP TO THRESHOLD OF THE REACTION WITH MORE THAN
C ONE PARTICLE IN THE EXIT CHANNEL  (E.g. it gives correct result
C for n+Fe-56 reactions up to energy of (n,2n) reaction threshold)
C
C To use this subroutine it is necessary to repeat input card with
C the same incident energy three times introducing for the first run
C neutron angular distribution calculations, then proton ang. distri-
C butions and for the third run - alpha distributions. The last case
C of the output will contain sum of recoil spectra for neutron,
```

```
C proton and alpha emission
C
C Kalbach option for angular distributions is recommended to use

C this routine
C
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/SHFT/QVAL,AP,AT,ZP,ZT,CLD,MC,MP,INVER,IKE,IPCH,BARFAC
      COMMON/PAR3/EQ,SIGML(300),ACRS(300) /INCR/ED
      COMMON/SEND/IRFR,DLT,IADST
      COMMON/DIST/PROB(37,301),XZ(3),ALMIN(300),ALMAX(300),FIN,DTUP
     1,DSIGP(36,301),DSIGT(36,301),POD,PCS,N,NI,KE,EK,DADEG,TDEG,TDEG2
     2,AMN(300),AMX(300),XMIX
      COMMON/SFT5/EXC(10,24),XMAX
      COMMON/PL3/EB(70),RCSP(70),ZEE,AMASS,PLEX,NEPR
      COMMON/DIST1/GDPR(36,301),GL(36,301),CFRAC
     3,DTAU,SIGN(36),TMIX,IREFR,BJI(10)
      COMMON/MEMO4/RMEMT(31),KEY
      DIMENSION SPEREC(31),EKE(31),EMEMT(31)
      IF(IADST.eq.0) RETURN
c
c iadst i1  11 if=0,no angular distribution,if=1,yes-for neutrons;
c              =2,yes for protons; =3 for neutrons using Kalbach systematics;
c              =4 for protons using Kalbach systematics
c              =5 for alphas using Kalbach systematics
c
      IF(IADST.le.4) RM1 = 1.
      IF(IADST.eq.5) RM1 = 4.
                     RM2 = AMASS - RM1
                     RMA = 4.
        EMREC=9.*EQ/AT
                  HMEMT=EMREC+0.2
                  HMEMT=HMEMT/30.
               EMEMT(1)=0.
      DO 567 NU=2,31
  567     EMEMT(NU)=EMEMT(NU-1)+HMEMT
          EMEMT(31)=EQ
       IF(IADST.EQ.2. or. IADST.eq.4 .or. IADST.eq.5) GOTO 569
C RMEMT=0 only for first neutron card
              RMEMT(1)=0.
          DO 568 NU=2,31
  568     RMEMT(NU)=0.
                  Open(501,file='recoil.spe')
                  KEY=777
  569     Continue
                  If(KEY.eq.777)Rewind 501
       VCI = ( AP/(AP+AT) )*DSQRT(2.D+00*EQ/AP)
       CONFAC=3.1415926*5.D0/180.D0
      EOUT = DLT+ED/2.D0  -  DLT
      DO 519 KEF=1,300
      EOUT = EOUT+DLT
      V2SH=DSQRT( 2.D+00*EOUT*RM1/(RM2*RM2+RM2*RM1) )
      DO 509 ITH=1,36
      ANGLE =5.*DFLOAT(ITH)-2.5D0
         ANGLER=ANGLE*3.1415926/180.
      V2 = DSQRT( (VCI-V2SH*DCOS(ANGLER))**2 + (V2SH*DSIN(ANGLER))**2 )
      TREC = RM2*(V2**2)/2.0D+00
C Pseudo number of particles emitted
      DSS = SIGN(ITH)*DSIGT(ITH,KEF)*CONFAC   *  DLT
```

```
            If(DSS.eq.0.D+00) goto 509
            DO 500 ITT=1,31
            IF(TREC.LE.EMEMT(ITT)) GOTO 501
500         CONTINUE
            GOTO 90000
  501       RMEMT(ITT)=RMEMT(ITT)+DSS
  509  CONTINUE
  519  CONTINUE
              SUM = 0.0
              EKE(1) = EMEMT(1)
              DO 122 NU=2,31
122           EKE(NU)=(  EMEMT(NU-1) + EMEMT(NU)  ) / 2.
       SPEREC(1)=RMEMT(1)/HMEMT
       DO 121 NU=2,31
       SPEREC(NU)=RMEMT(NU)/(EMEMT(NU)-EMEMT(NU-1))
121           SUM=SUM+SPEREC(NU)
              SUM=SUM*HMEMT
              If(KEY.ne.777) goto 2000
          DO 200 I=1,31
          If(I.eq.1) Write(501,1001)EKE(I),SPEREC(I),EQ,IADST
          If(I.eq.2) Write(501,1002)EKE(I),SPEREC(I)
          If(I.eq.3) Write(501,1003)EKE(I),SPEREC(I)
          If(I.eq.4) Write(501,1004)EKE(I),SPEREC(I)
          If(I.ge.5) Write(501,1005)EKE(I),SPEREC(I)
200       Continue
1001      Format(1x,2g12.5,'    Recoil spectra for INCIDENT ENERGY',
     #    F8.1,10x,i5)
1002      Format(1x,2g12.5,
     #'   Pay attention, that correct result may be obtained only')
1003      Format(1x,2g12.5,
     #'   for projectile energies up to threshold of the reaction')
1004      Format(1x,2g12.5,
     #'   with more than one particle in the exit channel        ')
1005      Format(1x,2g12.5)
               If(IADST.eq.5) Close(501)
2000    RETURN
90000   PRINT 90001,TREC
90001   FORMAT(1X,'ERROR:    SUB PLOTRE   TREC=',G12.5)
        STOP
        END
*
*********************************************************************
*
      Subroutine PLOTSP(SON,SOP,SOA,SOD,SUMAPR,SUMDER,CSNON)
*     ------------------------------------------------------
*
C Printing particle production cross-section and particle spectra in
C separate files
C
      IMPLICIT REAL*8 (A-H,O-Z)
      Character Namful*12, Namrd*8, Inform(6)*8, Endcha(6)*3, Zero*6
      Character Parti(3)*1, C6*6
      COMMON/INCR/ED /MEMO/SCRS(300,4)
      COMMON/MEMO2/SCRA2(300,3) /MEMO2D/SCRD2(300,3)
      COMMON/SF6/AOZ,ZOZ,EN(4,300)
      COMMON/PAR3/EQ,SIGML(300),ACRS(300)
      COMMON/SHFT/QVAL,AP,AT,ZP,ZT,CLD,MC,MP,INVER,IKE,IPCH,BARFAC
      COMMON/ADDPC1/IWR(4),NAMRD /HOT/KPG,MPG
      COMMON/LCSCMS/LCS
```

```
      DIMENSION SCRX2(300,3)
      DATA ENDCHA/'nnn','ppp','aaa','ddd','ttt','hhh'/
      DATA INFORM/8H Neutron,8H  Proton,8H   Alpha,8HDeuteron,
     #            8H  Triton,8H    He-3/
      DATA ZERO/6H"0.00"/,Parti/1HN,1HP,1HX/
      CALL PLOTRE
                   IZP=IDINT(ZP+0.001)
                   IAP=IDINT(AP+0.001)
                   IZT=IDINT(ZT+0.001)
                   IAT=IDINT(AT+0.001)
                                          Iparti=3
                   If(IZP.eq.0 .and. IAP.eq.1)Iparti=1
                   If(IZP.eq.1 .and. IAP.eq.1)Iparti=2
         III=4+KPG
         Write(10,500)EQ,SOA,SUMAPR,SOD,SUMDER,SOP,CSNON,Inform(III),
     #   Inform(III),IZP,IAP,IZT,IAT
500      Format(f6.2,1pe12.3, 5e12.3,
     #   '  Energy,  Alpha(tot),  Alpha(pre), ',a8,
     #   '(tot),',
     #   a8,'(pre),',' Proton(tot), Csnon (all crs in mb),   Reaction:',
     #   2i2,' +',i3,i4)
      DO 1000 I=1,4
      IF(IWR(I).ne.1) goto 1000
                III = I
      IF(I.eq.4) III = I+KPG
                NAMFUL=NAMRD//'.'//ENDCHA(III)
                Open(3,file=Namful)
                If(I.eq.1) SUM=SOn
                If(I.eq.2) SUM=SOp
                If(I.eq.3) SUM=SOa
                If(I.eq.4) SUM=SOd
                If(I.eq.3) SUMPRE=SUMAPR
                If(I.eq.4) SUMPRE=SUMDER
      If(I.eq.3 .and. MPG.eq.1 ) then
                                 Do 70 ix1=1,300
                                 Do 70 ix2=1,3
   70                            SCRX2(ix1,ix2)=SCRA2(ix1,ix2)
                                 goto 900
                                 endif
      If(I.eq.4 .and. MPG.eq.2 ) then
                                 Do 72 ix1=1,300
                                 Do 72 ix2=1,3
   72                            SCRX2(ix1,ix2)=SCRD2(ix1,ix2)
                                 goto 900
                                 endif
          LLl=0
      DO 450 KEE=1,300
      IF(EN(I,KEE) .eq. 0.D0)GO TO 450
          LLl=LLl+1
      AKE0=DFLOAT(KEE)*ED-ED/2.
      AKE=AKE0
                           RKALB=0.
      If(EN(I,KEE).ne.0.0) RKALB=SCRS(KEE,I)/EN(I,KEE)
      If(RKALB.gt.1.0)     RKALB=1.0
      If(LCS.eq.1) CALL GOINLCS(III,AP,AT,EQ,AKE,RKALB,RLSCAN)
      C6='      '
      If(LCS.eq.1) Write(C6,'(f6.2)')RLSCAN
      SPEVAP = EN(I,KEE) - SCRS(KEE,I)
      If(LLl.eq.1)WRITE(3,1)AKE,SPEVAP,SCRS(KEE,I),EN(I,KEE),C6
```

```
      If(LLl.eq.2)WRITE(3,2)AKE,SPEVAP,SCRS(KEE,I),EN(I,KEE),C6,
     #            INFORM(III)
      If(LLl.eq.3)WRITE(3,3)AKE,SPEVAP,SCRS(KEE,I),EN(I,KEE),C6,
     #                      Parti(Iparti),IZT,IAT
      If(LLl.eq.4)WRITE(3,4)AKE,SPEVAP,SCRS(KEE,I),EN(I,KEE),C6,EQ
      If(LLl.eq.5)WRITE(3,5)AKE,SPEVAP,SCRS(KEE,I),EN(I,KEE),C6,MP
      If(LLl.eq.6)WRITE(3,6)AKE,SPEVAP,SCRS(KEE,I),EN(I,KEE),C6,SUM
      If(LLl.eq.7.and.I.le.2)WRITE(3,1)AKE,SPEVAP,SCRS(KEE,I),EN(I,KEE),
     #                       C6
      If(LLl.eq.7.and.I.ge.3)WRITE(3,7)AKE,SPEVAP,SCRS(KEE,I),EN(I,KEE),
     #                                 C6,SUMPRE
      If(LLl.eq.8.and.LCS.ne.1)WRITE(3,8)AKE,SPEVAP,SCRS(KEE,I),
     #                         EN(I,KEE),C6
      If(LLl.eq.8.and.LCS.eq.1)WRITE(3,88)AKE,SPEVAP,SCRS(KEE,I),
     #                         EN(I,KEE),C6
      If(LLl.eq.9)WRITE(3,1)AKE,SPEVAP,SCRS(KEE,I),EN(I,KEE),C6
      If(LLl.eq.10.and.LCS.ne.1)WRITE(3,1)AKE,SPEVAP,SCRS(KEE,I),
     #                          EN(I,KEE),C6
      If(LLl.eq.10.and.LCS.eq.1)WRITE(3,101)AKE,SPEVAP,SCRS(KEE,I),
     #                          EN(I,KEE),C6
      If(LLl.gt.10.and.SPEVAP.gt.0.0)
     # WRITE(3,1)AKE,SPEVAP,SCRS(KEE,I),EN(I,KEE),C6
      If(LLl.gt.10.and.SPEVAP.le.0.0)
     # WRITE(3,10)AKE,ZERO,SCRS(KEE,I),EN(I,KEE),C6
1     Format(f9.3,1pe14.3,2e14.3,A6)
2     Format(f9.3,1pe14.3,2e14.3,A6,3x,A8,'-spectrum')
3     Format(f9.3,1pe14.3,2e14.3,A6,6x,a1,' +',i3,i4)
4     Format(f9.3,1pe14.3,2e14.3,A6,3x,'Projectile energy =',0pf6.2)
5     Format(f9.3,1pe14.3,2e14.3,A6,3x,'MP=',i3)
6     Format(f9.3,1pe14.3,2e14.3,A6,3x,'Xsect(tot)=',0pf10.4)
7     Format(f9.3,1pe14.3,2e14.3,A6,3x,'Xsect(pre)=',0pf10.4)
8     Format(f9.3,1pe14.3,2e14.3,A6,3x,'A-Energy, B-Eq, C-Pre, D-Tot')
88    Format(f9.3,1pe14.3,2e14.3,A6,3x,'A-Energy, B-Eq, C-Pre, D-Tot,',
     #                               ' E-Energy(LCS)/E(chan)')
10    Format(f9.3,a14,1pe14.3,e14.3,A6)
101   Format(f9.3,1pe14.3,2e14.3,A6,3x,'Outgoing energy is in LCS ')
  450 Continue
                Close(3)
                Goto 1000
C
C Alphas and deuterons with MULTIPLE precompound option
900       LLl=0
      DO 750 KEE=1,300
      IF(EN(I,KEE) .eq. 0.D0)GO TO 750
          LLl=LLl+1
      AKE0=DFLOAT(KEE)*ED-ED/2.
      AKE=AKE0
      SPEVAP = EN(I,KEE) - SCRS(KEE,I) - SCRX2(KEE,1) - SCRX2(KEE,2) -
     #         SCRX2(KEE,3)
      SPPRE = SCRS(KEE,I) + SCRX2(KEE,1) + SCRX2(KEE,2) +
     #         SCRX2(KEE,3)
                          RKALB=0.
      If(EN(I,KEE).ne.0.0) RKALB=SPPRE/EN(I,KEE)
      If(RKALB.gt.1.0)     RKALB=1.0
      If(RKALB.lt.0.0)     RKALB=0.0
      If(LCS.eq.1) CALL GOINLCS(III,AP,AT,EQ,AKE,RKALB,RLSCAN)
      IF(EN(I,KEE) .le. 1.D-45) EN(I,KEE)=1.d-45
      If(SPPRE.gt.0.d0.and.SPPRE.le.1.D-45) SPPRE=1.d-45
      If(LLl.eq.1)WRITE(3,11)AKE,SPEVAP,SCRS(KEE,I),
```

```
#SCRX2(KEE,1),SCRX2(KEE,2),SCRX2(KEE,3),SPPRE,
#EN(I,KEE)
 If(LLl.eq.2)WRITE(3,12)AKE,SPEVAP,SCRS(KEE,I),
#SCRX2(KEE,1),SCRX2(KEE,2),SCRX2(KEE,3),SPPRE,
#EN(I,KEE),INFORM(i)
 If(LLl.eq.3)WRITE(3,13)AKE,SPEVAP,SCRS(KEE,I),
#SCRX2(KEE,1),SCRX2(KEE,2),SCRX2(KEE,3),SPPRE,
#EN(I,KEE),
#                     Parti(Iparti),IZT,IAT
 If(LLl.eq.4)WRITE(3,14)AKE,SPEVAP,SCRS(KEE,I),
#SCRX2(KEE,1),SCRX2(KEE,2),SCRX2(KEE,3),SPPRE,
#EN(I,KEE),EQ
 If(LLl.eq.5)WRITE(3,15)AKE,SPEVAP,SCRS(KEE,I),
#SCRX2(KEE,1),SCRX2(KEE,2),SCRX2(KEE,3),SPPRE,
#EN(I,KEE),MP
 If(LLl.eq.6)WRITE(3,16)AKE,SPEVAP,SCRS(KEE,I),
#SCRX2(KEE,1),SCRX2(KEE,2),SCRX2(KEE,3),SPPRE,
#EN(I,KEE),SUM
 If(LLl.eq.7)WRITE(3,17)AKE,SPEVAP,SCRS(KEE,I),
#SCRX2(KEE,1),SCRX2(KEE,2),SCRX2(KEE,3),SPPRE,
#EN(I,KEE), SUMPRE
 If(LLl.eq.8)then
             If(MPG.eq.1) then
             WRITE(3,18)AKE,SPEVAP,SCRS(KEE,I),
c            SCRX2(KEE,1),SCRX2(KEE,2),SCRX2(KEE,3),SPPRE,
c            EN(I,KEE)
                        else
             WRITE(3,181)AKE,SPEVAP,SCRS(KEE,I),
c            SCRX2(KEE,1),SCRX2(KEE,2),SCRX2(KEE,3),SPPRE,
c            EN(I,KEE)
                        endif
             endif
 If(LLl.eq.9)then
             If(MPG.eq.1) then
             WRITE(3,19)AKE,SPEVAP,SCRS(KEE,I),

c            SCRX2(KEE,1),SCRX2(KEE,2),SCRX2(KEE,3),SPPRE,
c            EN(I,KEE)
                        else
             WRITE(3,191)AKE,SPEVAP,SCRS(KEE,I),
c            SCRX2(KEE,1),SCRX2(KEE,2),SCRX2(KEE,3),SPPRE,
c            EN(I,KEE)
                        endif
             endif
 If(LLl.eq.10.and.SPEVAP.gt.0.0)
# WRITE(3,11)AKE,SPEVAP,SCRS(KEE,I),
#SCRX2(KEE,1),SCRX2(KEE,2),SCRX2(KEE,3),SPPRE,
#EN(I,KEE)
 If(LLl.eq.10.and.SPEVAP.le.0.0)
# WRITE(3,20)AKE,ZERO,SCRS(KEE,I),
#SCRX2(KEE,1),SCRX2(KEE,2),SCRX2(KEE,3),SPPRE,
#EN(I,KEE)
 If(LLl.eq.11.and.SPEVAP.gt.0.0) then
 IF(LCS.ne.1) then
 WRITE(3,11)AKE,SPEVAP,SCRS(KEE,I),
#SCRX2(KEE,1),SCRX2(KEE,2),SCRX2(KEE,3),SPPRE,
#EN(I,KEE)
              else
 WRITE(3,1100)AKE,SPEVAP,SCRS(KEE,I),
```

```
     #SCRX2(KEE,1),SCRX2(KEE,2),SCRX2(KEE,3),SPPRE,
     #EN(I,KEE)
                  endif
                                      endif
      If(LLl.eq.11.and.SPEVAP.le.0.0) then
      IF(LCS.ne.1) then
      WRITE(3,20)AKE,ZERO,SCRS(KEE,I),
     #SCRX2(KEE,1),SCRX2(KEE,2),SCRX2(KEE,3),SPPRE,
     #EN(I,KEE)
                  else
      WRITE(3,2000)AKE,ZERO,SCRS(KEE,I),
     #SCRX2(KEE,1),SCRX2(KEE,2),SCRX2(KEE,3),SPPRE,
     #EN(I,KEE)
                  endif
                                      endif
      If(LLl.gt.11.and.SPEVAP.gt.0.0)
     # WRITE(3,11)AKE,SPEVAP,SCRS(KEE,I),
     #SCRX2(KEE,1),SCRX2(KEE,2),SCRX2(KEE,3),SPPRE,
     #EN(I,KEE)
      If(LLl.gt.11.and.SPEVAP.le.0.0)
     # WRITE(3,20)AKE,ZERO,SCRS(KEE,I),
     #SCRX2(KEE,1),SCRX2(KEE,2),SCRX2(KEE,3),SPPRE,
     #EN(I,KEE)
11    Format(f9.3,1pe14.3,6e14.3)
1100  Format(f9.3,1pe14.3,6e14.3,3x,'Outgoing energy is in LCS ')
12    Format(f9.3,1pe14.3,6e14.3,3x,A8,'-spectrum')
13    Format(f9.3,1pe14.3,6e14.3,6x,a1,' +',i3,i4)
14    Format(f9.3,1pe14.3,6e14.3,3x,'Projectile energy =',0pf6.2)
15    Format(f9.3,1pe14.3,6e14.3,3x,'MP=',i3)
16    Format(f9.3,1pe14.3,6e14.3,3x,'Xsect(tot)=',0pf10.4)
17    Format(f9.3,1pe14.3,6e14.3,3x,'Xsect(pre)=',0pf10.4)
18    Format(f9.3,1pe14.3,6e14.3,3x,
     #  'A-Energy, B-Eq, C-Pre(1a), D-Pre(na), E-Pre(pa)')
181   Format(f9.3,1pe14.3,6e14.3,3x,
     #  'A-Energy, B-Eq, C-Pre(1d), D-Pre(nd), E-Pre(pd)')
19    Format(f9.3,1pe14.3,6e14.3,3x,'F-Pre(aa), G-Pre(Sum), H-Tot')
191   Format(f9.3,1pe14.3,6e14.3,3x,'F-Pre(notused), G-Pre(Sum), H-Tot')
20    Format(f9.3,a14,1pe14.3,5e14.3)
2000  Format(f9.3,a14,1pe14.3,5e14.3,3x,'Outgoing energy is in LCS ')
  750 Continue
                Close(3)
 1000 Continue
      Return
      End
*
*********************************************************************
*
      Subroutine PLT
*     --------------
*
      IMPLICIT REAL*8 (A-H,O-Z)
      Character CCCZ*2,CCCA1*1,CCCA2*2,CCCA3*3,OUTNAM*12,OUTNA1*6
      DIMENSION MA(22)
      COMMON/PL1/ECM(70) /PL2/SUM(22,9,20) /NAME/K2
      COMMON/PL3/EB(70),RCSP(70),ZEE,AMASS,PLEX,NEPR
      COMMON/UG/IZ,IA /PL5/TITLE(20),NA,NZ
      COMMON/PL4/CRS(22,9)
      COMMON/SHFT/QVAL,AP,AT,ZP,ZT,CLD,MC,MP,INVER,IKE,IPCH,BARFAC
      Dimension NAMNUC(101)
```

```
      DATA NAMNUC/
     $2H_H, 2HHE, 2HLI, 2HBE, 2H_B, 2H_C, 2H_N, 2H_O,
     $2H_F, 2HNE, 2HNA, 2HMG, 2HAL, 2HSI, 2H_P, 2H_S,
     $2HCL, 2HAR, 2H_K, 2HCA, 2HSC, 2HTI, 2H_V, 2HCR,
     $2HMN, 2HFE, 2HCO, 2HNI, 2HCU, 2HZN, 2HGA, 2HGE,
     $2HAS, 2HSE, 2HBR, 2HKR, 2HRB, 2HSR, 2H_Y, 2HZR,
     $2HNB, 2HMO, 2HTC, 2HRU, 2HRH, 2HPD, 2HAG, 2HCD,
     $2HIN, 2HSN, 2HSB, 2HTE, 2H_I, 2HXE, 2HCS, 2HBA,
     $2HLA, 2HCE, 2HPR, 2HND, 2HPM, 2HSM, 2HEU, 2HGD,
     $2HTB, 2HDY, 2HHO, 2HER, 2HTM, 2HYB, 2HLU, 2HHF,
     $2HTA, 2H_W, 2HRE, 2HOS, 2HIR, 2HPT, 2HAU, 2HHG,
     $2HTL, 2HPB, 2HBI, 2HPO, 2HAT, 2HRN, 2HFR, 2HRA,
     $2HAC, 2HTH, 2HPA, 2H_U, 2HNP, 2HPU, 2HAM, 2HCM,
     $2HBK, 2HCF, 2HES, 2HFM, 2HMD/
       GO TO(5,15,25),K2
    5 DO 10 IZ=1,9
      DO 10 IA=1,22
      DO 10 NEPR = 1,20
   10 SUM(IA,IZ,NEPR) = 0.0
      RETURN
   15 DO 20 IM=1,NA
      DO 20 IZ=1,NZ
   20 SUM(IM,IZ,NEPR)=CRS(IM,IZ)
C   20 CONTINUE
      RETURN
   25 NZL=1
      NZPL=NZ
   30 IF(NZL.GT.PLEX)RETURN
      MZ=IDINT(ZEE)
      MA(1)=IDINT(AMASS)
      DO 35 IK=2,11
   35 MA(IK)=MA(IK-1)-1
   40 Write(7,80)TITLE
      Write(7,70)
      Write(7,60)MZ,MZ,MZ,MZ,MZ,MZ,MZ,MZ,MZ,MZ,MZ
      Write(7,65)(MA(I),I=1,11)
   45 CONTINUE
                  IZP=IDINT(ZP+0.001)
                  IAP=IDINT(AP+0.001)
                  IZT=IDINT(ZT+0.001)
                  IAT=IDINT(AT+0.001)
        DO 155 IA=1,11
        OPEN(700,file='erase.me')
        Write(700,1111)namnuc(MZ),MA(IA)
1111    Format(a2,i3)
        Backspace (700)
        If(MA(IA).ge.100) Read(700,2221)CCCZ,CCCA3
        If(MA(IA).ge.100) OUTNA1=CCCZ//'_'//CCCA3
2221    Format(a2,a3)
        If(10.le.MA(IA).and.MA(IA).lt.100)
     #  Read(700,2222)CCCZ,CCCA2
        If(10.le.MA(IA).and.MA(IA).lt.100)
     #  OUTNA1=CCCZ//'_'//CCCA2
2222    Format(a2,1x,a2)
        If(MA(IA).lt.10) Read(700,2223)CCCZ,CCCA1
        If(MA(IA).lt.10) OUTNA1=CCCZ//'_'//CCCA1
2223    Format(a2,2x,a1)
        OUTNAM='_'//OUTNA1//'.DAT'
        Close(unit=700)
```

```
C Check for zero xsect
                                    IFLAG=0
        DO 135 N=1,NEPR
        If(SUM(IA,NZL,N).ne.0.D+00) IFLAG=1
  135   CONTINUE
        IF(IFLAG.EQ.0) goto 155
        OPEN(700,file=OUTNAM)
        DO 145 N=1,NEPR

        If(N.eq.1.and.SUM(IA,NZL,N).ne.0.D+00)
     #  Write(700,751)EB(N),SUM(IA,NZL,N),MZ,NAMNUC(MZ),
     #  MA(IA), IZP,IAP,IZT,IAT
        If(N.eq.1.and.SUM(IA,NZL,N).eq.0.D+00)
     #  Write(700,7511)EB(N),SUM(IA,NZL,N),MZ,NAMNUC(MZ),
     #  MA(IA), IZP,IAP,IZT,IAT
  751   Format(1Pe12.5,5x,e12.5,'   "',i2,'-',a2,'-',i3,' production ',
     #  'in reaction:', 2i2,' +',i3,i4,'"')
 7511   Format(1Pe12.5,4x,'"',e12.5,'"  "',
     #  i2,'-',a2,'-',i3,' production ',
     #  'in reaction:', 2i2,' +',i3,i4,'"')
        If(N.eq.2.and.SUM(IA,NZL,N).ne.0.D+00)
     #  Write(700,752)EB(N),SUM(IA,NZL,N), MC,MP,INVER
        If(N.eq.2.and.SUM(IA,NZL,N).eq.0.D+00)
     #  Write(700,7522)EB(N),SUM(IA,NZL,N), MC,MP,INVER
  752   Format(1Pe12.5,5x,e12.5,
     #'   "ALICE parameters: MC=',i2,', MP=',i2,', INVER=',i2,'"')
 7522   Format(1Pe12.5,4x,'"',e12.5,
     #'"  "ALICE parameters: MC=',i2,', MP=',i2,', INVER=',i2,'"')
        If(N.gt.2.and.SUM(IA,NZL,N).ne.0.D+00)
     #  Write(700,753)EB(N),SUM(IA,NZL,N)
        If(N.gt.2.and.SUM(IA,NZL,N).eq.0.D+00)
     #  Write(700,7533)EB(N),SUM(IA,NZL,N)
  753   Format(1Pe12.5,5x,e12.5)
 7533   Format(1Pe12.5,4x,'"',e12.5,'"')
  145   CONTINUE
        Close(unit=700)
  155   CONTINUE
      DO 55 N=1,NEPR
      IF(RCSP(N))55,55,50
   50 Write(7,75)ECM(N),EB(N),RCSP(N),(SUM(IA,NZL,N),IA=1,11)
   55 CONTINUE
      NZL1 = NZL -1
      IF (NZL.LE.NZPL) CALL PLEXC (NZL,NEPR)
      IF (NZL.LE.NZPL) WRITE(7,85) TITLE,NZL1
      NZL = NZL + 1
      AMASS=AMASS-1.D0
      ZEE=ZEE-1.D0
      GO TO 30
   60 FORMAT('  EXC  ELAB  RCS ',11(3X,I3,4X))
   65 FORMAT(' (MEV) (MEV) (MB)',11(3X,I3,4X))
   70 FORMAT(' EXCITATION FUNCTION DATA ')
   75 FORMAT(1X,F5.1,1X,F5.1,1X,F6.1,11(1X,F8.3,1X))
   80 FORMAT(1H1,20A4)
   85 FORMAT (1H0,20A4/1H ,'PLOT SYMBOL = NUMBER OF NEUTRONS EMITTED'/
     1 1H ,'NUMBER OF PROTONS EMITTED = ',I1,' FOR THIS SET OF EXCITATIO
     2N FUNCTIONS')
      END
*
*********************************************************************
```

```
*
      Subroutine QROT(A,BET,SIG,U,QR)
*     ------------------------------
*
C Written by A.V.Ignatyuk
C
C QROT INCLUDING DAMPING
      IMPLICIT REAL*8 (A-H,O-Z)
      FR(U)=1./(1.+DEXP((U-UCR)/DCR))
      UCR=120.*BET*BET*A**.33333333
      DCR=1400.*BET*BET/A**.66666666
      IF(BET) 10,10,11
   10 QR=1.D0
      GOTO 12
   11 QR=FR(U)*(SIG-1.)+1.
   12 RETURN
      END
*
*********************************************************************
*
      Real*8 Function QUASID(EXX,EG,DANG)
*     -----------------------------------
*
C VERSION: No angular distributions
C
C To include angular distributions delete comments ***ANG in this
C routine and FASTG
C
        IMPLICIT REAL*8 (A-H,O-Z)
        COMMON/XXXXXX/EIN(41),D(41,71,2),DA(71,2),KEYKEY
           E=EXX
           IF(KEYKEY.EQ.1234567) GOTO 22222
           open(888,file='data')
C See below open(888,file='angle')
           Data STAR0/'*'/
           Do 2 IT=1,41
           EIN(IT) = 1000.
           Do 2 IE=1,71
C Max energy
           D(IT,IE,1) = 1000.
           DA(IE,1) = 1000.
C dN/dE
           D(IT,IE,2) = 0.0
2          DA(IE,2) = 0.0
           Read(888,1,end=70000)STAR,T
1          Format(a1,g12.5)
              Do 1000 IT=1,111111111
                         IF(IT.gt.41) then
                                      Print *,' IT invalid ...'
                                      Stop
                                      endif
           EIN(IT) = T
              Do 100 IE=1,1111111111
                         IF(IE.gt.71-1) then
                                        Print *,' IE invalid ...'
                                        Stop
                                        endif
           Read(888,1,end=2000)STAR,T
           If(STAR.eq.STAR0) goto 1000
```

```
          Backspace 888
          Read(888,*)EE,DD
          D(IT,IE,1) = EE
          D(IT,IE,2) = DD
100       Continue
1000      Continue
2000      Close(888)
C
***ANG          Open(888,file='angle')
***ANG             Do 101 IE=1,1111111111
***ANG                         IF(IE.gt.71-1) Print *,'(833) IE invalid ...'
***ANG                         IF(IE.gt.71-1) Stop
***ANG          Read(888,*,end=2001)EE,DD
***ANG          DA(IE,1) = EE
***ANG          DA(IE,2) = DD
***ANG 101      Continue
***ANG 2001     Continue
***ANG          Close(888)
C
           KEYKEY=1234567
22222      Continue
           DO 11 IEIN=1,41
           If(E.lt.EIN(IEIN)) goto 22
11         Continue
           Print *,'ERROR  E=',E
           Stop
22         Continue
           If(IEIN.eq.1) RETURN
         IEIN1=IEIN-1
         IEIN2=IEIN
           RR1=ABS(E-EIN(IEIN1))
           RR2=ABS(E-EIN(IEIN2))
                          ICH=IEIN1
           IF(RR2.lt.RR1) ICH=IEIN2
C
           DO 10 IE=1,71
           If(EG.lt.D(ICH,IE,1)) goto 20
10         Continue
           Print *,'ERROR(DO 10)  EG=',EG
           Stop
20         If(IE.eq.1) Print *,'After Do 10 Error IE=1'
           If(IE.eq.1) STOP
          CALL REGR1(D(ICH,IE-1,1),D(ICH,IE,1),
     #               D(ICH,IE-1,2),D(ICH,IE,2),AAA,BBB)
           D1 = AAA*EG+BBB
           QUASID = D1
        If(QUASID.le.0.0D+00) QUASID = 0.0D+00
* ANGULAR
***ANG           DO 1111 IE=1,71
***ANG           If(EG.lt.DA(IE,1)) goto 2222
***ANG 1111      Continue
***ANG           Print *,'ERROR(DO 1111)  EG=',EG
***ANG           Stop
***ANG 2222      If(IE.eq.1) Print *,'After Do 1111 Error IE=1'
***ANG           If(IE.eq.1) STOP
***ANG         CALL REGR1(DA(IE-1,1),DA(IE,1),
***ANG     #              DA(IE-1,2),DA(IE,2),AAA,BBB)
***ANG           DANG = AAA*EG+BBB
***ANG       If(DANG.le.0.0D+00) DANG = 0.0D+00
```

```
C
        Return
70000   PRINT 70001
        WRITE(7,70001)
70001   FORMAT(//,'DATA FILE NEEDED FOR CALCULATIONS OF GAMMA SPECTRA',
     #  ' PRODUCED IN QUASI-DEUTERON PROCESS IS ABSENT...')
        STOP
        End
*
*********************************************************************
*
      Subroutine QVIBR(T,OM,CGA,LAM,Q)
*     ------------------------------
*
C Written by A.V.Ignatyuk
C
C  QVIBR INCLUDING DAMPING
      IMPLICIT REAL*8 (A-H,O-Z)
      Q=1.D0
      IF(T.LT.0.05) GOTO 10
      GAM=CGA*(OM**2+(2.*3.141593*T)**2)/2.
      FN=DEXP(-GAM/OM)/(DEXP(OM/T)-1.)
      IF(FN.LT.0.) GOTO 10
      U=LAM*OM*FN
      S=LAM*((1.+FN)*DLOG(1.+FN)-FN*DLOG(FN))
      Q=DEXP(S-U/T)
   10 RETURN
      END
*
*********************************************************************
*
        Subroutine READD(CHANGEXS,
     #                   NAME_of_FILE_with_NONelastic_CROSS_SECTION)
*       ----------------------------------------------------------
*
         IMPLICIT REAL*8 (A-H,O-Z)
         Character NAME_of_FILE_with_NONelastic_CROSS_SECTION*12,C1*1
         COMMON/EREN95/EREN(1500),CSREN(1500),NMAX
         COMMON/SHFT/QVAL9,AP9,AT9,ZP9,ZT9,CLD9,MC9,MP9,INVER9,IKE9,
     c              IPCH9,BARFAC9
         Backspace 5
*
* if first symbol is "C", "c", "*", "+" or "-" omit the reading of
* new nonelastic cross-section
*
         Read(5,'(a1)') C1
         If(C1.eq.'C'.or.C1.eq.'c'.or.C1.eq.'*'.or.C1.eq.'+'.or.
     #   C1.eq.'-') then
                    Return
                    endif
                    backspace 5
         read(5,'(a12)')NAME_of_FILE_with_NONelastic_CROSS_SECTION
         open(79,file=NAME_of_FILE_with_NONelastic_CROSS_SECTION)
*
                                       IZP=Idint(ZP9+0.001d0)
                                       IAP=Idint(AP9+0.001d0)
                                       IZT=Idint(ZT9+0.001d0)
                                       IAT=Idint(AT9+0.001d0)
*
```

```
Check if file contains correct information
*
         read(79,*,err=90000,end=90000) ZP2,AP2,ZT2,AT2
                                        IZP2=Idint(ZP2+0.001d0)
                                        IAP2=Idint(AP2+0.001d0)
                                        IZT2=Idint(ZT2+0.001d0)
                                        IAT2=Idint(AT2+0.001d0)
         If(IZP.ne.IZP2.or.IAP.ne.IAP2.or.IZT.ne.IZT2.or.IAT.ne.IAT2)
     c   goto 95000
         nmax=0
         Do I=1,111111111
         READ(79,*,err=90000,end=1)EREN(I),CSREN(I)
         nmax=nmax+1
            IF(nmax.gt.1500)then
            Print *,
     #      'Subroutine READD:  Dimension of ARRAYS is NOT sufficient !'
                        pause
                        stop
                        endif

         Enddo
    1    Close(79)
         If(nmax.eq.0) goto 90000
         CHANGEXS=1.0
         Return
90000    Print 90001,NAME_of_FILE_with_NONelastic_CROSS_SECTION
90001    Format(/1x,'S u b r o u t i n e   READD:'/1x,7x,
     #   'File ',a12,' with new Nonelastic cross-section is absent',
     #   /1x,' OR prepared incorrectly !')
         print *,'                          press <Enter>...'
         pause
         stop
95000    Print 95001,IZP,IAP,IZT,IAT,
     c   NAME_of_FILE_with_NONelastic_CROSS_SECTION,IZP2,IAP2,IZT2,IAT2
95001    Format(///1x,10(' ERROR ')//
     c   ' ALICE main input is prepared for ',i2,i3,' + ',i3,i4,
     c   ' interaction'/1x,32x,'B U T '/1x,
     c   'Reaction cross-section will be taken from file ',a12,'  for'/
     c   t35,i2,i3,' + ',i3,i4//
     c  '(message from  subroutine READD)'/)
         print *,'                                    press <Enter>...'
         pause
         stop
         End
*
**********************************************************************
*
      Subroutine REGR1(X1,X2,Y1,Y2,A,B)
*     ---------------------------------
*
       IMPLICIT REAL*8 (A-H,O-Z)
       RR=X2-X1
       A=(Y2-Y1)/RR
       B=(Y1*X2-X1*Y2)/RR
       RETURN
       END
*
**********************************************************************
*
```

```
        Subroutine RENCS(EQ,CROSS)
*       -------------------------
*
C Renormalization of nonelastic cross-section
C
        IMPLICIT REAL*8 (A-H,O-Z)
        COMMON/EREN95/EREN(1500),CSREN(1500),NMAX
             EN = EQ
         Do I=1,NMAX
         IR=I
         If(EN.le.EREN(I)) goto 2
         Enddo
         Print 80000,EN,EREN(nmax)
80000    Format(' S u b r o u t i n e   RENCS: '/
     #   'Energy of PROJECTILE =',g12.5,' MeV'/1x,
     #   20x,'B U T'/1x,' maximal EREN =',g12.5,'MeV   is TOO SMALL !')
         print *,'                          press <Enter>...'
         pause
         stop
    2    IF(IR.eq.1)then
         Print 80001,EN,EREN(1)
80001    Format(' S u b r o u t i n e   RENCS: '/
     #   'Energy of PROJECTILE =',g12.5,' MeV'/1x,
     #   20x,'B U T'/1x,' minimal EREN =',g12.5,'MeV   is TOO BIG !')
         print *,'                          press <Enter>...'
         pause
         stop
         endif
              X1 = EREN(IR-1)
              X2 = EREN(IR)
              Y1 = CSREN(IR-1)
              Y2 = CSREN(IR)
         RR=x2-x1
         AAA=(y2-y1)/rr
         BBB=(y1*x2-x1*y2)/rr
              CS = AAA*EN+BBB
         CROSS = CS
         RETURN
         END
*
*************************************************************************
*
       Subroutine SHAFT
*      ----------------
*
       IMPLICIT REAL*8 (A-H,O-Z)
       Character Partix(3)*9, Partx(3)*5
       DIMENSION MS(22),ASUM(10)
       COMMON/CS/CRSUM /MEMO/SCRS(300,4) /PL7/MAS
       COMMON/S1/JFRAC,JUPPER /PL8/JAMMA(10,24),NULIM(10,24)
       COMMON/UG/IZ,IA /SS/SOR,RR
       COMMON/SHFT/QVAL,AP,AT,ZP,ZT,CLD,MC,MP,INVER,IKE,IPCH,BARFAC
       CHARACTER*4 SYMB,SYMBP,SYMBS
       COMMON/LYM1/BE(11,24,4),SYMB(11,24),PAIR(11,24),SYMBP(11,24),
      1SYMBS(11,24),XMAS(11,24),DELSHL(11,24),AMAS(11,24)
       COMMON/PL3/EB(70),RCSP(70),ZEE,AMASS,PLEX,NEPR
       COMMON/PAR3/EQ,SIGML(300),ACRS(300)
       COMMON/SFT5/EXC(10,24),XMAX /PL5/TITLE(20),NA,NZ
       COMMON/SF6/AOZ,ZOZ,EN(4,300) /LAB3/SIG(4,300)
```

```
      COMMON/NHY/TD,EX1,EX2,TMX,AV,GAV,IJ,COST,JL,JI,JJ,B(3)
      COMMON/NHY2/GDO,BISP /SFT9/K5,PLD,JMAX,C(4),DELT,ALT
      COMMON/SF/M3,KPLT /SEND/IRFR,DLT,IADST
      COMMON/NR34/NR3,NR4,KE5,TEM(36),I3D,IRTST,I3T2,IJKL
      COMMON/PL4/CRS(22,9) /HJK/RCSS,JANG /INCR/ED
      COMMON/SHFT2/K3,FS(22),DSP(22),BRR(22),DER(22),ER(22),FISS,SUMIZ
     1,CX(22),BILSUM,JCAL,XMISS /SHFT3/CORG(30) /SCR/K9 /TST/TEST
      COMMON/DIST/PROB(37,301),XZ(3),ALMIN(300),ALMAX(300),FIN,DTUP
     1 ,DSIGP(36,301),DSIGT(36,301),POD,PCS,N,NI,KE,EK,DADEG,TDEG,TDEG2
     2,AMN(300),AMX(300),XMIX /DIST1/GDPR(36,301),GL(36,301),CFRAC
     3,DTAU,SIGN(36),TMIX,IREFR,BJI(10)
      COMMON/IST/ISOT,FRACTS,FRACT,CCRS(32,9,20)
      COMMON/IST1/EEN(4,300,20),IIKL,ENGBUF(20),KNZ,EXD,IDELM
      COMMON/IALPH/IALPHA /RATMP/RATMP1,SUMAPR,SUMDER
      COMMON/HOT/KPG,MPG
      DATA PARTIX/9HDEUTERONS,9HTRITONS  ,9HHELIONS  /
      DATA PARTX/5HDEUTR,5HTRIT ,5HHE-3 /
C (x,2n)
      IZN2N = Int( ZP + ZT +      0.001)
      IAN2N = Int( AP + AT - 2. + 0.001)
C (x,p)
      IZNP = Int( ZP + ZT - 1. + 0.001 )
      IANP = Int( AP + AT - 1. + 0.001 )
C (x,a)
      IZNA = Int( ZP + ZT - 2. + 0.001 )
      IANA = Int( AP + AT - 4. + 0.001 )
C (x,na)
      IZNNA = Int( ZP + ZT -2. + 0.001 )
      IANNA = Int( AP + AT -5. + 0.001 )
C (x,np)
      IZNNP = Int( ZP + ZT -1. + 0.001 )
      IANNP = Int( AP + AT -2. + 0.001 )
              IZP7 = INT(ZP+0.001)
              IAP7 = INT(AP+0.001)
              IZT7 = INT(ZT+0.001)
              IAT7 = INT(AT+0.001)
      IF(K3.EQ.1)GO TO 60
      IF(K3.EQ.2)GO TO 95
      IF(K3.EQ.3)GO TO 340
      IF(K3.EQ.4)GO TO 430
      IF(K3.EQ.5)GO TO 531
   60 K3=0
      MS(1)=MAS
                          LN2N = 0
                          LNP  = 0
                          LNA  = 0
                          LNNA = 0
                          LNNP = 0
        If(MS(1 ).eq.IANP)  LNP  = 1
      DO 65 IN=2,22
      MS(IN)=MS(1)-IN+1
        If(MS(IN).eq.IAN2N) LN2N = IN
        If(MS(IN).eq.IANP)  LNP  = IN
        If(MS(IN).eq.IANA)  LNA  = IN
        If(MS(IN).eq.IANNA) LNNA = IN
        If(MS(IN).eq.IANNP) LNNP = IN
   65 Continue
C
      DO 70 IM=1,NA
```

```
      IF(ISOT.GT.0)IQ=IM+IDELM
      IF (IZ.EQ.1.AND.IM.EQ.1.AND.JCAL.NE.1) GO TO 69
      SUMIZ=SUMIZ+CX(IM)
   69 IF(ISOT.GT.0)CCRS(IQ,IZ,IIKL)=CCRS(IQ,IZ,IIKL)+FRACT*CX(IM)
   70 CRS(IM,IZ)=CRS(IM,IZ)+CX(IM)
      IIZ=IDINT(ZOZ)
      IF(TEST.NE.0.)GO TO 76
      Write(7,480)IIZ,IIZ,IIZ,IIZ,IIZ,IIZ,IIZ,IIZ,IIZ,IIZ,IIZ
      Write(7,485)(MS(IN),IN=1,11)
      WRITE(8,480)IIZ,IIZ,IIZ,IIZ,IIZ,IIZ,IIZ,IIZ,IIZ,IIZ,IIZ
      WRITE(8,485)(MS(IN),IN=1,11)
   75 Write(7,490)EQ,(CRS(N,IZ),N=1,11)
      Write(7,590)   (CORG(N),  N=1,11)
      WRITE(8,4900)  (CRS(N,IZ),N=1,11)
      If(IIZ.eq.IZN2N  .and.   LN2N.ne.0)
     #WRITE(21,1111)EQ,CRS(LN2N,IZ),IZN2N,IAN2N,iZP7,iAP7,iZT7,iAT7
1111  Format(f6.2,1pe17.4,'  Residual: ',2I4,' Reaction:',2i2,' +',2i4)
      If(IIZ.eq.IZNP  .and.   LNP.ne.0)
     #WRITE(22,1111)EQ,CRS(LNP,IZ),IZNP,IANP,iZP7,iAP7,iZT7,iAT7
      If(IIZ.eq.IZNA  .and.   LNA.ne.0)
     #WRITE(23,1111)EQ,CRS(LNA,IZ),IZNA,IANA,iZP7,iAP7,iZT7,iAT7
      If(IIZ.eq.IZNNA  .and.   LNNA.ne.0)
     #WRITE(24,1111)EQ,CRS(LNNA,IZ),IZNNA,IANNA,iZP7,iAP7,iZT7,iAT7
      If(IIZ.eq.IZNNP  .and.   LNNP.ne.0)
     #WRITE(25,1111)EQ,CRS(LNNP,IZ),IZNNP,IANNP,iZP7,iAP7,iZT7,iAT7
   76 IF(JCAL)85,85,1176
   85 IF(TEST.NE.0.) GO TO 90
      Write(7,491)EQ,(CX(I),I=1,11)
      Write(7,590)   (CORG(I),  I=1,11)
      WRITE(8,491)EQ,(CX(I),I=1,11)
      Write(7,505)( FS(IA),IA=1,11)
      Write(7,515)(DSP(IA),IA=1,11)
      Write(7,510)(BRR(IA),IA=1,11)
      Write(7,520)(DER(IA),IA=1,11)
      Write(7,525)( ER(IA),IA=1,11)
1176    IF(NA.LE.11)GO TO 90
      Write(7,480)IIZ,IIZ,IIZ,IIZ,IIZ,IIZ,IIZ,IIZ,IIZ,IIZ,IIZ
      Write(7,485)(MS(IN),IN=12,NA)
      WRITE(8,480)IIZ,IIZ,IIZ,IIZ,IIZ,IIZ,IIZ,IIZ,IIZ,IIZ,IIZ
      WRITE(8,485)(MS(IN),IN=12,NA)
  975 Write(7,490)EQ,(CRS(N,IZ),N=12,NA)
      Write(7,590)   (CORG(N),  N=12,NA)
      WRITE(8,4900)  (CRS(N,IZ),N=12,NA)
      IF(JCAL)976,976,90
  976 Write(7,491)EQ,(CX(I),I=12,NA)
      Write(7,590)   (CORG(I),  I=12,NA)
      WRITE(8,491)EQ,(CX(I),I=12,NA)
      Write(7,505)( FS(IA),IA=12,NA)
      Write(7,515)(DSP(IA),IA=12,NA)
      Write(7,510)(BRR(IA),IA=12,NA)
      Write(7,520)(DER(IA),IA=12,NA)
      Write(7,525)( ER(IA),IA=12,NA)
   90 XMISS=RCSS-FISS-SUMIZ
C   ADD NEUTRON WIDTH CALCULATION
C
      DO 175 N=2,NA
      BARNUN=BARNUN+CRS(N,IZ)*DFLOAT(N-1)
      BRNSQN=BRNSQN+CRS(N,IZ)*DFLOAT(N-1)**2
      BARNUD=BARNUD+CRS(N,IZ)
```

```
 175 CONTINUE
     IF(BARNUD.LE.0.D0)BARNU=0.D0
     IF(BARNUD.LE.0.D0)BRNSQ=0.D0
     IF(BARNUD.LE.0.D0)W=0.D0
     IF(BARNUD.LE.0.D0)GO TO 180
     BARNU=BARNUN/BARNUD
     BRNSQ=BRNSQN/BARNUD
     WSQ=BRNSQ-BARNU**2
     IF(WSQ.LT.0.D0)Write(7,176)
     IF(WSQ.LT.0.D0)GO TO 180
     W=DSQRT(WSQ)
 180 CONTINUE
 176 FORMAT('  NEUTRON WIDTH NEGATIVE')
     IF(JCAL.LE.0)XMISS=CRSUM-FISS-SUMIZ
     IF(TEST.NE.0.D0) GO TO 91
     PROFIS=FISS/RCSS
     IF(TEST.EQ.0.D0) Write(7,530)FISS ,SUMIZ,XMISS
     IF(TEST.EQ.0.D0) WRITE(8,530)FISS ,SUMIZ,XMISS
  91 RETURN
  95 NZ=NZ+1
     NA=NA+1
     BARNUN=0.D0
     BARNUD=0.D0
     BRNSQN=0.D0
     DO 100 IZ=1,9
     DO 100 IA=1,22
 100 CRS(IA,IZ)=0.D0
 105 EXC(1,1)=XMAX
 110 DO 115 IZ=2,NZ
 115 EXC(IZ,1)=EXC(IZ-1,1)-BE(IZ-1,1,2)
     NZ=NZ-1
 120 NNA=NA-1
 125 DO 135 IZ=1,NZ

 130 DO 135 IA=1,NNA
 135 EXC(IZ,IA+1)=EXC(IZ,IA)-BE(IZ,IA,1)
 140 NZ=NZ+1
 145 DO 150 IA=1,NNA
 150 EXC(NZ,IA)=EXC(NZ-1,IA)-BE(NZ-1,IA,2)
     DO 155 NDL=3,9,2
     IF (NZ.LT.NDL.OR.NA.LT.NDL) GO TO 255
     DO 155 IZ=NDL,NZ
     DO 155 IA=NDL,NA
 155 EXC(IZ,IA)=EXC(IZ,IA)+28.3D0
 255 NZ=NZ-1
     NA=NA-1
     Write(7,305) EQ,AT,AMASS,QVAL
     WRITE (8,305) EQ,AT,AMASS,QVAL
     Write(7,265) JCAL,JFRAC,JUPPER,JANG
     WRITE(8,265) JCAL,JFRAC,JUPPER,JANG
     IF(IADST.EQ.0)Write(7,8857)
8857 FORMAT(//35X,' IADST=0,NO ANGULAR DISTRIBUTIONS WILL BE CALCULATED'//)
    1'//)
1000 FORMAT(//,' IADST = 1  ANGULAR DISTRIBUTIONS CALCULATED FOR NEUTRO
    1NS USING NUCLEON-NUCLEON KINEMATICS (PHYS REV C 30, 1493 (1984))')
1001 FORMAT(//,' IADST = 2  ANGULAR DISTRIBUTIONS CALCULATED FOR PROTON
    1S USING NUCLEON-NUCLEON KINEMATICS (PHYS REV C 30, 1493 (1984))')
1002 FORMAT(//,' IADST = 3  ANGULAR DISTRIBUTIONS CALCULATED FOR NEUTRO
    1NS USING KALBACH SYSTEMATICS (PHYS. REV. C 37, 2350 (1988)')
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 1003 FORMAT(//,' IADST = 4  ANGULAR DISTRIBUTIONS CALCULATED FOR PROTON
     1S USING KALBACH SYSTEMATICS (PHYS. REV. C 37, 2350 (1988)')
 1004 FORMAT(//,' IADST = 5  ANGULAR DISTRIBUTIONS CALCULATED FOR  ALPHA
     1S USING KALBACH SYSTEMATICS (PHYS. REV. C 37, 2350 (1988)')
      IF(IADST.EQ.0)GO TO 8850
      IF(IADST.EQ.1)Write(7,1000)
      IF(IADST.EQ.2)Write(7,1001)
      IF(IRFR.EQ.0)Write(7,8851)IRFR
      IF(IRFR.EQ.1)Write(7,8852)IRFR
      IF(IRFR.EQ.2)Write(7,8853)IRFR
      IF(IRFR.EQ.3)Write(7,8854)IRFR
      IF(I3D.EQ.0)Write(7,9857)I3D
      IF(I3D.GT.0)Write(7,9858)I3D
 9857  FORMAT(//41X,'I3D FOLDING=',I2,5X,' DIRECTION COSINES FOR 3D FOLDING'//)
     1NG'//)
 9858  FORMAT(//41X,'I3D= ',I2,5X,'  USE TWO DIMENSIONAL FOLDING'//)
 8851  FORMAT(//41X,' IRFR=',I2,5X,'  NO REFRACTION'//)
 8852  FORMAT(//41X,' IRFR=',I2,5X,'  SNELL LAW ENTRANCE REFRACTION ONLY'//)
     1//)
 8853  FORMAT(//41X,' IRFR=',I2,5X,'  SNELL REFRACTION IN,HEISENBERG OUT'//)
     1//)
 8854  FORMAT(//41X,' IRFR=',I2,5X,'  HEISENBERG REFRACTION IN AND OUT'//)
     1)
 8850  CONTINUE
      IF(XMAX.GT.300.D0)Write(7,260)
      IF(XMAX.GT.300.D0)RETURN
  260 FORMAT(25X,'EXCITATION ENERGY EXCEEDS DIMENSIONED LIMIT.  CALCULAT
     1ION AT THIS ENERGY TERMINATED.')
      IF(JCAL.LE.0)Write(7,325)
      IF(JCAL.EQ.1)Write(7,330)
      IF(JCAL.EQ.1)WRITE(8,330)
  265 FORMAT(/////32X,'  JCAL=',I5,'  START J=',I5,' STOP J =',I5,'  JAN
     1G =',I5/)
      IF(JCAL.EQ.2)Write(7,295)
      IF(JCAL.EQ.3)Write(7,300)
      IF(JANG.GT.0)Write(7,315)
      IF(TD.GT.0.D0.AND.TMX.EQ.0.D0)Write(7,320)
      IF(TD.GT.0.D0.AND.TMX.GT.0.D0)Write(7,335)
      IF(TD.GT.0.D0.AND.TMX.GT.0.D0)WRITE(8,335)
  295 FORMAT(' S WAVE APPROXIMATION WITH ROTATING LIQUID DROP MOMENT OF
     1INERTIA AT EQUILIBRIUM DEFORMATION ')
  300 FORMAT(' S WAVE APPROXIMATION WITH RIGID ROTOR MOMENT OF INERTIA')
  305 FORMAT (28X,'LABORATORY BOMBARDMENT ENERGY = ',F6.1,'MEV',3X,'TARG
     1ET MASS = ',F6.1,//22X,'COMPOUND NUCLEUS MASS = ',F6.1,2X,'COMPOUN
     2D NUCLEUS FORMATION Q VALUE = ',F6.1/)
  315 FORMAT(41H OPTION PARTICLES REMOVE ANGULAR MOMENTUM/)
  320 FORMAT(41X,' HYBRID CALCULATION HAS BEEN SELECTED '/)
  325 FORMAT(41X,' CALCULATION INCLUDES FISSION COMPETITION'/)
  330 FORMAT(41X,' STANDARD WEISSKOPF-EWING OPTION SELECTED'/)
  335 FORMAT(41X,' GEOMETRY DEPENDENT HYBRID MODEL SELECTED'/)
      Write(7,236)
  236 FORMAT (1H ,1H )
      K3=0
      RETURN
  340 DO 345 LZ=1,10
      DO 345 IA=1,22
      NULIM(LZ,IA)=1
  345 JAMMA(LZ,IA)=1
      DELT = 0.0D0
```

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    ALT = 0.0D0
    DO 360 L=1,JMAX
    DO 360 K = 1,3
    IF (K-2) 360,350,355
350 IF (SIG(K,L).LE.0.D0) DELT = DELT + 1.0D0
    GO TO 360
355 IF (SIG(K,L).LE.0.D0) ALT =ALT + 1.0D0
360 CONTINUE
    IF(K9.EQ.1)GO TO 371
365 DO 370 K=1,M3
    DO 370 JE=JMAX,300
370 SIG(K,JE)=SIG(K,JMAX)
371 CONTINUE
372   IF(M3.LT.3)ALT=48.D0/ED
    JMAX=300
    PELT=DELT*ED-ED/2.D0
    AAT=ALT*ED-ED/2.D0
    IF(TEST.EQ.0.D0)Write(7,500)DELT,ALT,CLD
    DO 400 LZ=1,NZ
    DO 400 IA=1,NA
    IF(BE(LZ,IA,1)-(BE(LZ,IA,2)+PELT)) 375,380,380
375 IF(BE(LZ,IA,1)-(BE(LZ,IA,3)+AAT))390,390,380
380 IF(BE(LZ,IA,2)+PELT-(BE(LZ,IA,3)+AAT)) 395,395,385
385 JAMMA(LZ,IA)=IDINT((BE(LZ,IA,3)+AAT)/ED)
    GO TO 400
390 JAMMA(LZ,IA)=IDINT(BE(LZ,IA,1)/ED)
    GO TO 400
395 JAMMA(LZ,IA)=IDINT((BE(LZ,IA,2)+PELT)/ED)
400 JAMMA(LZ,IA)=JAMMA(LZ,IA)+1
    DO 415 LZ=1,NZ
    DO 415 IA=1,NA
    IF (JAMMA(LZ,IA)) 405,405,415
405 Write(7,410)LZ,IA
410 FORMAT(' CROSS SECTION FOR NUCLIDE OF IZ = ',I2,' AND IA = ' ,I2,'
   1 WILL BE MEANINGLESS DUE TO NEGATIVE BINDING ENERGY')
    JAMMA(LZ,IA)=1
415 CONTINUE
    IF(K9.EQ.1)K3=0
    IF(K9.EQ.1)RETURN
420 C(1)=(AMASS-1.)/AMASS
    C(2)=C(1)
    C(3)=2. *(AMASS-4.)/AMASS
    IF(KPG.eq.0) C(4)=3.*(AMASS-2.)/AMASS
    IF(KPG.eq.1) C(4)=3.*(AMASS-3.)/AMASS
    IF(KPG.eq.2) C(4)=3.*(AMASS-3.)/AMASS
    DO 425 L =1,300
    BL=DFLOAT(L)*ED-ED/2.
    DO 425 K=1,M3
425 SIG(K,L)=C(K)*SIG(K,L)*BL*ED
    K3=0
    RETURN
430 IF(IKE.EQ.4.AND.IA.EQ.NA.AND.IZ.EQ.NZ)Write(7,435)
    IF(IKE.EQ.4.AND.(IA.NE.NA.OR.IZ.NE.NZ)) GO TO 461
    IF(ISOT.EQ.0)GO TO447
    DO 448 I=1,M3
    DO 449 KEE=1,300
    EEN(I,KEE,IIKL)=EEN(I,KEE,IIKL)+FRACT*EN(I,KEE)
449 CONTINUE
448 CONTINUE
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  447 CONTINUE
  435 FORMAT(1H /' PARTICLE SPECTRA SUMMED OVER ALL EMITTING ',
     1 'NUCLEI (AND PARTIAL WAVES IF APPLICABLE) WITH PRECOMPOUND ',
     2 'INCLUDED.')
      Write(7,440)AOZ,ZOZ
  440 FORMAT(1H /' KINETIC ENERGY SPECTRA FROM A = ',F5.1,'  Z = ',
     1 F5.1,' (NOTE THAT ACTUAL CHANNEL ENERGY ',
     2 'EQUALS KE INDEX )')
      Write(7,455)Partix(KPG+1)
      DO 450 KEE=1,300
      AKE=DFLOAT(KEE)*ED-ED/2.
      CMS=EN(1,KEE)+EN(2,KEE)+EN(3,KEE)+EN(4,KEE)
      IF(CMS.EQ.0.D0)GO TO 450
  445 Write(7,460)AKE,EN(1,KEE),EN(2,KEE),EN(3,KEE),EN(4,KEE)
  450 CONTINUE
  456 CONTINUE
      NMX=IDINT(XMAX/ED)
      If(IADST.eq.5 .and. BE(1,1,3) .lt. 0.D+00)
     #  NMX=IDINT( (XMAX-BE(1,1,3))/ED )
      If(IADST.eq.5 .and. BE(1,1,3) .lt. 0.D+00 .and. NMX .gt.300)
     #  Print 1234
 1234 FORMAT(//20X,' ATTENTION !'//
     #'ENERGY RANGE FOR ALPHA ANGULAR DISTRIB CALCULATIONS TRUNCATED'//)
      IF(NMX.GT.300)NMX=300
      IF(IADST.EQ.0)GO TO 451
      DO 4511 KE=1,NMX
      BTST=1.D0
      RKE=DFLOAT(KE)*ED-ED/2.
      RKE=RKE/DLT
      IRKE=IDINT(RKE)
Corr. Oct. 95
      FDEL=( ED/(2.D0*DLT)     + 1.D-06)
      EDEL=( RKE-DFLOAT(IRKE)  + 1.D-06)
C   CHANGE SEPT 1984
C
      JEDEL=1000.*EDEL
      JFDEL=1000.*FDEL
      IF(JEDEL.EQ.JFDEL)BTST=0.D0
      IF(IRKE.LT.1)GO TO 4511
      KE5=IRKE
      IF(BTST.NE.0.D0)GO TO 4511

C
      J=1
      IF(IADST.EQ.2.OR.IADST.EQ.4)J=2
      IF(IADST.EQ.5)J=3
      IF(IKE.NE.4)GOTO 45100
      DO4510 ITT=1,36
4510  DSIGT(ITT,KE5)=DSIGT(ITT,KE5)+(EN(J,KE)-SCRS(KE,J))/12.566
      GOTO 4511
45100 DO4512 ITT=1,36
4512  DSIGT(ITT,KE5)=DSIGT(ITT,KE5)+EN(J,KE)/12.566
C
4511  CONTINUE
      CONFAC=3.1415926*5.D0/180.D0
      IF(IADST.EQ.3)Write(7,1002)
      IF(IADST.EQ.4)Write(7,1003)
      IF(IADST.EQ.5)Write(7,1004)
      Write(7,406)
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  406 FORMAT('   TOTAL ANGULAR DISTRIBUTION  COMPOUND PLUS PRECOMPOUND')
      NEND=IDINT(XMAX/(10.D0*DLT)+0.99D0)
      If(IADST.eq.5 .and. BE(1,1,3) .lt. 0.D+00)
     #  NEND=IDINT( (XMAX-BE(1,1,3))/(10.D0*DLT)+0.99D0)
      If(NEND.gt.300) Print *,'Bad calculations in SHAFT (check also HY
     # BRID)'
      If(NEND.gt.300) Stop
      DO 519 J=1,NEND
      BJI(1)=10.D0*DLT*DFLOAT(J-1)+DLT+ED/2.D0
      DO 8406 II=2,10
8406  BJI(II)=BJI(II-1)+DLT
      Write(7,401)(BJI(II),II=1,10)
      NII=J*10-9
      NIF=NII+9
      DO 6510 ID=1,10
6510  ASUM(ID)=0.D0
C
      DO 509 ITH=1,36
      III=0
      DO 6511 KEF=NII,NIF
      III=III+1
6511  ASUM(III)=ASUM(III)+SIGN(ITH)*DSIGT(ITH,KEF)*CONFAC
      ANGLE=5.*DFLOAT(ITH)-2.5D0
      Write(7,402)ANGLE,(DSIGT(ITH,KEF),KEF=NII,NIF)
  509  CONTINUE
      Write(7,6512)(ASUM(II),II=1,10)
6512  FORMAT(' INTEGRAL=',10(E10.3))
  519 CONTINUE
  451 CONTINUE
      SON=0.D0
      SOP=0.D0
      SOA=0.D0
      SOD=0.D0
      DO 457 KEE=1,300
      SON=SON+EN(1,KEE)
      SOP=SOP+EN(2,KEE)
      SOA=SOA+EN(3,KEE)
      SOD=SOD+EN(4,KEE)
457   CONTINUE
      SON=SON*ED
      SOP=SOP*ED
      SOA=SOA*ED
      SOD=SOD*ED
          RATMP2=SOA/RATMP1
          RDTMP2=SOD/RATMP1
      Write(7,4620)SON,SOP,SOA,Partx(KPG+1),SOD
      IF(IKE.EQ.4.AND.IA.EQ.NA.AND.IZ.EQ.NZ)WRITE(8,4620)SON,SOP,SOA,
     # Partx(KPG+1),SOD
      IF(IKE.EQ.4.AND.IA.EQ.NA.AND.IZ.EQ.NZ)
     # CALL PLOTSP(SON,SOP,SOA,SOD,SUMAPR,SUMDER,RATMP1)
      IF(IALPHA.NE.0.AND.IKE.EQ.4.AND.IA.EQ.NA.AND.IZ.EQ.NZ)
     $Write(7,4625)SUMAPR,RATMP2,Partx(KPG+1),SUMDER,Partx(KPG+1),
     $             RDTMP2
      IF(IALPHA.NE.0.AND.IKE.EQ.4.AND.IA.EQ.NA.AND.IZ.EQ.NZ)
     $Write(8,4625)SUMAPR,RATMP2,Partx(KPG+1),SUMDER,Partx(KPG+1),
     $             RDTMP2
4620  FORMAT(' SUM NEUTRON=',E10.3,'   SUM PROTON =',E10.3,
     1'  SUM ALPHA=',E10.3,'  SUM ',A5,'=',E10.3)
4625  FORMAT('     ALPHA PRECOMPOUND PRODUCTION CROSS SECTION ',
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   +E10.3,'   TOTAL ALPHA MULTIPL   ',E10.3/
   +       '     ',A5,' PRECOMPOUND PRODUCTION CROSS SECTION ',
   +E10.3,'   TOTAL ',A5,' MULTIPL   ',E10.3)
 455 FORMAT('  KE  DS/DE(MB/MEV)= NEUTRONS    PROTONS     ALPHAS',
   1'     ',A9)
 460 FORMAT(' ',F8.3,'               ',E11.4,'  ',E11.4,'  ',E11.4,' '
   1,' ',E11.4)
 461 K3=0
     RETURN
 531  CONTINUE
     IIKL=IIKL-1
     DO 541 KIJ=1,IIKL
     Write(7,550)ENGBUF(KIJ)
 550 FORMAT('  ISOTOPICALLY WEIGHTED RESULTS FOR INCIDENT ENERGY',1X,
   CF10.3,' MEV(LAB)')
     NZ=KNZ
     ED=EXD
     DO 542 LZ=1,NZ
     ILZ=IDINT(ZEE+1.D0-DFLOAT(LZ))
     DO 549 KN=1,22
     MS(KN)=IDINT(AMASS+2.D0-DFLOAT(KN)+DFLOAT(IDELM)-DFLOAT(LZ))
549   CONTINUE
     Write(7,480)ILZ,ILZ,ILZ,ILZ,ILZ,ILZ,ILZ,ILZ,ILZ,ILZ,ILZ
     Write(7,485)(MS(IN),IN=1,11)
     Write(7,490)EQ,(CCRS(N,LZ,KIJ),N=1,11)
 542 CONTINUE
     LPA=IA+IDELM
     IF(LPA.LE.11)GO TO 543
     Write(7,480)ILZ,ILZ,ILZ,ILZ,ILZ,ILZ,ILZ,ILZ,ILZ,ILZ,ILZ
     Write(7,485)(MS(IN),IN=12,22)
     Write(7,490)EQ,(CCRS(N,LZ,KIJ),N=12,22)
 543 CONTINUE
     Write(7,455)
     DO 650 KEE=1,300
     AKE=DFLOAT(KEE)*ED-ED/2.
     CMS=EEN(1,KEE,KIJ)+EEN(2,KEE,KIJ)+EEN(3,KEE,KIJ)+EEN(4,KEE,KIJ)
     IF(CMS.EQ.0.)GO TO 650
 645 Write(7,460)AKE,EEN(1,KEE,KIJ),EEN(2,KEE,KIJ),EEN(3,KEE,KIJ),EEN(4
   1,KEE,KIJ)
 650 CONTINUE
 541 CONTINUE
     K3=0
     RETURN
 401 FORMAT(' ANGLE/DEG. KE=',F6.2,9(4X,F6.2))
 402 FORMAT(1X,F5.1,5X,1PE10.3,9E10.3)
 480 FORMAT(15H0ATOMIC NUMBER I3,10(7X,I3))
 485 FORMAT(15H MASS NUMBER   I3,10(7X,I3))
 490 FORMAT(4H E"=,F10.2, E10.3,10(   E10.3))
 590 FORMAT(14H GAMMA X SECT ,E10.3,10(   E10.3))
4900 FORMAT(15H ER XSECT S(J) E10.3,10(   E10.3))
 491 FORMAT(4H EJ=,F10.2,4H J , E10.3,10(   E10.3))
 500 FORMAT (/34X,'DELT = ',F10.1,6X,'ALT = ',F10.1,6X,'CLD =',F10.5/)
 505 FORMAT(15H FISS X SECT   11E10.3)
 510 FORMAT(15H FISS BARRIER  11E10.3)
 515 FORMAT(15H DEL SADDLE PT 11E10.3)
 520 FORMAT(15H DEL ROTATION  11E10.3)
 525 FORMAT(15H ROTATIONAL EN 11E10.3/)
 530 FORMAT(' FISSION CROSS SECTION TO HERE=',E10.3,2X,' ER XSECT TO HE
   1RE  =',E10.3,2X,' MISSING CROSS SECTION  =',E10.3)
```

```
      END
*
*************************************************************************
*
      Subroutine SIGI
*     ---------------
*
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/NHY/TD,EX1,EX2,TMX,AV,GAV,IJ,COST,JL,JI,JJ,B(3)
      COMMON/SFT9/K5,PLD,JMAX,C(4),DELT,ALT /UG/IZ,IA
      COMMON/PL3/EB(70),RCSP(70),ZEE,AMASS,PLEX,NEPR
      COMMON/LAB3/SIG(4,300) /HOT/KPG,MPG
      COMMON/SHFT2/K3,FS(22),DSP(22),BRR(22),DER(22),ER(22),
     1FISS,SUMIZ,CX(22),BILSUM,JCAL,XMISS /INCR/ED
      DO 6 I=1,300
      DO 6 K=1,4
  6   SIG(K,I)=0.D0
      AZ=DFLOAT(IZ)
      AEFF=AMASS+2.D0-AZ-AZ
      ZEFF=ZEE-AZ+1.D0
      RP=1.21*((AEFF-1.D0)**.333333+1.)
      RA=1.21*((AEFF-4.D0)**.333333+1.587)
      IF(KPG.eq.0) RD=1.21*((AEFF-2.D0)**.333333+1.260)
      IF(KPG.eq.1) RD=1.21*((AEFF-3.D0)**.333333+1.260)
      IF(KPG.eq.2) RD=1.21*((AEFF-3.D0)**.333333+1.587)
      CONRP=31.42*RP*RP
      CONRA=31.42*RA*RA
      CONRD=31.42*RD*RD
      VP=(ZEFF-1.)*1.15/(RP+1.6)
      VA=(ZEFF-2.)*2.64/(RA+1.6)
      IF(KPG.eq.0) VD=(ZEFF-1.)*1.32/(RD+1.6)
      IF(KPG.eq.1) VD=(ZEFF-1.)*1.32/(RD+1.6)
      IF(KPG.eq.2) VD=(ZEFF-2.)*2.64/(RD+1.6)
      RMP=1.-1./AEFF
      RMA=2.-8./AEFF
      IF(KPG.eq.0) RMD=3.-6./AEFF
      IF(KPG.eq.1) RMD=3.-9./AEFF
      IF(KPG.eq.2) RMD=3.-9./AEFF
      DO 10 IK=1,300
      EI=DFLOAT(IK)*ED-ED/2.
      SIG(1,IK)=31.42*(RP+3.4/DSQRT(EI+.5))**2
      IF(VD.GE.EI) GO TO 11
      SIG(4,IK) = CONRD*(1.-VD/EI)
   11 IF(VP.GE.EI)GO TO 10
      SIG(2,IK)=CONRP*(1.-VP/EI)
      IF(VA.GE.EI) GO TO 10
      SIG(3,IK)=CONRA*(1.-VA/EI)
10    CONTINUE
      IF (JL.NE.JI) GO TO 160
      AJMAX=100.*ED-ED/2.
  160 DO 200 K=1,300
      EI=(DFLOAT(K)*ED-ED/2.)*ED
      SIG(1,K)=SIG(1,K)*EI*RMP
      SIG(2,K)=SIG(2,K)*EI*RMP
      SIG(3,K)=SIG(3,K)*EI*RMA
      SIG(4,K)=SIG(4,K)*EI*RMD
200   CONTINUE
      K3=3
      CALL SHAFT
```

```
      RETURN
      END
*
*************************************************************************
*
      Subroutine TLJ(H4,N1,J1,H1,Z,W1,STPLTH)
*     ---------------------------------------
*
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION SG(2),S(16,4),F(101,2),G(101,3),R(2,3),H(502),A(502),B(5
     102),Q(502),D(300),E(300),Y(300),U(300),Z1(5),U1(7),Y1(7)
      COMMON /LAB2/T(3,81),V(15),V1(3)
      B1 = 0.D0
    5 I1=IDINT(2.0D0*V1(1)) + 2
      I3=I1+2
      I4=I1*(I1-2)
      J1=I1-1
      B7=V(1)
      V(1)=DABS(V(1))
      RB=V(1)+9.*V(2)
      RB=DMAX1(RB,V(10)+9.0*V(11))
      T1=V(3)+9.*V(4)
      IF(RB-T1)10,15,15
   10 RB=T1
   15 IRB=IDINT(10.D0*RB)
      RB=DFLOAT(IRB)
      RB=RB/10.D0
      M4=IDINT(RB/STPLTH)
      IF(M4-299)25,25,20
   20 M4=299
   25 D1=RB/DFLOAT(M4)
      M4=M4+1
      M1=M4+1
      M3=M4+2
      N1=IDINT(V1(3))+1
      V1(3)=DFLOAT(N1-1)
      Z2=Z*Z
      DT=2.D0*D1
      DTT=D1*D1/12.D0
      W2=W1
      W1=W1*DTT
      DT3=-2.D0*DTT
      H2=1.D0+DTT*H4
      HY=DT3*H1*Z
      S(16,1)=1.D0
      S(16,2)=1.D0
      S(16,3)=0.D0
      S(16,4)=0.D0
      T1=1.D0
      T2=2.D0
      T3=0.D0
      DO 30 I=1,15
      J=16-I
      T7=T1*Z/T2
      T6=-T3*(T3+1.D0)+Z2
      T4=T6/T2
      T5=(2.D0+T6)/T2
      S(J,1)=T7*S(J+1,1)-T4*S(J+1,3)
      S(J,2)=T7*S(J+1,2)-T5*S(J+1,4)
```

```
   S(J,3)=T7*S(J+1,3)+T4*S(J+1,1)
   S(J,4)=T7*S(J+1,4)+T5*S(J+1,2)
   T1=T1+2.D0
   T2=T2+2.D0
30 T3=T3+1.D0
   TM=RB
   IF(Z)35,50,35
35 DO 45 I=1,4
   T1=(DEXP((13.816+DLOG(DABS(S(1,I))))/15.D0))/H1
   IF(T1-TM)45,45,40
40 TM=T1
45 CONTINUE
50 M2=IDINT((TM-RB)/D1) + 1
   TM=RB+D1*DFLOAT(M2)
   T1=Z2+16.D0
   SG(1)=-Z+Z*(DLOG(T1))/2.0+3.5*DATAN(Z/4.0)-DATAN(Z)-DATAN(Z/2.0)-
  1 DATAN(Z/3.)-Z*(1.+(Z2-48.)/(30.*T1*T1)+(Z2*Z2-160.*Z2+1280.)/
  2(105.*T1*T1*T1*T1))/(12.*T1)
   SG(2)=SG(1)-1.5707963+DATAN(Z)
   T1=TM+DT
   DO 65 I=1,2
   T1=T1-D1
   T2=T1*H1
   T3=T2-Z*DLOG(2.0D0*T2)
   DO 60 J=1,2
   T7=0.D0
   T8=0.D0
   DO 55 K=1,15
   T7=(T7+S(K,J))/T2
55 T8=(T8+S(K,J+2))/T2
   T7=T7+1.D0
   T4=T3+SG(J)
   T5=DCOS(T4)
   T6=DSIN(T4)
60 G(J,I)=T7*T5-T8*T6
   R(1,I)=H2+HY/T1
65 R(2,I)=R(1,I)+DT3/(T1*T1)
   DO 70 I=1,M2
   T1=T1-D1
   R(1,3)=H2+HY/T1
   R(2,3)=R(1,3)+DT3/(T1*T1)
   DO 70 J=1,2
   G(J,3)=((12.D0-10.D0*R(J,2))*G(J,2)-R(J,1)*G(J,1))/R(J,3)
   DO 70 K=1,2
   R(J,K)=R(J,K+1)
70 G(J,K)=G(J,K+1)
   T1=T1+D1
   DO 130 I=1,2
   T2=T1*H1
   T3=1.D0/T2
   T1=T1-D1
   T7=0.D0
   N4=0
   N2=IDINT((T2/1.4142)*DSQRT(25.-2.*Z*T3+10.*
  1 DSQRT((Z*T3-.5D0)**2+6.D0)))
   IF(N2-N1-8)75,80,80
75 N2=N1+8
80 IF (N2-500) 85,85,230
85 T6=DFLOAT(N2)
```

```
    N3=N2+1
    T5=T7
    H(N3+1)=0.D0
    H(N3)=1.0D-20
    A(N3)=DSQRT(Z2+(T6+1.D0)**2)/(T6+1.D0)
    DO 105 K=1,N2
    M=N3-K
    IF(N4-M)90,95,95
 90 A(M)=DSQRT(Z2+T6*T6)/T6
    B(M)=(2.*T6+1.D0)*(Z/(T6*(T6+1.D0))+T3)
    T6=T6-1.D0
 95 H(M)=(B(M)*H(M+1)-A(M+1)*H(M+2))/A(M)
    IF(DABS(H(M+2))-(10.0**30)) 105,105,100
100 H(M)=H(M)/(10.0**25)
    H(M+1)=H(M+1)/(10.0**25)
105 CONTINUE
    N4=N2
    N2=N2+10
    T7=H(2)/H(1)
    IF(DABS((T5-T7)/T7)-0.00001D0) 115,115,110
110 IF(N2.LE.500) GO TO 80
    N2 = 500
115 T5=1./(A(1)*(H(1)*G(2,I)-H(2)*G(1,I)))
    F(1,I)=T5*H(1)
    F(2,I)=T5*H(2)
    DO 130 K=3,N1
    IF(DABS(H(K)/H(K-1))-10.0**15) 125,125,120
120 T5=T5/(10.0**25)
125 F(K,I)=T5*H(K)
130 G(K,I)=(B(K-2)*G(K-1,I)-A(K-2)*G(K-2,I))/A(K-1)
    Q(1)=0.D0
    Q(2)=0.D0
    H(1)=0.D0
    H(2)=0.D0
    A(1)=0.D0
    A(2)=1.0D-20
    B(1)=0.D0
    B(2)=1.0D-20
    HZ3=H2+1.5*HY/V(9)
    HZ=-HY/(2.*(V(9)**3))
    T101=1.0/DEXP(V(10)/V(11))
    T1=1.0/DEXP(V(1)/V(2))
    T102=DEXP(D1/V(11))
    T2=DEXP(D1/V(2))
    IF(B7)135,140,140
135 A2=V(5)*V(5)/16.
    V(5)=1.D0
    A1=4.*W2*A2
    B1=DEXP(4.0*A2*H4)
140 V5=V(5)
    IF(V5)145,150,150
145 V(5)=-V5
    V4=V(4)
    V(4)=0.69*V(4)
150 T9=V(8)*(1.D0-V(5))
    T3=1.0D0/DEXP(V(3)/V(4))
    T4=DEXP(D1/V(4))
    T6=0.D0
    DO 200 K=1,M4
```

```
      T6=T6+D1
      Y(K)=T6*T6
      T1=T1*T2
      T101=T101*T102
      T3=T3*T4
      T5=V(7)/(1.D0+T1)
      T7=1.D0/(1.D0+T3)
      IF(V5)155,170,170
  155 T8=((T6-V(3))/V4)**2
      IF(T8-10.D0)165,160,160
  160 T8=0.D0
      GO TO 185
  165 T8=V(8)*DEXP(-T8)
      GO TO 185
  170 T8=4.*T3*T7*T7*V(8)
      IF(B7)175,185,185
  175 P5=A2/(T5*T5+T8*T8)
      P8=T1/(1.D0+T1)
      P9=T3*T7
      P6=-T5*P8/V(2)
      P7=T8*(1.D0-2.*P9)/V(4)
      P8=P6*(1.D0-2.*P8)/V(2)
      P9=T8*(1.D0-6.*P9*(1.-P9))/(V(4)*V(4))
      U2=P5*((T5*P6+T8*P7)*2./T6+T5*P8+T8*P9)
      Y2=P5*((T5*P7-T8*P6)*2./T6+T5*P9-T8*P8)
      Y1(1)=T8/(B1*B1+2.*B1*A1*T5)
      U1(1)=(T5+T8*A1*Y1(1))/(B1+A1*T5)
      DO 180 J=1,6
      P5=A1*Y1(J)-Y2
      P6=DSIN(P5)
      P5=DCOS(P5)
      P7=1.0D0/(B1*DEXP(A1*U1(J)-U2))
      U1(J+1)=(T5*P5+T8*P6)*P7
  180 Y1(J+1)=(T8*P5-T5*P6)*P7
      T5=U1(7)-((U1(7)-U1(6))**2)/(U1(7)-2.*U1(6)+U1(5))
      T8=Y1(7)-((Y1(7)-Y1(6))**2)/(Y1(7)-2.*Y1(6)+Y1(5))
  185 H(K+2)=W1*(T9*T7+V(5)*T8)
      U(K)=2.*W1*V(6)*T101/(V(11)*T6*((1.+T101)**2))
C NOTE CHANGE V1 TO V9 JUNE81
      IF(T6-V(9))190,195,195
  190 E(K)=W1*T5+HZ3+HZ*Y(K)
      GO TO 200
  195 E(K)=W1*T5+H2+HY/T6
  200 CONTINUE
      T8=0.D0
      DO 225 I=1,N1
      I2=2*I
      T1=DTT*T8*(T8+1.D0)
      T8=T8+1.D0
      DO 205 K=1,M4
  205 D(K)=E(K)-T1/Y(K)
      DO 225 J=1,J1
      L=I2-I3+2*J

      IF(IABS(I2-I1)-L)215,215,210
  210 T(J,I)=0.D0
      GO TO 225
  215 T9=(DFLOAT(L*(L+2)-I2*(I2-2)-I4))/4.D0
      DO 220 K=1,M4
```

```
      Q(K+2)=D(K)+T9*U(K)
      T3=12.D0-10.*Q(K+1)
      T4=10.*H(K+1)
      T1=T3*A(K+1)-Q(K)*A(K)+T4*B(K+1)+H(K)*B(K)
      T2=T3*B(K+1)-Q(K)*B(K)-T4*A(K+1)-H(K)*A(K)
      T3=Q(K+2)**2+H(K+2)**2
      A(K+2)=(Q(K+2)*T1+H(K+2)*T2)/T3
  220 B(K+2)=(Q(K+2)*T2-H(K+2)*T1)/T3
      T3=A(M3)**2+B(M3)**2
      T1=(A(M1)*A(M3)+B(M1)*B(M3))/T3
      T2=(A(M3)*B(M1)-A(M1)*B(M3))/T3
      T5=F(I,2)-F(I,1)*T1
      T6=F(I,1)*T2
      T3=T5-G(I,1)*T2
      T4=G(I,2)-G(I,1)*T1+T6
      T7 = (T3/T4)*T3+ T4
      T1=(T3*T5+T4*T6)/T7
      T2=(T4*T5-T3*T6)/T7
      T7 = T4
      T1 = T1/T7
      IF(T1.LT..0000001D0)T1=0.D0
      T2 = T2/T7
C NOTE CHANGE T2 TO ABS T2 JUNE 1981
      T90=DABS(T2)
      IF(T90.LT..0000001D0)T2=0.D0
      T(J,I)=4.D0*(T1-T1**2-T2**2)
      IF(T(J,I).LT.0.D0)T(J,I)=0.D0
  225 CONTINUE
  230 CONTINUE
      RETURN
      END
*
*********************************************************************
*
      Subroutine TREED
*     ---------------
*
C  THIS PROGRAM IS DESIGNED TO DO 3D SCATTERING FOR A COORDINATE
C  SYSTEM IN THE ZX PLANE WHERE ZERO DEGREES IS THE POSITIVE Z
C  DIRECTION.
C  THE DIRECTION COSINES ARE DEFINED BY:
C  A=X=SIN(THETA)*COS(PHI)
C  B=Y=SIN(THETA)*SIN(PHI)
C  G=Z=COS(THETA)
C
C  ANGLES ARE STEPPED THRU IN 5 DEG. STEPS BEGINNING AT 2.5 DEG.
C  THETA1(INITIAL PARTICLE DIRECTION WRT Z AXIS) GOES 2.5 TO 177.5 DEG.
C  THETA2(SCATTERING ANGLE WRT THETA1) ALSO 2.5 TO 177.5 DEG
C  PHI1,PHI2(ROTATION AROUND THETA DIRECTIONS)GO 2.5 TO 357.5 DEG.
C
C   TRIG SIN AND COS FUNCTIONS ARE STORED IN SSIGN,CSIGN ARRAYS;
C   FINAL DISTRIBUTION WILL BE STORED IN PRB ARRAY.
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/TR1/SSIGN(72),CSIGN(72),SRT(72)
      COMMON/PL3/EB(70),RCSP(70),Z,AMASS,PLEX,NEPR
      COMMON/DIST/PROB(37,301),XX(3),ALMIN(300),ALMAX(300),FIN,DTUP
     1 ,DSIGP(36,301),DSIGT(36,301),POT,PCS,JN,JNI,IK,AK,DADEG,TDEG,
     2 TDEG2
     3,AMN(300),AMX(300),XMAX
```

```
       COMMON/DIST1/GDPR(36,301),GL(36,301),CFRAC
     3,DTAU,SIGN(36),TMIX,IREFR,BJI(10)
       COMMON/SEND/IRFR,DLT,IADST
       COMMON/INCR/ED
       COMMON/NR34/NR3,NR4,KE5,PRB(36),I3D,IRTST,I3T2,IJKL
C
C   THTA,PHI GIVE 2.5 DEG IN RADIANS;DEL IS 5 DEG IN RADIANS
       THTA=0.043633194D0
       PHI=0.043633194D0
       DEL=0.087266388D0
       DO 5 II=1,36
   5   PRB(II)=0.D0
C
       DO 3 I=1,72
       DG=5.*DFLOAT(I)-2.5D0
       ARG=DG*3.141592654D0/180.D0
       CSIGN(I)=DCOS(ARG)
       SRT(I)=DSQRT(1.D0-(CSIGN(I)*CSIGN(I)))
3      SSIGN(I)=DSIN(ARG)
C
       NR5=1
       NR6=36
       W1=1.0D0
       IF(I3T2.LT.4)NR5=NR3
       IF(I3T2.LT.4)NR6=NR4
C
       DO 1000 ITH1=NR5,NR6
C THIS LOOP CONSIDERS EACH INITIAL SCATTERING ANGLE THETA1
       IF(I3T2.EQ.4)W1=GDPR(ITH1,KE5)
       IF(W1.EQ.0.D0)GO TO 1000
       DO 900 IPHI1=1,18
C
C THIS LOOP ROTATES INITIAL THETA1 DIRECTION ABOUT THE Z AXIS;
C WE WILL THEN CONSIDER SECOND SCATTERING FOR EVERY THETA1 AND PHI
       A=SSIGN(ITH1)*CSIGN(IPHI1)
       B=SSIGN(ITH1)*SSIGN(IPHI1)
       G=CSIGN(ITH1)
       ST=DSQRT(1.D0-G*G)
C
C NEXT CONSIDER EACH SECOND SCATTERING ANGLE THETA2 WRT THETA1=0,
C AND ALL ROTATIONS PHI2. WE WISH TO STORE ONLY THOSE EVENTS WITH
C AN ANGLE ZERO TO 5 DEG OF THE ZX PLANE.
C
C      THA2=THTA
       DO 800 ITH2=1,36
C
       IF(I3T2.EQ.1)W2=PROB(ITH2,KE5)
       IF(I3T2.EQ.2)W2=GL(ITH2,KE5)
       IF(I3T2.EQ.3)W2=GDPR(ITH2,KE5)
       IF(I3T2.EQ.4)W2=PROB(ITH2,KE5)
       IF(W2.EQ.0.D0)GO TO 800
       THETA=CSIGN(ITH2)
       GTHETA=G*THETA
       ATHETA=A*THETA
       BTHETA=B*THETA
       XRX=SRT(ITH2)
       XRDST=SRT(ITH2)/ST
       XRMST=SRT(ITH2)*ST
       BGX=B*G*XRDST
```

```
      AX=A*XRDST
      AGX=A*G*XRDST
      BX=B*XRDST
      DO 700 IPHI2=1,72
C
C    THETA IS THE SCATTERING ANGLE RELATIVE TO THE PARTICLE THAT HAS
C      DIRECTION COSINES A,B,G.
C    A IS THE DIRECTION COSINE OF THE PROJECTILE RELATIVE TO X AXIS
C    B IS THE DIRECTION COSINE OF THE PROJECTILE RELATIVE TO Y AXIS
C    G IS THE DIRECTION COSINE OF THE PROJECTILE RELATIVE TO Z AXIS
C
C  AP IS THE DIRECTION COSINE OF THE SCATTERED PARTICLE RELATIVE TO X AXIS
C  BP IS THE DIRECTION COSINE OF THE SCATTERED PARTICLE RELATIVE TO Y AXIS
C  GP IS THE DIRECTION COSINE OF THE SCATTERED PARTICLE RELATIVE TO Z AXIS
C
      BP =((BGX*(CSIGN(IPHI2)) + AX*SSIGN(IPHI2)) )+BTHETA
       BP=DABS(BP)
      IF(BP.GT.0.087266388D0)GO TO 700
      AP =((AGX*(CSIGN(IPHI2)) -BX*SSIGN(IPHI2)) )+ATHETA
      AP=DABS(AP)
      GP =-XRMST * (CSIGN(IPHI2))  + GTHETA
C
C   REPLACE ARCTAN OF STMT 600 WITH APPROXIMATION
C
      XZ=AP/GP
      XZSQ=XZ*XZ
      IF(XZSQ.GT.1.D0)GO TO 590
      THT=XZ/(1.D0+.28D0*XZSQ)
      GO TO 600
 590  THT=1.5708D0-(1.D0/XZ)/(1.D0+.28D0/XZSQ)
 600  CONTINUE
      IF(THT.LT.0.D0)THT=3.141592654D0+THT
      IND=IDINT(11.4591559D0*THT+1.D0)
      PRB(IND)=PRB(IND)+SSIGN(ITH1)*W1*
     1SSIGN(ITH2)*W2
  700 CONTINUE
  800 CONTINUE
  900 CONTINUE
 1000 CONTINUE
      RETURN
       END
*
*********************************************************************
*
      Subroutine TRIT95(TT9,EX9,X9,L91,L92,GIB,GE,G,DEP,
     $                  XMAX,ED9,BA,CNCS, PAIRXA)
*     ------------------------------------------------
*
C     TRITON PRECOMPOUND ROUTINE FOR ALICE/ASH
C
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/IALPH/IALPHA
      COMMON/MEMO/SCRS(300,4)
      COMMON/IWATRI/FLM(300,3)
      DIMENSION GIB(4,300),GE(4),DEP(2)
      IF(IALPHA.LT.20)CALL IWAMOT(IALPHA,WIMAG)
      IF(L91.NE.L92.AND.L92.NE.1) IALPHA=IALPHA+1
         N=IDINT(TT9+0.01D+00)
      E=XMAX
```

```
      ED=ED9
         NP=IDINT(EX9+0.01D+00)
         P=DFLOAT(NP)
         NH=IDINT(X9+0.01D+00)
      IF(NH.NE.(N-NP)) GOTO 23232
      IF(NP.EQ.0)GOTO 33333
      U=XMAX-BA-ED/2.
      NU=U/ED+1.
      IF(NU.LE.0)GOTO 111
      IF(NU.GT.300)GOTO 44444
      LMAX=MIN0(NP,3)
      BAA=(BA /ED) + DSIGN(0.5D0,BA)
      ISHIFT=IDINT(BAA)
C
      DO 1000 L=1,LMAX
      U=XMAX-BA-ED/2. - PAIRXA
                        UU = U
      IF(PAIRXA.LT.0.0) UU = XMAX-BA-ED/2.
      NU=UU/ED+1.
      AKOEF=1.
          DO 100 K1=1,L
100       AKOEF=AKOEF*DFLOAT(NP-K1+1)*DFLOAT(N-K1)
      AKOEF=CNCS*DEP(2)*GE(4)*AKOEF
C
      DO 777 KE=1,NU
      RW=((U/E)**(N-1-L))/((G*E)**L)
      RV=2.*GIB(4,KE)/(2.*GIB(4,KE)+8.27E+03*WIMAG)
      IF(RW.LT.0..OR.RV.LT.0.)GOTO 55555
      KESUM=ISHIFT+KE
      IF(KESUM.GT.300) KESUM=300
      IF(KESUM.LT.1  ) KESUM=1
      FLMSH=FLM(KESUM,L)
      SCRS(KE,4)=SCRS(KE,4)+AKOEF*FLMSH    *RW*RV
      IF(RW.LT.1.0E-50)GOTO 1000
      U=U-ED
      IF(U.LE.0.)GOTO 1000
  777 CONTINUE
 1000 CONTINUE
C
      RETURN
C
  111 WRITE(7,112)U,XMAX,BA,ED,NU
      WRITE(8,112)U,XMAX,BA,ED,NU
  112 FORMAT(1X,80('+')/1X,'PRECOMPOUND TRIT  COULD NOT EMITTED, BECAU
     1SE:'/1X,' U=',G12.5,' XMAX=',G12.5,' BA=',G12.5,' ED=',G12.5,' NU=
     2',I6/1X,80('+'))
      RETURN
C
23232 WRITE(7,23233)
      WRITE(8,23233)
23233 FORMAT(1X,'SUBR.TRIT95: STRANGE ERROR...')
      STOP
33333 WRITE(7,33334)NP
      WRITE(8,33334)NP
33334 FORMAT(1X,'SUBR.TRIT94: —^C‹O —ACT^- = 0      ',I3)
      STOP
44444 WRITE(7,44445)U,XMAX,BA,ED,NU
      WRITE(8,44445)U,XMAX,BA,ED,NU
44445 FORMAT(1X,'SUBR.TRIT94: ERROR NU > 300 '/1X,' U=',G12.5,' XMAX='
```

```
     1,G12.5,' BA=',G12.5,' ED=',G12.5,' NU=',I6)
      STOP
55555 WRITE(7,55556)RW,RV,KE,U,E,N,L
      WRITE(8,55556)RW,RV,KE,U,E,N,L
55556 FORMAT(1X,'SUBR.TRIT94: ERROR RW OR RV < 0'/1X,' RW=',G12.5,' RV
     1=',G12.5,' KE=',I5/1X,' U=',G12.5,' E=',G12.5,' N=',I5,' L=',I5)
      STOP
      END
```