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UFFAXX - A FORTRAN PROGRAMME FOR THE ANALYSIS OF RESONANT SCATTERING OF NUCLEONS FROM SPIN-O NUCLEI

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1. - INTRODUCTION

In the study of the level structure of a nucleus, the yield of the elastic scattering of nucleons from nuclei can give some useful informations. In this way in fact the levels of the compound nucleus appear as resonances in the elastic scattering excitation function and often also in the allowed inelastic channels. The main problem in the analysis of this kind of data consists then in extracting the required spectroscopic informations (like energy, angular momentum, spin, widths of the resonances) from the experimental data.

This problem can be easily resolved if the resonances appear as isolated structures in the excitation function; but if the excitation energy of the compound system increases, the level density becomes so high that it becomes necessary to take into account simultaneously a large number of resonances, some of these having also the same spin and parity. In some analysis of this kind performed by our group, the code ANSPEC was used. This code ([1]) calculates the elastic excitation function for spin-0 or $1/2$ particles scattered by spin 0 target nuclei, when a maximum number of five resonances, having different spin and parity, are present. This limitation forced us to develop a new code (UFFAXX), written in FORTRAN language for CDC 6000 series computer, based on a very simple multilevel formula, capable of taking into account simultaneously a maximum number of 50 resonances, and also able to consider the presence of resonances of the same spin and parity.

The UFFAXX programme was written starting from the optical model code SMOG ([2]); many suggestions for the code were also taken from the ANSPEC code. In the following sections we shall describe the scattering formalism (section 2), the program structure (section 3) and two examples of application of the code (section 4). In the Appendix A we shall report the complete listing of UFFAXX.

$$(9) \qquad \alpha^{\ell}_{J-\ell} = \alpha^{o\ell}_{J-\ell}\left[1+i\,\exp(2i\,\Phi^{R}_{\ell j})\sum_{K}^{N}\frac{\Gamma^{K}_{\lambda\ell j}}{E^{K}_{R}-E-\frac{i}{2}\Gamma^{K}_{\lambda}}\right] + $$

$$+\frac{1}{2}\exp\left(2i\,\Phi^{R}_{\ell j}\right)\sum_{K}^{N}\frac{\Gamma^{K}_{\lambda\ell j}}{E^{K}_{R}-E-\frac{i}{2}\Gamma^{K}_{\lambda}}$$

This formula reduces itself to the (7) for N=1 and is also very suitable for the programme organisation. The unitarity condition is given by

$$(10) \qquad \left\{ Jm\,(\alpha^{\ell}_{j-\ell}) - |\alpha^{\ell}_{j-\ell}|^{2} \right\} \geq 0$$

2.2 Non-elastic channel analysis

A non-elastic reaction channel can sometimes give the J-value of a resonance for a given l-wave, and therefore the possibility of calculating the non-elastic angular distribution was inserted in the programme. The cross-section for a non-elastic channel is assumed to be simply given by

$$(11) \qquad \sigma(\Theta) = \frac{\pi\lambda\!\!\!^{-2}\,(2J+1)}{(2I+1)(2s+1)}\;\frac{\Gamma_{\lambda\ell j}\,\Gamma^{i}_{\lambda\ell j}}{(E_R-E)+\frac{\Gamma^2_{\lambda}}{4}}\;\sum_{n}\alpha_n\,P_n\,(\cos\vartheta)$$

In the formula (11)

- $\Gamma^{i}_{\lambda\ell j}$ is the width of the given non-elastic channel
- J is the J-value of the resonance
- I is the spin of the target nucleus
- s is the spin of the incident particle
- $\Gamma_{\lambda\ell j}$, Γ_{λ}, E_R are the elastic and total resonance width and the resonance energy respectively, to be extracted from the fit of the elastic data (see subsection 2.1)
- α_n are the angular distribution coefficients for the considered transition sequence (for example, the coefficients given by Sheldon and Van Patter [3]).

2.3 Compound elastic scattering calculation

The requirements for a single isolated resonance can seldom be satisfied. Thus, the absorved elastic cross section may be regarded as composed both by a term due to direct processes (represented by the formulas of section 2.1) and by a term due to processes which proceed through a compound nucleus formation and decay. Compound nucleus cross sections can be generally calculated by standard methods ([4]) and therefore we have considered only the most simple case, that is the compound elastic scattering. With the symbols used in refs.([4]), the compound nucleus cross-section can be written

$$(12) \qquad \frac{d\sigma(\Theta)}{d\Omega} = \frac{1}{8}\lambda\!\!\!^{-2} \sum_{i,\nu} \alpha_{i\nu}\, \tau_i P_\nu (\cos\vartheta)$$

where

$$(13) \qquad \tau_i = \frac{T_{\ell_1}(E_1)\, T_{\ell_2}(E_2)}{\sum_{\ell jE} T_\ell (E)}$$

If the only energetically allowed (or strongly prominent) channel is the elastic channel, the term τ_i reduces itself to

$$(14) \qquad \tau_i = T_{\ell_1}(E_1)$$

The code UFFAXX then contains the values α_ν for a $0^+ \rightarrow j^\pi \rightarrow 0^+$ transition sequence, and by using in the formulas (12) and (13) the transmission coefficients calculated from the optical model potential (section 2.1), the value of the compound elastic cross section can be calculated.

3. - PROGRAMME DESCRIPTION

The subroutine description appears apart from the main programme UFFAXX.

1) UFFAXX: the main programme reads all the data: control cards, kinematical variables, optical model and resonance parameters. It controls the whole flow of the programme and prints out the results. The numerical integration of the Schroedinger equation is performed by using the Cowell (Fox-Goodwing) method ([5]).

2) SHAPE (taken from programme SMOG ([2])): calculates the total reaction and shape elastic cross sections.

3) STIRL (taken form programme ANSPEC ([1])): calculates Stirling's series for natural logarithm of a factorial.

4) RESML computes the resonance amplitudes. The scattering amplitudes are calculated according to the formula (9).

5) DES (modification of the DES subroutine of programme SMOG ([2])): computes the scattering amplitudes a (Θ) and b (Θ) following the formulas (5) and (6). Cross section and polarization are calculated.

6) DAUX (modification of the DAUX subroutine of programme SMOG ([2])): produces the complex optical model potential.

7) SIGMAO (taken form programme SMOG ([2])): computes the absolute Coulomb phase shifts σ_0 and σ_1.

8) FGET (taken form programme SMOG ([2])): computes the regular and irregular Coulomb wavefunctions and their first derivatives.

9) to 12) COSD, SIND, ACOSD, ATAND (taken form ref.([2])) are trigonometrical functions.

4. - SAMPLE CASE

Two sample cases are presented in the Appendices B and C. The first case shows the fit performed with the code UFFAXX to the $^{32}S(p,p)^{32}S$ elastic scattering data ([6]); the second the fit performed to the data of the $^{12}C(n,n)^{12}C$ angular distributions ([7]). The complete input-output data are listed in the Appendice B and C, and more details on the data can be found in the original papers.

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(6) U. Abbondanno, M. Lagonegro, G. Pauli, G. Poiani and R.A. Ricci, Nuovo Cimento A13, 321 (1973).

(7) F. Demanins, G. Nardelli and G. Pauli, Report INFN/BE - 71/8.

APPENDIX A

```
      PROGRAM UFFAXX(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C-----DESCRIPTION OF INPUT DATA
C
C
C
C-----CONTROLS
C
C     K=0 VOLUME ABSORBTION
C     K=1 GAUSSIAN ABSORBTION
C     K=2 PEREY-BUCK ABSORBTION
C     K=3 PEREY-BUCK ABSORBTION PLUS VOLUME ABSORBTION
C     IF ISCAMP=0 OPTICAL SCATTERING AMPLITUDES ARE CALCULATED
C     IF ISCAMP NOT EQUAL TO 0 OPTICAL SCATTERING AMPLITUDES ARE
C             INPUTTED
C     KPOL=0 NO POLARIZATION CALCULATIONS
C     KPOL NOT EQUAL TO 0 OTHERWISE
C     IF LEGEND NOT EQUAL TO 0 LEGENDRE POLYNOMIALS ARE PRINTED
C     LEGEND =0 OTHERWISE
C     IF KSITOT=0 NO TOTAL CROSS SECTION CALCULATIONS
C     IF KSITOT NOT EQUAL TO 0 TOTAL CROSS SECTIONS ARE CALCULATED
C     IF KOMPEL NOT EQUAL TO ZERO,COMPOUND ELASTIC CROSS SECTION IS
C     CALCULATED FOLLOWING FORMULA OF SHELDON AND VAN PATTER(REF.4)
C     IF KOMPEL=0 OTHERWISE
C     LMAXM MAXIMUM VALUE OF THE RELATIVE MOTION ANGULAR MOMEMTUM
C             (MAXIMUM=10)
C     NPTN NUMBER OF OPTICAL MODEL PARAMETERS SETS TO BE USED IN THE
C             CALCULATIONS
C     KS=0 SPIN ORBIT POTENTIAL ARE NOT TAKEN INTO ACCOUNT
C     KS=1 OTHERWISE
C     NPAS= NUMBER OF STEPS OF THE NUMERICAL INTEGRATION (MAXIMUM=300)
C     KPEN=0 NO PENETRABILITY CALCULATION
C     KPEN NOT EQUAL TO 0 PENETRABILITY ARE CALCULATED STARTING FROM
C             A RADIUS RPEN WITH NRPEN INCREMENTS DRPEN
C     IFRES=0 ONLY OPTICAL MODEL CALCULATIONS
C     IFRES NOT EQUAL TO ZERO OPTICAL MODEL PLUS RESONANCE TERMS ARE
C             CALCULATED
C     IFTL=0 IF NO TRANSMISSION COEFFICIENTS ARE REQUIRED
C     IFTL NOT EQUAL TO ZERO TRANSMISSION COEFFICIENTS ARE PRINTED
C     IDELTA NOT EQUAL TO ZERO PHASES ARE PRINTED
C     IDELTA=0 OTHERWISE
C-----BASIC DATA
C
C     NUCLEAR MASSES ARE EXPRESSED IN AMU
C     POTENTIAL DEPTH,RESONANCE WIDTHS AND ENERGIES ARE EXPRESSED IN MEV
C     NUCLEAR RADII AND DIFFUSENESS ARE EXPRESSED IN FERMIS
C-----FMI MASS OF THE INCIDENT PARTICLE
C     FMB MASS OF THE TARGET
C     ZZ CHARGE PRODUCT BETWEEN INCIDENT AND TARGET NUCLEI
C     RCOL RADIAL PARAMETER FOR COULOMB POTENTIAL
C     RACC ACCURACY CONTROL FOR MATCHING CONDITION
C
C-----SET OF NPTN GROUPS OF TWO CARDS,CONTAINING O.M. PARAMETERS
C     VP DEPTH OF THE REAL WOODS-SAXON WELL
C     WP DEPTH OF  ABSORBTION WELL
C     VSP DEPTH OF THE REAL SPIN-ORBIT WELL
C     WSP DEPTH OF THE IMAGINARY SPIN -ORBIT WELL
C     WCP DEPTH OF THE VOLUME ABSORBTION WELL(OPTION K=3)
C     ENER BOMBARDING ENERGY(IN LAB.SYST.) OF THE INCIDENT PARTICLE
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C      SALTI NUMBER OF BOMBARDING ENERGIES AT WHICH THE CALCULATION
C              SHOULD BE MADE
C      VARINE UNIFORM ENERGY INCREMENT FOR SALTI-1 ADDITIONAL BOMBARDING
C              ENERGIES
C      VA REAL WOODS-SAXON WELL DIFFUSENESS
C      VRO ITS RADIAL PARAMETER
C      VBG IMAGINARY GAUSSIAN WELL DIFFUSENESS
C      VRG ITS RADIAL PARAMETER
C      VBB IMAGINARY PEREY-BUCK WELL DIFFUSENESS
C      VRB ITS RADIAL PARAMETER
C      VCC IMAGINARY WOODS-SAXON WELL DIFFUSENESS(OPTION K=3)
C      VRCC ITS RADIAL PARAMETER
C
C      JMAX NUMBER OF CENTRE-OF-MASS ANGLES (MAXIMUM 40)
C-----SET OF JMAX CARDS CONTAINING
C      TETA ARRAY OF THE CENTRE-OF-MASS ANGLES (JMAX VALUES)
C      POLAX ARRAY OF EXPERIMENTAL VALUES OF POLARIZATION (JMAX VALUES)
C      DIPOL ARRAY OF ERRORS IN EXPERIMENTAL VALUES OF POLARIZATION(JMAX
C              VALUES)
C      SGMAEX ARRAY OF EXPERIMENTAL CROSS SECTIONS (MB/SR)
C      DSMEX ARRAY OF EXPERIMENTAL CROSS SECTIONS ERRORS (MB/SR)
C
C      IF IFRES NOT EQUAL TO ZERO,FOLLOWS A CARD CONTAINING
C      NRES,NUMBER OF RESONANCES(MAXIMUM 50)
C
C-----SET OF NRES CARDS CONTAINING RESONANCE PARAMETERS
C      RL RESONANT L-VALUE
C      RJ RESONANT J-VALUE
C      ER RESONANCE ENERGY IN THE CENTRE-OF-MASS FRAME
C      GAT RESONANCE TOTAL WIDTH IN THE CENTRE-OF-MASS FRAME
C      GAP RESONANCE PARTIAL WIDTH IN THE CENTRE-OF-MASS FRAME
C      PHI RESONANCE MIXING PHASE (DEGREES)
C      INEL IS A PARAMETER WICH ALLOWS COMPUTATIONS FOR A NON
C      ELASTIC OUTPUT CHANNEL
C      IF INEL NOT EQUAL TO ZERO,THE FOLLOWING PARAMETERS SHOULD BE
C      INPUTTED
C      A(I) LEGENDRE POLYNOMIALS EXPANSION COEFFICIENTS FOR A GIVEN SPIN-
C              -SEQUENCE IN NONELASTIC CHANNEL
C      GAI RESONANCE PARTIAL WIDTH FOR A NON ELASTIC CHANNEL
C
C-----FOLLOWS A CARD WIYH TARGET THICKNESS AND DET.OUT. PAR. FOR B.W.
C      DELTA= TARGET THICKNESS (MEV) IN THE LABORATORY FRAME
C      IF FUORI NOT EQUAL TO 0 REAL AND IMAGINARY PART OF BREIT-WIGNER
C              CONTRIBUTION ARE PRINTED
C      FUORI=0 OTHERWISE
C
C-----IF ISCAMP NOT EQUAL TO ZERO,THE FOLLOWING DATA SHOULD BE INPUTTED
C      AMPR= OPTICAL SCATTERING AMPLITUDES TO BE INPUTTED IF ISCAMP NOT
C              EQUAL TO ZERO
C      VR= INCREMENT OF AMPR PER MEV
C
       DIMENSION VA(10),VRO(10),VBG(10),VRG(10),VBB(10),VRB(10),VCC(10),
      1VRCC(10)
       DIMENSION SALTI(10),VARINE(10)
       DIMENSION TITLE(12),AMPR1(11),AMPR2(11),AMPI1(11),AMPI2(11),VR1(11
      1),VR2(11),VI1(11),VI2(11),UCCMI(11),UCCMII(11)
       DIMENSION WAVER(320),AR(320),AI(320),X(320),Y(320)
       DIMENSION VP(10),WP(10),VSP(10),ENER(10),WCP(10),WSP(10)
       DIMENSION DR1(11),DR2(11),DG1(11),DG2(11)
       COMMON/COULOM/ZZ,ETA,RHOBNC,RCOL,SIGO(2),PENET(11),ESSE(11)
       COMMON/OMPOT/K,V,W,VS,WS,CC,RO,RR,A,BB,BG,RHOMAX,RHOBN,RHOBNG,W1,P
      1,Q,RCC,RHOCC
       COMMON/SCAMP/CR1(11),CR2(11),CI1(11),CI2(11),UCS(11),UCG(11)
       COMMON/FASI/D1(11),D2(11),COTI1(11),COTI2(11),COTR1(11),COTR2(11)
       COMMON/STAMPA/TETA(40),SDIFE(40),SIGR(40),SGMAEX(40),POL(40),POLAX
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     1(40),DSMEX(40),DIPOL(40),SDAFE(40),SIGMAR,SIGMAT,SSHAPE,SUMAO,KPOL
      COMMON/ENERGY/ELAB,ECM,FKAY,IEN,NPOT,LMAX,LMAXM,L,JMAX,WAVE,PLATA2
      COMMON/VANZUM/                          X1(11),X2(11),Y1(11),Y2(11)
     1,RAPA,LEGEND,QUAPIG,                DRO,KS,T6,KT,FMI,FMB
      COMMON/AFAC/ACOFA(11)
      COMMON/GEIPAI/RL(50),RJ(50),ER(50),GAT(50),GAP(50),PHI(50),DELTA,N
     1RES,FUORI,BWINEL(50),INEL(50)
      COMMON/RAMENG/A0(50),A2(50),A4(50),A6(50),A8(50),GAI(50)
      COMMON/MATCH/CAIP,PAIS,CIFE,PIC
      COMMON/RAITV/TR(11),TPLUS(11),TMENO(11),KOMPEL
      QUAPIG=12.5663708
4     WRITE(6,101)
101   FORMAT(1H1,40X,40H   U   F   F   A   X   X                      )
      READ 100,(TITLE(MIAO),MIAO=1,12)
100   FORMAT(12A6)
      IF(EOF(5)) 77,1945
1945  PRINT 100,TITLE
      READ(5,102) K,ISCAMP,KPOL,LEGEND,KSITOT,KOMPEL
102   FORMAT(16I5)
      DO 3600 I=1,50
      RL(I)=0.
      RJ(I)=0.
      ER(I)=0.
      GAT(I)=0.
      GAP(I)=0.
      BWINEL(I)=0.
      PHI(I)=0.
      INEL(I)=0
      GAI(I)=0.
      A0(I)=0.
      A2(I)=0.
      A4(I)=0.
      A6(I)=0.
      A8(I)=0.
3600  CONTINUE
      NRES=0
      FUORI=0.
      DELTA=0.
      IF(K-4  )5,77,77
5     READ 102,LMAXM        ,NPTN,KS,NPAS,KPEN,NRPEN,IFRES,IFTL,IDELTA
      IF(LMAXM.GT.10) LMAXM=10
      IF(NPTN.GT.10) NPTN=10
      READ 103,FMI,FMB,ZZ,RCOL,RPEN,DRPEN,RACC
103   FORMAT(8F10.5)
      DO 1806 I=1,NPTN
      READ103,VP(I),WP(I),VSP(I),WSP(I),WCP(I),ENER(I),SALTI(I),VARINE(I
     1)
      READ103,VA(I),VRO(I),VBG(I),VRG(I),VBB(I),VRB(I),VCC(I),VRCC(I)
1806  CONTINUE
      DO 1946 I=1,40
      SIGR(I)=0.
      SDAFE(I)=0.
      SGMAEX(I)=0.
      DSMEX(I)=0.
      POLAX(I)=0.
      DIPOL(I)=0.
      POL(I)=0.
      TETA(I)=0.
1946  SDIFE(I)=0.
      READ 102,JMAX
      IF(JMAX.GT.40) JMAX=40
      READ(5,113)(TETA(J),POLAX(J),DIPOL(J),SGMAEX(J),DSMEX(J),J=1,JMAX)
113   FORMAT(5F10.3)
      IF(IFRES.EQ.0) GO TO 5300
      READ 102,NRES
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      DO 5008 I=1,NRES
      READ 5009,RL(I),RJ(I),ER(I),GAT(I),GAP(I),PHI(I),INEL(I)
5009  FORMAT(6F10.5,I5)
      IF(INEL(I).EQ.0) GO TO 5008
      READ103,A0(I),A2(I),A4(I),A6(I),A8(I),GAI(I)
5008  CONTINUE
      READ103,DELTA,FUORI
      IF(ISCAMP.EQ.0) GO TO 5300
      LMAX=LMAXM+1
      DO 3751 I=1,LMAX
3751  READ 103,AMPR1(I),VR1(I),AMPI1(I),VI1(I),AMPR2(I),VR2(I),AMPI2(I),
     1VI2(I)
5300  NPOT=0
    7 IEN=1
      NPOT=NPOT+1
      IF(NPOT.GT.NPTN) GO TO 4
      MAXEN=SALTI(NPOT)
      DEPE=VARINE(NPOT)
6     ELAB=ENER(NPOT)+DEPE*FLOAT(IEN-1)
      IF(ISCAMP.EQ.0) GO TO 436
      DO 3753 I=1,LMAX
      CR1(I)=AMPR1(I)+VR1(I)*DEPE*FLOAT(IEN-1)
      CR2(I)=AMPR2(I)+VR2(I)*DEPE*FLOAT(IEN-1)
      CI1(I)=AMPI1(I)+VI1(I)*DEPE*FLOAT(IEN-1)
3753  CI2(I)=AMPI2(I)+VI2(I)*DEPE*FLOAT(IEN-1)
436   IF(IEN.GT.1) GO TO 11
      V=VP(NPOT)
      W1=WCP(NPOT)
      W=WP(NPOT)
      WS=WSP(NPOT)
      VS=VSP(NPOT)
      A=VA(NPOT)
      RO=VRO(NPOT)
      BG=VBG(NPOT)
      RG=VRG(NPOT)
      BB=VBB(NPOT)
      RB=VRB(NPOT)
      CC=VCC(NPOT)
      RCC=VRCC(NPOT)
      CIUCI=FMB**0.33333333
      PR=RO*CIUCI
      PGA=RG*CIUCI
      PBU=RB*CIUCI
      PCO=RCOL*CIUCI
      PCC=RCC*CIUCI
    9 CO=FMI+FMB
   10 FMU=(FMI*FMB)/CO
11    ECM=(ELAB-DELTA/2.)*FMU
   12 FKAY=.218728 *SQRT(ABS(FMU*ECM))
      PLATA2=31.415927/(FKAY**2)
      ETA=0.157454 *ZZ*SQRT(FMI/(ELAB-DELTA/ 2.))
   13 TIM=FKAY*CIUCI
250   IF(IEN.NE.1) GO TO 230
 6662 WRITE(6,190)
  190 FORMAT(15H  INPUT DATA    )
      IF(K-1)600,601,602
  600 WRITE(6,610)
  610 FORMAT(24H ONLY VOLUME ABSORBTION )
      GOTO 232
  601 WRITE(6,611)
  611 FORMAT(23H GAUSSIAN ABSORBTION    )
      GOTO 232
  602 IF(K-2)77,603,604
  603 WRITE(6,613)
  613 FORMAT(24H PEREY-BUCK ABSORBTION   )
```

```
      GOTO 232
  604 IF(K-3)77,606,77
  606 WRITE(6,614)
  614 FORMAT(55H PEREY-BUCK PLUS VOLUME ABSORBTION                     )
232   PRINT 121,FMI,FMB,PR,PGA,PBU,PCO,A,BG,BB,CC,V,W,W1,VS,WS,ZZ
121   FORMAT(3X,3HMI=,F8.3,3X,3HMT=,F8.3/3X,10HSW RADIUS=,F8.3/3X,16HGAU
     1SSIAN RADIUS=,F8.3/3X,18HPEREY-BUCK RADIUS=,F8.3/3X,25HCOULOMB POT
     2ENTIAL RADIUS=,F8.3/3X,9HSW DIFF.=,F8.3/3X,20HGAUSSIAN ABS. DIFF.=
     3,F8.3/3X,22HPEREY-BUCK ABS. DIFF.=,F8.3/3X,18HVOLUME ABS. DIFF.=,F
     48.3/3X,9HSW DEPTH=,F8.3/3X,20HSURFACE IMAG. DEPTH=,F8.3/3X,19HVOLU
     5ME IMAG. DEPTH=,F8.3/3X,22HREAL SPIN-ORBIT DEPTH=,F8.3/3X,23HIMAG.
     6 SPIN-ORBIT DEPTH=,F8.3/3X,15HCHARGE PRODUCT=,F8.0)
      PRINT1804,PCC
1804  FORMAT(3X,19HVOLUME ABS. RADIUS=,F8.3)
      PRINT 1947,LMAXM,NPAS,RACC
1947  FORMAT(5X,6HLMAXM=,I5/5X,6HNPAS =,I5/5X,24HACCURACY PARAMETER RACC
     1=,F10.7)
      IF(IFRES.EQ.0) GO TO 230
      PRINT 3601,NRES
3601  FORMAT(1X//20X,17HRESONANCES TABLE ,5X,3HN.=,I3)
      DO 3500 I=1,NRES
      JR=2.*RJ(I)
      LRI=RL(I)
      PRINT 3240,LRI,JR,ER(I),GAT(I),GAP(I),PHI(I),INEL(I)
3240  FORMAT(1X/                          1X,2HL=,I3,5X,2HJ=,I3,2H/2,3X,
     13HER=,F10.5,1X,3HMEV,3X,6HTO.W.=,F10.5,4H MEV,3X,6HPA.W.=,F10.5,4H
     2 MEV,3X,6HPHASE=,F10.5,8H DEGREES,3X,5HINEL=,I5)
      IF(INEL(I).EQ.0) GO TO 3500
      PRINT 103,A0(I),A2(I),A4(I),A6(I),A8(I),GAI(I)
3500  CONTINUE
      PRINT 3250,DELTA
3250  FORMAT(1X,14HTARGET IN MEV=,F10.5)
230   IF(JMAX.EQ.1) GO TO 14
      PRINT 161,ELAB,ECM,ETA
161   FORMAT(1X///1X,5HELAB=,F10.5,2X,4HECM=,F10.5,2X,4HETA=,F10.5/48H**
     1**********************************************          )
   14 RHOBN=TIM*RO
C-----PENETRABILITY CALCULATION
      IF(KPEN.LE.0) GO TO 10004
      NPEN=1
10002 TEM=PR+RPEN+FLOAT(NPEN-1)*DRPEN
      TOM=FKAY*TEM
      PRINT 10003,TEM
10003 FORMAT(1X///1X,32HPENETRABILITY CALCULATION RAD. =,F15.6,1X,6HFERM
     1IS)
      PRINT 10007
10007 FORMAT(8X,2HL ,5X,7H   F    ,2X,10HITS DERIV.,3X,9H    G    ,2X,10H
     1ITS DERIV.,2X,28HPENETRABILITY AND SHIFT           )
      LMAX=LMAXM+1
      DO 2001 L=1,LMAX
      LUI=L-1
      CALL FGET(LUI,LV,ETA,TOM,GG,GGP,FF,FFP,SIGM)
      PAL=FF*FF+GG*GG
      PEL=FF*FFP+GG*GGP
      PENET(L)=TOM/PAL
      ESSE(L)=PENET(L)*PEL
2001  PRINT 10006,LUI,FF,FFP,GG,GGP,PENET(L),ESSE(L)
10006 FORMAT(I10,6E12.5)
      NPEN=NPEN+1
      IF(NPEN.GT.NRPEN) GO TO 10004
      GO TO 10002
10004 RHOBNC=RCOL*TIM
      RR=TIM*RB
      RHOCC=RCC*TIM
```

```
   15 RHOBNG=TIM*RG
      IF(K-3)18,18,77
   18 T6=FKAY*A
      IF(ISCAMP.NE.0) GO TO 17
C-----FIRST MATCHING RADIUS CALCULATION
      IF(IEN.GT.1)GO TO 5900
      IF(ZZ.EQ.0.) GO TO 5901
      PIP=RHOBN
      DPIP=RHOBN/FLOAT(NPAS)
10015 PIC=PIP
      CALL DAUX
      SWFF=CAIP
      PBFF=PAIS
      PICCIO=CIFE
      TRAPA=SQRT(SWFF**2+PBFF**2)/PICCIO
      IF(TRAPA-RACC) 10013,10014,10014
10013 SCOTCH=PIP/FKAY
      PIC=0.
      GO TO 5900
5901  SCOTCH=      PR+10.*AMAX1(A,BG,BB,CC)
5900  RHOMAX=SCOTCH*FKAY
      IF(JMAX.EQ.1) GO TO 17
233   PRINT 122,SCOTCH,FKAY
122   FORMAT(1X,24HMATCHING RADIUS(FERMIS)=,F10.3,4H  K=,E11.4)
      GO TO 17
10014 PIP=PIP+DPIP
      GO TO 10015
   17 LMAX=LMAXM+1
    2 PASSI=NPAS
      NPASSI=NPAS
      CALL SIGMAO(ETA,SIGO)
      IF(ZZ.EQ.0.) SIGO(1)=0.
   96 DO 50  L=1,LMAX
      IF(ISCAMP.NE.0) GO TO 1948
      KT=0
      KONTRL=0
   86 KPAS=NPASSI
      IC=0
      FL=L
      LH=L-1
  302 DRO=RHOMAX/PASSI
      DRO2=DRO**2
      DRO256=DRO2*0.83333333
      DRO212=DRO256/10.
C-----CALCULATION OF POTENTIAL AND LOCAL WAVE NUMBER
      LPAS=NPAS+20
      IF(LPAS.GT.320) LPAS=320
      DO 3700 MI=1,LPAS
      RAPA=DRO*FLOAT(MI)
      CALL DAUX
      WAVER(MI)=WAVE
      AR(MI)=P
3700  AI(MI)=Q
C-----STARTING VALUES FOR  F=X+I*Y (SEE REF. 1, SUB YZ12)
      VNOR=STIRL(2.*FL)-STIRL(FL)
      X(1)=EXP(FL*ALOG(2.*WAVER(1))-VNOR)
      Y(1)=0.0
      X(2)=EXP(FL*ALOG(2.*WAVER(2))-VNOR)
      Y(2)=0.0
C-----CALCULATION OF X AND Y FOR GIVEN L AND J
C-----FOX-GOODWIN METHOD, REF. 3
      DO 3701 MI=3,LPAS
      AX=(2.+DRO256*AR(MI-1))*X(MI-1)-DRO256*AI(MI-1)*Y(MI-1)
      BX=(2.+DRO256*AR(MI-1))*Y(MI-1)+DRO256*AI(MI-1)*X(MI-1)
      CX=(1.-DRO212*AR(MI-2))*X(MI-2)+DRO212*AI(MI-2)*Y(MI-2)
```

```
      DX=(1.-DRO212*AR(MI-2))*Y(MI-2)-DRO212*AI(MI-2)*X(MI-2)
      EX=1.-DRO212*AR(MI)
      FX=DRO212*AI(MI)
      DEN=EX**2+FX**2
      X(MI)=((AX-CX)*EX-(BX-DX)*FX)/DEN
3701  Y(MI)=((AX-CX)*FX+(BX-DX)*EX)/DEN
C-----OPTICAL SCATTERING AMPLITUDES CALCULATION
      RHOMAX=DRO*FLOAT(NPAS)
      CALL FGET(LH,LV,ETA,RHOMAX,GG,GGP,FF,FFP,SIGM)
C-----COULOMB FUNCTIONS AT THE FIRST MATCHING RADIUS HAVE BEEN
C             CALCULATED
      X1(L)=FF
      Y1(L)=GG
      NPASII=NPAS+16
      RHOSEC=DRO*FLOAT(NPASII)
3704  CALL FGET(LH,LV,ETA,RHOSEC,GG,GGP,FF,FFP,SIGM)
C-----COULOMB FUNCTIONS AT THE SECOND MATCHING RADIUS HAVE BEEN
C             CALCULATED
      X2(L)=FF
      Y2(L)=GG
      XA=X(NPAS)*Y2(L)-Y(NPAS)*X2(L)
      XB=Y(NPAS)*Y2(L)+X(NPAS)*X2(L)
      XC=X(NPASII)*Y1(L)-Y(NPASII)*X1(L)
      XD=Y(NPASII)*Y1(L)+X(NPASII)*X1(L)
C-----TEST AGAINST DISASTERS AND REMEDIANDI ATTEMPT
      IF(ABS(XC)+ABS(XD)) 3702,3703,3702
3703  RHOSEC=0.5*(RHOMAX+RHOSEC)
      NPASII=(NPAS+NPASII)/2
      GO TO 3704
C-----TEST AGAINST CATASTROPHICALLY INACCURATED CALCULATIONS
3702  IF(ABS(XB/XD-1.)-0.1) 3705,3705,3706
3705  IF(ABS(XA/XC-1.)-0.1)3703,3703,3706
3706  XE=X1(L)*X(NPASII)-X2(L)*X(NPAS)
      XF=X1(L)*Y(NPASII)-X2(L)*Y(NPAS)
      ZING=XA-XC
      ZANG=XB-XD
      ZONG=ZING**2+ZANG**2
      SMPLR=(ZING*XE+ZANG*XF)/ZONG
      SMPLI=(ZING*XF-ZANG*XE)/ZONG
      IF(KS) 3707,3708,3707
3707  IF(KT) 3710,3709,3710
3708  CR1(L)=SMPLR
      CR2(L)=SMPLR
      CI1(L)=SMPLI
      CI2(L)=SMPLI
      GO TO 1948
3709  CR1(L)=SMPLR
      CI1(L)=SMPLI
      KT=1
      GO TO 86
3710  CR2(L)=SMPLR
      CI2(L)=SMPLI
1948  UCS(L)=SQRT((1.-2.*CI1(L))**2+(2.*CR1(L))**2)
      UCG(L)=SQRT((1.-2.*CI2(L))**2+(2.*CR2(L))**2)
50    CONTINUE
      CR2(1)=0.
      CI2(1)=0.
      SIGMAR=0.
      SIGMAT=0.
      SSHAPE=0.
      IF(IFRES) 10016,216,10016
C-----RESONANT SCATTERING AMPLITUDES ARE CALCULATED
10016 CALL RESML
216   DO229L=1,LMAX
```

```
      PARZ1=CR1(L)**2+CI1(L)**2
      PARZ2=CR2(L)**2+CI2(L)**2
      D1(L)=-0.25*ALOG(1.0-4.0*(CI1(L)-PARZ1))
      D2(L)=-0.25*ALOG(1.0-4.0*(CI2(L)-PARZ2))
      IF(JMAX.EQ.1) GO TO 5902
      DG1(L)=D1(L)*57.295779
      DG2(L)=D2(L)*57.295779
      UIMMI=2.*CR2(L)
      URREI=1.-2.*CI2(L)
      UIMMII=2.*CR1(L)
      URREII=1.-2.*CI1(L)
      UCCMI(L)=SQRT(UIMMI**2+URREI**2)
      UCCMII(L)=SQRT(UIMMII**2+URREII**2)
      DR1(L)=28.6478895 * ATAN2(UIMMII,URREII)
      DR2(L)=28.6478895 * ATAN2(UIMMI,URREI)
 5902 COTI1(L)=(PARZ1-CI1(L))/PARZ1
      COTI2(L)=(PARZ2-CI2(L))/PARZ2
      COTR1(L)=CR1(L)/PARZ1
      COTR2(L)=CR2(L)/PARZ2
      FL=L-1
      TPLUS(L)=4.*(CI1(L)-PARZ1)
      TMENO(L)=4.*(CI2(L)-PARZ2)
      IF(L.EQ.1) TMENO(1)=0.
      TR(L)=((FL+1.)*(TPLUS(L))+FL*TMENO(L))/(2.*FL+1.)
      SIGMC=(2.*FL+1.)*TR(L)*31.415927/(FKAY**2)
      SIGMAR=SIGMAR+SIGMC
      IF(IFTL.EQ.0) GO TO 229
      PRINT 125,FL,TPLUS(L),TMENO(L),TR(L),SIGMC
 125  FORMAT(1X,2HL=,F4.0,5X,3HT+=,E11.4,5X,3HT-=,E11.4,5X,3HT =,E11.4,5
     1X,11HSIGMRC(MB)=,F10.4)
 229  CONTINUE
      DR2(1)=0.0
      DG2(1)=0.0
      D2(1)=0.0
      COTR2(1)=0.
      COTI2(1)=0.
      UCG(1)=0.
      UCCMI(1)=0.
C-----TOTAL CROSS SECTIONS CALCULATION
      IF(KSITOT.EQ.0) GO TO 5001
      CALL SHAPE
      IF(JMAX.EQ.1) GO TO 5001
      WRITE(6,2522)SIGMAR,SIGMAT,SSHAPE
 2522 FORMAT(18H   SIGMA REACTION=F15.8,10HMILLIBARNS/18H   SIGMA   TOTA
     1L =F15.8,10HMILLIBARNS/18H  SHAPE EL. SIGMA=F15.8,10HMILLIBARNS)
C-----DIFFERENTIAL CROSS SECTIONS CALCULATION
 5001 CALL DES
      IF(JMAX.EQ.1) GO TO 5002
      IF(KOMPEL.EQ.0) PRINT 405
      IF(KOMPEL.NE.0) PRINT 5100
 405  FORMAT(1X, 119HCMTETA  SIGMA EL.    SIGMA INEL.   SIGMA RUTH.  SIG
     1MA(TETA) EXP   DSIGMA EXP      POL(TETA)       POL(TETA) EXP   DPOL E
     2XP  )
 5100 FORMAT(1X, 119HCMTETA  SIGMA SH.    SIGMA C.EL.   SIGMA T.EL.  SIG
     1MA(TETA) EXP   DSIGMA EXP      POL(TETA)       POL(TETA) EXP   DPOL E
     2XP  )
      GO TO 5003
 5002 IF(IEN.GT.1) GO TO 5003
      PRINT 5006,TETA(1)
 5006 FORMAT(1X,10HCM ANGLE =,F10.3/1X,20H********************     )
      IF(KOMPEL.EQ.0) PRINT 5004
      IF(KOMPEL.NE.0) PRINT 3577
 5004 FORMAT(11X,9HELAB(MEV),1X,9HSIGMA EL.,1X,9HSIGMA IN.,1X,9HSIGMA RU
     1.,2X,8HPOLARIZ.,1X,9HSIGMA RE.,1X,9HTOTAL IN.,1X,9HSIGMA SH.     )
```

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3577  FORMAT(1X, 119H ELAB   SIGMA SH.    SIGMA C.EL.   SIGMA T.EL.  SIG
     1MA(TETA) EXP   DSIGMA EXP     POL(TETA)       POL(TETA) EXP    DPOL E
     2XP   )
5003  DO 406 J=1,JMAX
      STETA=TETA(J)
      IF(KOMPEL.NE.0) GO TO 409
      IF(STETA.EQ.0.) GO TO 409
      SIGR(J)=(ETA**2)/((4.*FKAY**2)*(SIND(STETA/2.)**4))*10.
409   IF(JMAX.EQ.1) GO TO 5005
      PRINT 410,TETA(J),SDIFE(J),SDAFE(J),SIGR(J),SGMAEX(J),DSMEX(J),POL
     1(J),POLAX(J),DIPOL(J)
  410 FORMAT(F6.1,F10.3,2F15.5,F13.5,F15.3,F13.5,F17.5,F15.4)
      GO TO 406
5005  PRINT 5000,ELAB,SDIFE(J),SDAFE(J),SIGR(J),POL(J),SIGMAR,SUMAO ,SSH
     1APE
5000  FORMAT(10X,F10.5,7F10.3)
  406 CONTINUE
      IF(JMAX.EQ.1) GO TO 414
3412  WRITE(6,126)
126   FORMAT(1X,50HCOULOMB PHASES AND SCATTERING AMPLITUDES TABLE       //2
     1X,1HL,2X,1HJ,4X,8HCO.PHAS.,1X,20HMOD U RES.AND OPTIC.,1X,20HREAL A
     2ND IMAG.AMPL. ,8X,1HL,2X,1HJ,2X,20HMOD U RES.AND OPTIC.,1X,20HREAL
     3 AND IMAG.AMPL.          )
      DO 62 L=1,LMAX
      LIX=L-1
      LUX=2*L-1
      LEX=2*L-3
      IF(LEX.LT.0) LEX=0
      PRINT 129,LIX,LUX,ACOFA(L),UCCMII(L),UCS(L),CR1(L),CI1(L),LIX,LEX,
     1UCCMI(L),UCG(L),CR2(L),CI2(L)
129   FORMAT(2I3,2H/2,F8.4,1X,2F10.7,1X,2F10.4,6X,2I3,2H/2,2F10.7,1X,2F1
     10.4)
      IF(IDELTA.EQ.0) GO TO 62
      PRINT 11000,LIX,LUX,DR1(L),DG1(L),LIX,LEX,DR2(L),DG2(L)
11000 FORMAT(1X,15HSCATTERING PHAS,5X,2I3,2H/2,2F10.3,6X,2I3,2H/2,2F9.3)
62    CONTINUE
  414 IEN=IEN+1
      IF(IEN-MAXEN)6,6,7
77    PRINT 20
20    FORMAT(30X,44HCRAZY CONTROL PARAMETER FOR POTENTIAL CHOICE/30X,38H
     1BRAUEREI IST GESCHLOSSEN.HILFE,HILFE          )
      STOP
      END
$IBFTC ACDX    NODECK
      FUNCTION ACOSD(X)
C---------THIS FUNCTION IS TAKEN FROM PROGRAM SMOG (REF. 2)
      ACOSD= ACOS(X)*57.295779
      RETURN
      END

$IBFTC ATAX    NODECK
      FUNCTION ATAND(X)
C---------THIS FUNCTION IS TAKEN FROM PROGRAM SMOG (REF. 2)
      ATAND=ATAN (X)*57.295779
      RETURN
      END

$IBFTC COSDXX  NODECK
      FUNCTION COSD(X)
C---------THIS FUNCTION IS TAKEN FROM PROGRAM SMOG (REF. 2)
      COSD=COS(X*0.017453292)
      RETURN
      END
```

```
$IBFTC DAUXX    NODECK
      SUBROUTINE DAUX
C---------MODIFICATION OF THE DAUX SUBROUTINE OF THE PROGRAM SMOG (REF2)
      COMMON/COULOM/ZZ,ETA,RHOBNC,RCOL,SIGO(2)
      COMMON/OMPOT/K,V,W,VS,WS,CC,RO,RR,A,BB,BG,RHOMAX,RHOBN,RHOBNG,W1,P
     1,Q,RCC,RHOCC
      COMMON/ENERGY/ELAB,ECM,FKAY,IEN,NPOT,LMAX,LMAXM,L,JMAX,WAVE
      COMMON/VANZUM/                          X1(11),X2(11),Y1(11),Y2(11)
     1,RAPA,LEGEND,QUAPIG,                DRO,KS,T6,KT,FMI,FMB
      COMMON/MATCH/CAIP,PAIS,CIFE,PIC
      IF(PIC.LE.0.) GO TO 100
      FL=0.
      RAPA=PIC
      RHOBB=RR
      GO TO 5
100   RHOBB=RR
      IF(KS)77,5,18
   18 IF(KT)77,2,3
    2 D=L-1
      GO TO 20
    5 D=0.0
      GO TO 20
    3 D=-L
   20 EX=1.0/(1.0+EXP((RAPA-RHOBN)/T6))
      IF(K-1)4,7,13
   13 IF(K-2)77,40,35
   35 IF(K-3)77,31,77
31    PARZ=EXP((RAPA-RHOCC)/(FKAY*CC))
      FCI1=1.0/(1.0+PARZ)
   40 PBUC=EXP((RAPA-RHOBB)/(FKAY*BB))
      FCI =4.0*PBUC/(1.0+PBUC)**2
      FCR    =EX
      GO TO 6
    4 FCR    =EX
      FCI    =EX
    6 FSI =EXP((RAPA-RHOBN)/T6)/RAPA*EX**2
      FSR    =FSI
      GO TO 8
    7 PGAUS=((RAPA-RHOBNG)/(FKAY*BG))**2
      FCR    =EX
      IF(PGAUS-15.)30,30,22
   22 FCI =0.
      GOTO 6
   30 FCI =EXP(-PGAUS)
      GO TO 6
    8 FL=L-1
      IF(RAPA-RHOBNC)50,50,51
   50 QQ=ETA/RHOBNC*(3.0-(RAPA/RHOBNC)**2)
      GO TO 52
   51 QQ=2.0*ETA/RAPA
52    XR=-1.-V*FCR/ECM+QQ
      XRSO=    -D*VS*FKAY*FSR/(ECM*A)
      XGF=FL*(FL+1.)/(RAPA**2)
      XI=(-W*FCI-W1*FCI1)/ECM
      XISO=    -D*WS*FKAY*FSI/(ECM*A)
      P=XR+XRSO+XGF
      Q=XI+XISO
      WAVE=RAPA*(XR**2+XI**2)**0.25
      IF(PIC.LE.0.) RETURN
      CAIP=-(XR+1.-QQ)
      PAIS=-XI
      CIFE=QQ
77    RETURN
      END
```

```
$IBFTC DESX     NODECK
      SUBROUTINE DES
C---------MODIFICATION OF THE DESX SUBROUTINE OF THE PROGRAM SMOG (REF2)
      COMMON/AFAC/ACOFA(11)
      COMMON/COULOM/ZZ,ETA,RHOBNC,RCOL,SIGO(2),PENET(11),ESSE(11)
      COMMON/SCAMP/CR1(11),CR2(11),CI1(11),CI2(11)
      COMMON/STAMPA/TETA(40),SDIFE(40),SIGR(40),SGMAEX(40),POL(40),POLAX
     1(40),DSMEX(40),DIPOL(40),SDAFE(40),SIGMAR,SIGMAT,SSHAPE,SUMAO,KPOL
      COMMON/ENERGY/ELAB,ECM,FKAY,IEN,NPOT,LMAX,LMAXM,L,JMAX,WAVE,PLATA2
      COMMON/GEIPAI/RL(50),RJ(50),ER(50),GAT(50),GAP(50),PHI(50),DELTA,N
     1RES,FUORI,BWINEL(50),INEL(50)
      COMMON/RAMENG/A0(50),A2(50),A4(50),A6(50),A8(50),GAI(50)
      COMMON/VANZUM/                          X1(11),X2(11),Y1(11),Y2(11)
     1,RAPA,LEGEND,QUAPIG,              DRO,KS,T6,KT,FMI,FMB
      COMMON/RAITV/TR(11),TPLUS(11),TMENO(11),KOMPEL
      DIMENSION P(14,40),PP(14,40),AR(40),BR(40),AI(40),BI(40)
      DIMENSION FATMOL(50),EXSGMR(11),EXSGMI(11)
      IF(IEN.GT.1) GO TO 203
    1 DO 20 J=1,JMAX
   51 DSQ=SIND(TETA(J))
      IF(DSQ)82,83,82
   83 SI2=0.0
      GO TO 4
   82 SI2=1.0/DSQ
    4 CO=COSD(TETA(J))
   64 P(1,J)=1.0
      P(2,J)=CO
      PP(1,J)=0.0
      TWOLP1=3.0
      FL=1.0
      DO 20 L=1,11
      TL=FL+1.0
      P(L+2,J)=(TWOLP1*CO*P(L+1,J)-FL*P(L,J))/TL
      PP(L+1,J)=TL*SI2*(CO*P(L+1,J)-P(L+2,J))
      TWOLP1=TWOLP1+2.0
   20 FL=TL
      IF(LEGEND.EQ.0) GO TO 203
      PRINT 206
206   FORMAT(1X,21HLEGENDRE POLYN.TABLE /3X,4HTETA,8X,2HP1,8X,2HP2,8X,2H
     1P3,8X,2HP4,8X,2HP5,8X,2HP6,8X,2HP7,8X,2HP8,8X,2HP9,7X,3HP10,7X,3HP
     211,7X,3HP12    )
      DO 204 J=1,JMAX
204   PRINT205,TETA(J),P(2,J),P(3,J),P(4,J),P(5,J),P(6,J),P(7,J),P(8,J),
     1P(9,J),P(10,J),P(11,J),P(12,J),P(13,J)
205   FORMAT(F7.2,12F10.7)
203   FKAYD=1.0/FKAY
      DO 300 L=1,LMAX
      FLIII=L-1
      IF(FLIII) 100,100,101
100   ACOFA(L)=SIGO(1)
      GO TO 102
101   ACOFA(L)=ACOFA(L-1)+ATAN2(ETA,FLIII)
102   EXSGMR(L)=COS(2.*ACOFA(L)-2.*SIGO(1))
      EXSGMI(L)=SIN(2.*ACOFA(L)-2.*SIGO(1))
300   CONTINUE
      DO 21 J=1,JMAX
   23 TNC=TETA(J)
   25 SN=(SIND(TNC/2.0))**2
      IF(SN)90,91,90
   91 FNO=0.0
      FLN=0.0
      GOTO 92
   90 DLOG=ALOG(SN)
      IF(DLOG)93,91,93
```

```
93    FLN=ETA*DLOG
      FNO=ETA/(2.0*FKAY*SN)
   92 ECI=FNO*SIN(FLN)
      ECR=-FNO*COS(FLN)
      ASUMR=0.0
      ASUMI=0.0
      BSUMR=0.0
      BSUMI=0.0
      DO 10 L=1,LMAX
      FL=L
      ATR1=FL*CR1(L)+(FL-1.0)*CR2(L)
      ATI1=FL*CI1(L)+(FL-1.0)*CI2(L)
      BTR1=CR1(L)-CR2(L)
      BTI1=CI1(L)-CI2(L)
      ASUMR=ASUMR+(ATR1*EXSGMR(L)-ATI1*EXSGMI(L))*P(L,J)
      ASUMI=ASUMI+(ATR1*EXSGMI(L)+ATI1*EXSGMR(L))*P(L,J)
      BSUMR=BSUMR+(BTR1*EXSGMR(L)-BTI1*EXSGMI(L))*PP(L,J)
 10   BSUMI=BSUMI+(BTR1*EXSGMI(L)+BTI1*EXSGMR(L))*PP(L,J)
      AR(J)=ECR+FKAYD*ASUMR
      AI(J)=ECI+FKAYD*ASUMI
      BR(J)=FKAYD*BSUMI
      BI(J)=-FKAYD*BSUMR
   21 SDIFE(J)=(AR(J)**2+AI(J)**2+BR(J)**2+BI(J)**2)*10.
      IF(KOMPEL.GT.0) GO TO 1000
      IF(NRES.EQ.0) GO TO 1002
      DO 201 J=1,JMAX
      SDAFE(J)=0.
      DSDAFE=0.
      SUMAO=0.
      DO 200 I=1,NRES
      FATMOL(I)=BWINEL(I)*PLATA2*(2.*RJ(I)+1.)/2.
      SUMAO=SUMAO+FATMOL(I)
      IF(INEL(I).EQ.0) GO TO 200
      AO=FATMOL(I)/QUAPIG
      DSEZ=(A0(I)*P(1,J)+A2(I)*P(3,J)+A4(I)*P(5,J)+A6(I)*P(7,J)+A8(I)*
     1P(9,J))/A0(I)
      DSDAFE=DSDAFE+AO*DSEZ
200   CONTINUE
201   SDAFE(J)=SDAFE(J)+DSDAFE
      IF(KOMPEL.EQ.0) GO TO 1002
1000  COP0=2.*(TPLUS(1)+TMENO(2))+4.*(TPLUS(2)+TMENO(3))+6.*(TPLUS(3)+
     1TMENO(4))+8.*TPLUS(4)
      COP2=4.*(TPLUS(2)+TMENO(3))+6.85714*(TPLUS(3)+TMENO(4))+9.5238*
     1TPLUS(4)
      COP4=5.*(TPLUS(3)+TMENO(4))+8.41558*TPLUS(4)
      DO 1001 J=1,JMAX
      SDAFE(J)=PLATA2/(8.*3.1415927)*(COP0+COP2*P(3,J)+COP4*P(5,J))
1001  SIGR(J)  =SDIFE(J)+SDAFE(J)
1002  IF(KPOL)40,41,40
   40 DO 42J=1,JMAX
      IF(SDIFE(J).EQ.0.) GO TO 42
      IF(KOMPEL.EQ.0) GO TO 43
      POL(J)  =-(2.*(AR(J)*BR(J)+AI(J)*BI(J)))/SIGR  (J)*10.
      GO TO 42
   43 POL(J)=-(2.0*(AR(J)*BR(J)+AI(J)*BI(J)))/(SDIFE(J))*10.
42    CONTINUE
   41 RETURN
       END
$IBFTC FGETNX  NODECK
      SUBROUTINE FGET (LU,LV,ETB,ROT,G,GP,F,FP,SIGM)
C---------THIS SUBROUTINE IS TAKEN FROM PROGRAM SMOG (REF.2)
      DIMENSION A(30)
      DATA A/1.70611767,5.4649554E-03,-5.319326E-05,8.1355E-07,-1.50046E
```

```
 1-08,3.10943E-10,-10.E-11,8.33333333E-02,2.7777777E-03,7.9365076E-0
 24,5.952380E-04,8.4175084E-04,1.9175269E-03,6.4102564E-03,.98940093
 34,.944575023,.865631202,.755404408,.617876244,.458016777,.28160355
 40,.950125098E-01,.271524594E-01,.622535239E-01,.951585116E-01,.124
 5628971,.149595988,.169156519,.182603415,.189450610/
  LM=LU
  L=0
  ETA=ETB
  RAU=ROT
  IF(ETA-27.7)16,16,63
16 IF(L)65,18,15
18 IF(ETA-1.E-15)25,1,1
25 CO=1.
  CL=CO
  SIGO=0.
  GO TO 26
 1 IF(ETA-2.02)2,2,5
 2 I=7
  P=A(I)
  DO 3 K=1,6
  I=I-1
  P=P*ETA*ETA+A(I)
 3 CONTINUE
  P=P*ETA
  SIG=0.
  DO 4 K=1,5
  SIG=SIG+ATAN(ETA/FLOAT(K))
4   CONTINUE
  SIGO=-SIG+P
  GO TO 7
 5 I=14
  P=A(I)
  ATE=1./(ETA*ETA)
  DO 6 K=1,6
  I=I-1
  P=P*ATE+A(I)
 6 CONTINUE
  P=P*1./ETA
  SIGO=3.1415927/4.+ETA*(ALOG(ETA)-1.)-P
 7 CO=EXP(-3.1415927*ETA)*SQRT((6.2831852*ETA)/(1.-EXP(-6.2831852*ETA
 1)))
  CL=CO
26 RAU1=1.6666666*ETA+7.5
  B=0.
  IF(RAU-RAU1)9,8,8
 8 ITE=-1
  GO TO 10
 9 ITE=1
  IF(ETA-2.)13,14,14
14 RAU1=1.2*ETA+8.
  IF(RAU-RAU1)13,10,10
23 IF(L-LM)19,24,62
24 LSECU=LM+1
  L=L+1
  TAC=ETA
  UAR=RAU
  G=GO
  GP=GPO
  F=FO
  FP=FPO
  SIGM=SIGO
  RETURN
15 IF(L-LSECU)65,27,65
27 IF(L-LM)28,28,60
```

```
 28 IF(ETA-TAC)65,29,65
 29 IF(RAU-UAR)65,36,65
 19 L=L+1
 36 B=FLOAT(L)
    Q=SQRT(B*B+ETA*ETA)
    R=B*B/RAU+ETA
    CL=Q*RAU/(2.*B*B+B)*CO
    CO=CL
    SIGL=SIGO+ATAN(ETA/B)
    SIGO=SIGL
    GL=R/Q*GO-B/Q*GPO
    GPL=Q/B*GO-R/B*GL
    GO=GL
    GPO=GPL
    MP=0
    IF(ITE)21,12,12
 21 IF(B*(B+1.)-RAU*(RAU-2.*ETA))50,50,22
 22 FL=FO
    FPL=FPO
 31 MP=MP+1
    GO TO 12
 33 WL=ABS(FPO*GO-FO*GPO-1.)
    IF(WL-5.E-05)35,34,34
 35 ITE=0
    GO TO 23
 34 FO=FL
    FPO=FPL
    IF(MP-2)50,66,66
 50 FL=R/Q*FO-B/Q*FPO
    FPL=Q/B*FO-R/B*FL
    FO=FL
    FPO=FPL
    WL=ABS(FPO*GO-FO*GPO-1.)
    IF(WL-5.E-05)23,30,30
 30 MP=MP+1
    IF(MP-2)31,66,66
 60 WRITE(6,205)
205 FORMAT(26HLM LT THE PRECEEDING       )
    GO TO 61
 62 WRITE(6,206)
206 FORMAT(15HL LESS THAN 0   )
    GO TO 61
 63 WRITE(6,207)
207 FORMAT(15H  ETA BIG       )
 64 WRITE(6,208)
208 FORMAT(32HUNDERFLOW GIVES 0 FOR F AND FP  )
    GO TO 61
 65 WRITE(6,209)
209 FORMAT(18H  CHANGED  L,ETA,R)
    GO TO 61
 66 WRITE(6,210)
210 FORMAT(38HE R R O R   I N    M E T H O D         )
 61 WRITE(6,211)L,LM,ETA,RAU
211 FORMAT(2I6,2E20.8)
 10 N=0
    PS=1.
    GS=0.
    PT=0.
    GT=1.-ETA/RAU
    SOMPS=PS
    SOMGS=GS
    SOMPT=PT
    SOMGT=GT
 45 AN=(2.*FLOAT(N)+1.)/(2.*FLOAT(N)+2.)*ETA/RAU
    BN=(ETA*ETA-FLOAT(N*(N+1)))/(RAU*FLOAT(2*N+2))
```

```
      PS1=AN*PS-BN*PT
      GS1=AN*GS-BN*GT-PS1/RAU
      PT1=AN*PT+BN*PS
      GT1=AN*GT+BN*GS-PT1/RAU
      IF(N-16)41,42,42
   41 PS=PS1
      GS=GS1
      PT=PT1
      GT=GT1
   42 SOMPS=SOMPS+PS1
      SOMGS=SOMGS+GS1
      SOMPT=SOMPT+PT1
      SOMGT=SOMGT+GT1
      IF(N-16)43,44,44
   43 N=N+1
      GO TO 45
   44 N=N+1
      TEST=PS**2+PT**2-PS1**2-PT1**2
      IF(TEST)47,47,46
   46 PS=PS1
      GS=GS1
      PT=PT1
      GT=GT1
      GOTO 45
   47 TETAO=RAU-ETA*ALOG(2.*RAU)+SIGO
      GO=SOMPS*COS(TETAO)-SOMPT*SIN(TETAO)
      GPO=SOMGS*COS(TETAO)-SOMGT*SIN(TETAO)
      IF(ITE)48,12,12
   48 FO=SOMPT*COS(TETAO)+SOMPS*SIN(TETAO)
      FPO=SOMGT*COS(TETAO)+SOMGS*SIN(TETAO)
      IF(LM)62,24,19
   13 JV=8
      AO=EXP(-3.1415927*ETA)/CO
      RINI=0.
      RINIP=0.
      RINJ=0.
      RINJP=0.
      P=(20.+2.*ETA)/(10.*RAU)
      IF(ETA-1.E-16)52,52,54
   54 IF(47.123889/ETA-10.)51,52,52
   51 Q=4.7123889/ETA
      GOTO 53
   52 Q=1.
   53 DO58 J=1,9,2
      ALPH=FLOAT(J)*P
      BETA=FLOAT(J)*Q
      DO 57 K=1,JV
      MU=K+14
      MV=K+22
      VA=ALPH+P*A(MU)
      AV=ALPH-P*A(MU)
      E1=EXP(-RAU*VA+2.*ETA*ATAN(VA))
      E2=EXP(-RAU*AV+2.*ETA*ATAN(AV))
      RINA=A(MV)*(E1+E2)
      RINI=RINI+RINA
      RINA=-A(MV)*(VA*E1+AV*E2)
      RINIP=RINIP+RINA
      VA=BETA+Q*A(MU)
      AV=BETA-Q*A(MU)
      T1=TANH(VA)
      T2=TANH(AV)
      A1=2.*ETA*VA
      A2=2.*ETA*AV
      IF(ETA-RAU-5.)55,56,56
```

```
   55 RINA=A(MV)*((1.-T1**2)*SIN(A1-RAU*T1)+(1.-T2**2)*SIN(A2-RAU*T2))
      RINJ=RINJ+RINA
   56 RINA=-A(MV)*(T1*(1.-T1**2)*COS(A1-RAU*T1)+T2*(1.-T2**2)*COS(A2-RAU
     1*T2))
      RINJP=RINJP+RINA
   57 CONTINUE
   58 CONTINUE
      RINI=P*RINI
      RINIP=P*RINIP
      RINJ=Q*RINJ
      RINJP=Q*RINJP
      GO=AO*RAU*(RINI+RINJ)
      GPO=AO*RAU*(RINIP+RINJP)+GO/RAU
   12 BSO=1.
      BS1=ETA*RAU/(B+1.)
      BB=BSO+BS1
      J=1
      S=FLOAT(J)*BS1
   76 J=J+1
      BS2=1./FLOAT(J**2+2*J*L+J)*(2.*ETA*RAU*BS1-RAU*RAU*BSO)
      IF(ABS(BS1/BB)-1.5E-08)71,72,72
   71 M=-1
      GO TO 78
   72 M=0
   78 BSO=BS1
      BS1=BS2
      BB=BB+BS2
      S=S+FLOAT(J)*BS2
      IF(ABS(BS2/BB)-1.5E-08)73,74,74
   73 I=-1
      GO TO 75
   74 I=1
   75 IF(M*I)76,76,77
   77 IF(CO)64,64,79
   79 FO=CO*RAU*BB
      FPO=CO*((B+1.)*BB+S)
      IF(ITE)33,70,70
   70 IF(LM)62,24,23
      END
$IBFTC RISMUL  NODECK
      SUBROUTINE RESML
      COMMON/ENERGY/ELAB,ECM,FKAY,IEN,NPOT,LMAX,LMAXM,L,JMAX,WAVE,PLATA2
      COMMON/GEIPAI/RL(50),RJ(50),ER(50),GAT(50),GAP(50),PHI(50),DELTA,N
     1RES,FUORI,BWINEL(50),INEL(50)
      COMMON/SCAMP/CR1(11),CR2(11),CI1(11),CI2(11),UCS(11),UCG(11)
      COMMON/RAMENG/A0(50),A2(50),A4(50),A6(50),A8(50),GAI(50)
      DIMENSION BWR1(11),BWI1(11),BWR2(11),BWI2(11)
      IF(NRES.EQ.0) GO TO 19
20    DO 3 LA=1,11
      BWR1(LA)=0.
      BWI1(LA)=0.
      BWR2(LA)=0.
3     BWI2(LA)=0.
      I=1
4     L=RL(I)+1.
      J=RJ(I)*2.
      IF(RL(I)-RJ(I)) 5,5,6
5     UCCMOD=UCS(L)
      GO TO 7
6     UCCMOD=UCG(L)
7     GAPR=GAP(I)/UCCMOD
      GAPP=GAI(I)
      DIE=ER(I)-ECM
      G22=0.25*GAT(I)**2
```

```
      GPT=GAPR*GAT(I)*0.5
      DENBW=DIE**2+G22
      IF(DELTA) 8,8,9
8     DBWR=DIE*GAPR/DENBW
      DBWI=GPT/DENBW
      BWINEL(I)=GAPR*GAPP/DENBW
      GO TO 10
9     SIP=DIE+DELTA/2.
      SOP=0.5*GAT(I)
      SUP=SIP/SOP
      SIT=SIP-DELTA
      SOT=SIT/SOP
      SUP2=SUP**2+1.
      SOT2=SOT**2+1.
      CAIJA=ATAN2(SIP,SOP)-ATAN2(SIT,SOP)
      DBWR=(GAPR*0.5/DELTA)*ALOG(SUP2/SOT2)
      DBWI=(GAPR/DELTA)*CAIJA
      BWINEL(I)=(2.*GAPR*GAPP/(GAT(I)*DELTA))*CAIJA
10    COSDXX=COSD(2.*PHI(I))
      SINDXX=SIND(2.*PHI(I))
      DBWRF=COSDXX*DBWR-SINDXX*DBWI
      DBWIF=SINDXX*DBWR+COSDXX*DBWI
      IF(RL(I)-RJ(I)) 21,21,22
21    BWR1(L)=BWR1(L)+DBWRF
      BWI1(L)=BWI1(L)+DBWIF
      IF(FUORI.EQ.0.) GO TO 100
      PRINT 1,L,J,GAT(I),GAP(I),BWR1(L),BWI1(L),UCCMOD
1     FORMAT(1X,2I5,5F10.5)
100   GO TO 23
22    BWR2(L)=BWR2(L)+DBWRF
      BWI2(L)=BWI2(L)+DBWIF
      IF(FUORI.EQ.0.) GO TO 23
      PRINT 1,L,J,GAT(I),GAP(I),BWR2(L),BWI2(L),UCCMOD
23    I=I+1
      IF(I.GT.NRES) GO TO 11
      GO TO 4
11    DO 12 K=1,LMAX
      JK=K-1
      J1=2*JK+1
      J2=2*JK-1
14    PEZZ=1.-BWI1(K)
      SNORT =CR1(K)*PEZZ          +(0.5-CI1(K))*BWR1(K)
      CUMO  =CR1(K)*BWR1(K)+CI1(K)*PEZZ          +0.5*BWI1(K)
      CR1(K)=SNORT
      CI1(K)=CUMO
      IF(CI1(K)-CR1(K)**2-CI1(K)**2) 16,15,15
16    PRINT 17,JK,J1
17    FORMAT(61 X,36HUNITARITY IS VIOLATED          FOR L=,I3,8HAND   J=,
     1I3,2H/2    )
15    ETTO=1.-BWI2(K)
      COCCO =CR2(K)*ETTO          +(0.5-CI2(K))*BWR2(K)
      DE    =CR2(K)*BWR2(K)+CI2(K)*ETTO          +0.5*BWI2(K)
      CR2(K)=COCCO
      CI2(K)=DE
      IF(CI2(K)-CR2(K)**2-CI2(K)**2) 18,12,12
18    PRINT 17,JK,J2
12    CONTINUE
19    RETURN
      END
$IBFTC SHAPEX  NODECK
      SUBROUTINE SHAPE
C---------THIS SUBROUTINE IS TAKEN FROM PROGRAM SMOG (REF.2)
      COMMON/FASI/D1(11),D2(11),COTI1(11),COTI2(11),COTR1(11),COTR2(11)
      COMMON/STAMPA/TETA(40),SDIFE(40),SIGR(40),SGMAEX(40),POL(40),POLAX
```

```
     1(40),DSMEX(40),DIPOL(40),SDAFE(40),SIGMAR,SIGMAT,SSHAPE,SUMAO,KPOL
      COMMON/ENERGY/ELAB,ECM,FKAY,IEN,NPOT,LMAX,LMAXM,L,JMAX,WAVE,PLATA2
      DIMENSIONSEN1(11),SEN2(11),COS1(11),COS2(11),RE1(11),RE2(11)
   31 DO 20 I=1,LMAX
    8 POSTO=COTI1(I)**2+COTR1(I)**2
    9 PESTO=COTI2(I)**2+COTR2(I)**2
   10 PASTO=EXP(2.0*D1(I))
   11 PISTO=EXP(2.0*D2(I))
   12 PER1=PASTO*(POSTO-1.0)/(POSTO+1.0-2.0*COTI1(I))
   13 PER2=PISTO*(PESTO-1.0)/(PESTO+1.0-2.0*COTI2(I))
      SEN1(I)=0.5*(1.0-PER1)
      SEN2(I)=0.5*(1.0-PER2)
      COS1(I)=PER1
      COS2(I)=PER2
      RE1(I)=EXP(-2.0*D1(I))
   20 RE2(I)=EXP(-2.0*D2(I))
      DO24I=1,LMAX
      FI=I-1
   21 PARZS= 1.0-RE1(I)
   22 PARZT= 1.0-RE2(I)
   23 SSHAPE=SSHAPE+(FI+1.0)*(RE1(I)*SEN1(I)+0.25*PARZS**2)+FI*(RE2(I)*S
     1EN2(I)+0.25*PARZT**2)
   24 SIGMAT=SIGMAT+(FI+1.0)*(SEN1(I)+0.5*COS1(I)*PARZS)+FI*(SEN2(I)+0.5
     1*COS2(I)*PARZT)
      SSHAPE=SSHAPE*4.0*PLATA2
      SIGMAT=SIGMAT*4.0*PLATA2
   30 RETURN
       END
$IBFTC SIGOX    NODECK
      SUBROUTINE SIGMAO      (ETA,SIGO)
C---------THIS SUBROUTINE IS TAKEN FROM PROGRAM SMOG (REF.2)
      DIMENSION SIGO(2)
      PE=ETA
      SIGO( 1)=-(PE/(12.0*(PE**2+16.0)))*(1.0+(PE**2-48.0)/(30.0*((PE**2
     1+16.0)**2))+(PE**4-160.0*(PE**2)+1280.0)/(((16.0+PE **2)**4)*105.0
     2))
      SIGO( 1)=SIGO( 1)-PE+(PE/2.0)*ALOG(PE**2+16.0)+((7.0/2.0)*ATAN(PE/
     14.0))-(ATAN(PE)+ATAN(PE/2.0)+ATAN(PE/3.0))
    2 SIGO(2)=SIGO(1)+ATAN(PE)
      RETURN
      END

$IBFTC SINDXX  NODECK
      FUNCTION SIND(X)
C---------THIS FUNCTION IS TAKEN FROM PROGRAM SMOG (REF. 2)
      SIND=SIN(X*0.017453292)
      RETURN
      END

$IBFTC STIRL   NODECK
      FUNCTION STIRL(X)
C---------TAKEN FROM PROGRAM ANSPEC  (REF.1)
      IF(X-2.) 5,3,4
5     STIRL=0.
      GO TO 8
3     STIRL=0.69314718
      GO TO 8
4     Y=X+1.
      STIRL=(Y-0.5)*ALOG(Y)-Y+0.91893853+(0.083333333-(0.0027777778-0.00
     1079365079*(1./(Y*Y)))*(1./(Y*Y)))/Y
8     RETURN
      END
```

APPENDIX B

```
CALCULATION OF EXCITATION FUNCTION


 INPUT DATA
PEREY-BUCK ABSORBTION
  MI=   1.000   MT=  32.000
  SW RADIUS=   4.000
  GAUSSIAN RADIUS=   0.000
  PEREY-BUCK RADIUS=   4.000
  COULOMB POTENTIAL RADIUS=   4.000
  SW DIFF.=    .650
  GAUSSIAN ABS. DIFF.=   0.000
  PEREY-BUCK ABS. DIFF.=    .700
  VOLUME ABS. DIFF.=   0.000
  SW DEPTH=  56.000
  SURFACE IMAG. DEPTH=   4.000
  VOLUME IMAG. DEPTH=   0.000
  REAL SPIN-ORBIT DEPTH=   5.500
  IMAG. SPIN-ORBIT DEPTH=   0.000
  CHARGE PRODUCT=     16.
  VOLUME ABS. RADIUS=   0.000
    LMAXM=    4
    NPAS =   60
    ACCURACY PARAMETER RACC=  .0010000

                     RESONANCES TABLE        N.= 15

L= 2    J= 5/2   ER=  4.57700 MEV   TO.W.=   .02800 MEV   PA.W.=   .02400 MEV   PHASE=   0.00000 DEGREES   INEL=  -0
L= 3    J= 5/2   ER=  4.64600 MEV   TO.W.=   .02000 MEV   PA.W.=   .00300 MEV   PHASE=   0.00000 DEGREES   INEL=  -0
L= 2    J= 3/2   ER=  4.70700 MEV   TO.W.=   .01000 MEV   PA.W.=   .00650 MEV   PHASE=   0.00000 DEGREES   INEL=  -0
L= 3    J= 5/2   ER=  4.71500 MEV   TO.W.=   .00700 MEV   PA.W.=   .00250 MEV   PHASE=   0.00000 DEGREES   INEL=  -0
L= 2    J= 5/2   ER=  4.82000 MEV   TO.W.=   .01800 MEV   PA.W.=   .01300 MEV   PHASE=   0.00000 DEGREES   INEL=  -0
L= 1    J= 3/2   ER=  4.90700 MEV   TO.W.=   .01300 MEV   PA.W.=   .00130 MEV   PHASE=   0.00000 DEGREES   INEL=  -0
L= 2    J= 5/2   ER=  4.93300 MEV   TO.W.=   .00270 MEV   PA.W.=   .00200 MEV   PHASE=   0.00000 DEGREES   INEL=  -0
L= 2    J= 3/2   ER=  4.98600 MEV   TO.W.=   .03000 MEV   PA.W.=   .02250 MEV   PHASE=   0.00000 DEGREES   INEL=  -0
L= 1    J= 3/2   ER=  5.00000 MEV   TO.W.=   .02000 MEV   PA.W.=   .01000 MEV   PHASE=   0.00000 DEGREES   INEL=  -0
L= 4    J= 9/2   ER=  5.02500 MEV   TO.W.=   .00400 MEV   PA.W.=   .00170 MEV   PHASE=   0.00000 DEGREES   INEL=  -0
L= 3    J= 7/2   ER=  5.04800 MEV   TO.W.=   .00300 MEV   PA.W.=   .00020 MEV   PHASE=   0.00000 DEGREES   INEL=  -0
L= 2    J= 5/2   ER=  5.12200 MEV   TO.W.=   .01100 MEV   PA.W.=   .00900 MEV   PHASE=   0.00000 DEGREES   INEL=  -0
L= 1    J= 3/2   ER=  5.17600 MEV   TO.W.=   .03500 MEV   PA.W.=   .01500 MEV   PHASE=   0.00000 DEGREES   INEL=  -0
L= 4    J= 7/2   ER=  5.19600 MEV   TO.W.=   .00150 MEV   PA.W.=   .00130 MEV   PHASE=   0.00000 DEGREES   INEL=  -0
L= 0    J= 1/2   ER=  5.20600 MEV   TO.W.=   .01300 MEV   PA.W.=   .01000 MEV   PHASE=   0.00000 DEGREES   INEL=  -0
TARGET IN MEV=     .00400
CM ANGLE =   140.200
*********************
         ELAB(MEV) SIGMA EL. SIGMA IN. SIGMA RU.  POLARIZ. SIGMA RE. TOTAL IN. SIGMA SH.
          5.25000    25.397     0.000    16.382     0.000   581.102     0.000   419.263
          5.25500    26.471     0.000    16.351     0.000   585.534     0.000   426.103
          5.26000    28.138     0.000    16.320     0.000   591.729     0.000   441.432
          5.26500    30.935     0.000    16.289     0.000   600.822     0.000   473.732
          5.27000    36.128     0.000    16.258     0.000   615.205     0.000   545.141
          5.27500    46.949     0.000    16.227     0.000   640.111     0.000   721.956
          5.28000    67.641     0.000    16.197     0.000   678.402     0.000  1162.048
          5.28500    65.249     0.000    16.166     0.000   638.836     0.000  1415.837
          5.29000    30.721     0.000    16.135     0.000   544.862     0.000   851.215
          5.29500    16.596     0.000    16.105     0.000   535.567     0.000   521.983
          5.30000    12.143     0.000    16.075     0.000   544.736     0.000   393.653
          5.30500    10.089     0.000    16.044     0.000   555.696     0.000   331.810
          5.31000     8.616     0.000    16.014     0.000   567.238     0.000   295.251
          5.31500     7.279     0.000    15.984     0.000   580.104     0.000   272.010
          5.32000     6.126     0.000    15.954     0.000   595.208     0.000   261.099
          5.32500     5.645     0.000    15.924     0.000   612.947     0.000   268.947
          5.33000     6.950     0.000    15.894     0.000   631.765     0.000   308.503
          5.33500    11.635     0.000    15.864     0.000   645.999     0.000   391.343
          5.34000    20.359     0.000    15.835     0.000   647.159     0.000   505.955
          5.34500    31.396     0.000    15.805     0.000   632.969     0.000   610.807
          5.35000    43.024     0.000    15.775     0.000   611.833     0.000   676.319
```

APPENDIX C

YIELD AND ANGULAR DISTRIBUTIONS WITH SELECTED OM PARAMETERS
INPUT DATA
PEREY-BUCK ABSORBTION
MI= 1.000 MT= 12.000
SW RADIUS= 2.862
GAUSSIAN RADIUS= 0.000
PEREY-BUCK RADIUS= 2.862
COULOMB POTENTIAL RADIUS= 2.862
SW DIFF.= .650
GAUSSIAN ABS. DIFF.= 0.000
PEREY-BUCK ABS. DIFF.= .470
VOLUME ABS. DIFF.= 0.000
SW DEPTH= 50.000
SURFACE IMAG. DEPTH= 4.000
VOLUME IMAG. DEPTH= 0.000
REAL SPIN-ORBIT DEPTH= 11.000
IMAG. SPIN-ORBIT DEPTH= 0.000
CHARGE PRODUCT= 0.
LMAXM= 3
NPAS = 70
ACCURACY PARAMETER RACC= .0100000

RESONANCES TABLE N.= 4

L= 2	J= 5/2	ER= 1.89200 MEV	TO.W.= .00700 MEV	PA.W.= .00600 MEV	PHASE= 0.00000 DEGREES	INEL= -0
L= 2	J= 3/2	ER= 2.68800 MEV	TO.W.= .08000 MEV	PA.W.= .06400 MEV	PHASE= 0.00000 DEGREES	INEL= -0
L= 2	J= 3/2	ER= 3.38000 MEV	TO.W.= .90000 MEV	PA.W.= .66000 MEV	PHASE= 0.00000 DEGREES	INEL= -0
L= 1	J= 1/2	ER= 3.92600 MEV	TO.W.= .18000 MEV	PA.W.= .13500 MEV	PHASE= 0.00000 DEGREES	INEL= -0

TARGET IN MEV= .03200

ELAB= 1.90000 ECM= 1.73908 ETA= 0.00000
****
MATCHING RADIUS(FERMIS)= 9.362 K= .2771E+00

L= 0.	T+= .7070E+00	T-= 0.	T = .7070E+00	SIGMRC(MB)= 289.2083
L= 1.	T+= .1497E+00	T-= .1442E+00	T = .1479E+00	SIGMRC(MB)= 181.4591
L= 2.	T+= .3636E+00	T-= .1005E+00	T = .2584E+00	SIGMRC(MB)= 528.4401
L= 3.	T+= .1097E-02	T-= .6205E-03	T = .8927E-03	SIGMRC(MB)= 2.5560

SIGMA REACTION= 1001.66356169MILLIBARNS
SIGMA TOTAL = 2165.55577774MILLIBARNS
SHAPE EL. SIGMA= 1163.89221605MILLIBARNS
LEGENDRE POLYN.TABLE

TETA	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
15.00	.9659258	.8995191	.8041639	.6846955	.5471259	.3983060	.2455411	.0961844	-.0427678	-.1650559	-.2654900	-.3402156
30.00	.8660254	.6250000	.3247596	.0234375	-.2232721	-.3740234	-.4101781	-.3387757	-.1895753	-.0070382	.1607048	.2732026
45.00	.7071068	.2500000	-.1767767	-.4062500	-.3756505	-.1484376	.1270582	.2983398	.2855358	.1151124	-.1041842	-.2467193
60.00	.5000000	-.1250000	-.4375000	-.2890625	.0898437	.3232422	.2231446	-.0736388	-.2678985	-.1882287	.0638713	.2337529
75.00	.2588191	-.3995190	-.3448846	.1434295	.3427278	.0431003	-.2730499	-.1702200	.1594938	.2316301	-.0305438	-.2274795
90.00	.0000000	-.5000000	-.0000001	.3750000	.0000001	-.3125000	-.0000001	.2734375	.0000001	-.2460937	-.0000001	.2255859
105.00	-.2588190	-.3995191	.3448845	.1434296	-.3427278	.0431001	.2730500	-.1702199	-.1594940	.2316300	.0305441	-.2274795
120.00	-.4999999	-.1250001	.4375000	-.2890624	-.0898439	.3232422	-.2231444	-.0736391	.2678986	-.1882285	-.0638716	.2337530
135.00	-.7071067	.2499999	.1767768	-.4062500	.3756504	-.1484373	-.1270584	.2983399	-.2855357	.1151121	.1041845	-.2467194
150.00	-.8660254	.6249999	-.3247594	.0234373	.2232723	-.3740235	.4101780	-.3387755	.1895750	-.0070378	-.1607051	.2732028
165.00	-.9659258	.8995190	-.8041638	.6846952	-.5471256	.3983057	-.2455407	.0961839	.0427683	-.1650564	.2654903	-.3402159

CMTETA	SIGMA SH.	SIGMA C.EL.	SIGMA T.EL.	SIGMA(TETA) EXP	DSIGMA EXP	POL(TETA)	POL(TETA) EXP	DPOL EXP
15.0	238.825	151.48055	390.30541	-0.00000	-0.000	-.15825	-0.00000	-0.0000
30.0	188.462	116.10215	304.56422	-0.00000	-0.000	-.30706	-0.00000	-0.0000
45.0	126.893	81.88429	208.77741	-0.00000	-0.000	-.41355	-0.00000	-0.0000
60.0	73.049	63.95917	137.00844	-0.00000	-0.000	-.40171	-0.00000	-0.0000
75.0	37.550	61.16625	98.71609	-0.00000	-0.000	-.21785	-0.00000	-0.0000
90.0	23.794	62.32678	86.12047	-0.00000	-0.000	.04904	-0.00000	-0.0000
105.0	33.165	61.16625	94.33153	-0.00000	-0.000	.28935	-0.00000	-0.0000
120.0	66.660	63.95917	130.61891	-0.00000	-0.000	.41679	-0.00000	-0.0000
135.0	120.813	81.88428	202.69759	-0.00000	-0.000	.39188	-0.00000	-0.0000
150.0	183.133	116.10214	299.23482	-0.00000	-0.000	.28114	-0.00000	-0.0000
165.0	233.546	151.48053	385.02618	-0.00000	-0.000	.14338	-0.00000	-0.0000

COULOMB PHASES AND SCATTERING AMPLITUDES TABLE

L	J	CO.PHAS.	MOD U RES.AND OPTIC.		REAL AND IMAG.AMPL.		L	J	MOD U RES.AND OPTIC.		REAL AND IMAG.AMPL.	
0	1/2	0.0000	.5412843	.5412843	.2040	.6778	0	0/2	0.0000000	0.0000000	0.0000	0.0000
1	3/2	0.0000	.9221135	.9221135	-.0624	.0432	1	1/2	.9251002	.9255815	-.1025	.0490
2	5/2	0.0000	.7977302	.7976661	-.0072	.1012	2	3/2	.9484281	.9448763	.2588	.1026
3	7/2	0.0000	.9994515	.9994515	.0018	.0003	3	5/2	.9996897	.9996897	.0010	.0002

FLAB= 1.95000 ECM= 1.78523 ETA= 0.00000

****

MATCHING RADIUS(FERMIS)= 9.362 K= .2808E+00

L	T+	T-	T	SIGMRC(MB)
L= 0.	T+= .7042E+00	T-= 0.	T = .7042E+00	SIGMRC(MB)= 280.5914
L= 1.	T+= .1534E+00	T-= .1473E+00	T = .1514E+00	SIGMRC(MB)= 180.9372
L= 2.	T+= .3755E+00	T-= .1061E+00	T = .2678E+00	SIGMRC(MB)= 533.5038
L= 3.	T+= .1202E-02	T-= .6782E-03	T = .9777E-03	SIGMRC(MB)= 2.7271

SIGMA REACTION= 997.75951862MILLIBARNS

SIGMA TOTAL = 2147.87389239MILLIBARNS

SHAPE EL. SIGMA= 1150.11437377MILLIBARNS

CMTETA	SIGMA SH.	SIGMA C.EL.	SIGMA T.EL.	SIGMA(TETA) EXP	DSIGMA EXP	POL(TETA)	POL(TETA) EXP	DPOL EXP
15.0	243.051	151.68905	394.74042	-0.00000	-0.000	-.15570	-0.00000	-0.0000
30.0	189.549	116.06489	305.61379	-0.00000	-0.000	-.30341	-0.00000	-0.0000
45.0	125.177	81.60274	206.77995	-0.00000	-0.000	-.41112	-0.00000	-0.0000
60.0	70.192	63.53891	133.73086	-0.00000	-0.000	-.40041	-0.00000	-0.0000
75.0	34.853	60.71139	95.56415	-0.00000	-0.000	-.21520	-0.00000	-0.0000
90.0	21.346	61.87340	83.21976	-0.00000	-0.000	.04812	-0.00000	-0.0000
105.0	30.560	60.71139	91.27152	-0.00000	-0.000	.28328	-0.00000	-0.0000
120.0	64.319	63.53891	127.85774	-0.00000	-0.000	.40928	-0.00000	-0.0000
135.0	120.355	81.60273	201.95771	-0.00000	-0.000	.38337	-0.00000	-0.0000
150.0	186.226	116.06487	302.29045	-0.00000	-0.000	.27372	-0.00000	-0.0000
165.0	240.263	151.68904	391.95180	-0.00000	-0.000	.13919	-0.00000	-0.0000

COULOMB PHASES AND SCATTERING AMPLITUDES TABLE

L	J	CO.PHAS.	MOD U RES.AND	OPTIC.	REAL AND	IMAG.AMPL.	L	J	MOD U RES.AND	OPTIC.	REAL AND	IMAG.AMPL.
0	1/2	0.0000	.5439204	.5439204	.2107	.6720	0	0/2	0.0000000	0.0000000	0.0000	0.0000
1	3/2	0.0000	.9201243	.9201243	-.0643	.0445	1	1/2	.9234050	.9239033	-.1055	.0505
2	5/2	0.0000	.7902263	.7900819	-.0020	.1049	2	3/2	.9454595	.9405788	.2670	.1099
3	7/2	0.0000	.9993987	.9993987	.0020	.0003	3	5/2	.9996608	.9996608	.0011	.0002

FLAB= 2.00000 ECM= 1.83138 ETA= 0.00000

****

MATCHING RADIUS(FERMIS)= 9.362 K= .2844E+00

L	T+	T-	T	SIGMRC(MB)
L= 0.	T+= .7013E+00	T-= 0.	T = .7013E+00	SIGMRC(MB)= 272.4256
L= 1.	T+= .1570E+00	T-= .1504E+00	T = .1548E+00	SIGMRC(MB)= 180.3824
L= 2.	T+= .3866E+00	T-= .1117E+00	T = .2766E+00	SIGMRC(MB)= 537.2701
L= 3.	T+= .1315E-02	T-= .7395E-03	T = .1068E-02	SIGMRC(MB)= 2.9049

SIGMA REACTION= 992.98298821MILLIBARNS

SIGMA TOTAL = 2133.47484917MILLIBARNS

SHAPE EL. SIGMA= 1140.49186096MILLIBARNS

CMTETA	SIGMA SH.	SIGMA C.EL.	SIGMA T.EL.	SIGMA(TETA) EXP	DSIGMA EXP	POL(TETA)	POL(TETA) EXP	DPOL EXP
15.0	252.126	151.67179	403.79806	-0.00000	-0.000	-.14335	-0.00000	-0.0000
30.0	192.026	115.88301	307.90884	-0.00000	-0.000	-.28266	-0.00000	-0.0000
45.0	122.330	81.25241	203.58254	-0.00000	-0.000	-.38922	-0.00000	-0.0000
60.0	66.117	63.08528	129.20259	-0.00000	-0.000	-.38150	-0.00000	-0.0000
75.0	32.229	60.22345	92.45230	-0.00000	-0.000	-.20048	-0.00000	-0.0000
90.0	19.423	61.38163	80.80492	-0.00000	-0.000	.04625	-0.00000	-0.0000
105.0	27.286	60.22345	87.50911	-0.00000	-0.000	.26762	-0.00000	-0.0000
120.0	60.113	63.08528	123.19875	-0.00000	-0.000	.38956	-0.00000	-0.0000
135.0	119.301	81.25240	200.55363	-0.00000	-0.000	.35866	-0.00000	-0.0000
150.0	193.043	115.88299	308.92569	-0.00000	-0.000	.25091	-0.00000	-0.0000
165.0	255.732	151.67178	407.40348	-0.00000	-0.000	.12599	-0.00000	-0.0000

COULOMB PHASES AND SCATTERING AMPLITUDES TABLE

L	J	CO.PHAS.	MOD U RES.AND	OPTIC.	REAL AND	IMAG.AMPL.	L	J	MOD U RES.AND	OPTIC.	REAL AND	IMAG.AMPL.
0	1/2	0.0000	.5465043	.5465043	.2170	.6660	0	0/2	0.0000000	0.0000000	0.0000	0.0000
1	3/2	0.0000	.9181582	.9181582	-.0663	.0457	1	1/2	.9217344	.9222509	-.1084	.0521
2	5/2	0.0000	.7831909	.7827699	.0168	.1088	2	3/2	.9425198	.9360571	.2755	.1177
3	7/2	0.0000	.9993423	.9993423	.0021	.0003	3	5/2	.9996302	.9996302	.0012	.0002

ELAB= 2.05000 ECM= 1.87754 ETA= 0.00000

****

MATCHING RADIUS(FERMIS)= 9.362 K= .2880E+00

L	T+	T-	T	SIGMRC(MB)
L= 0.	T+= .6986E+00	T-= 0.	T = .6986E+00	SIGMRC(MB)= 264.6775
L= 1.	T+= .1605E+00	T-= .1534E+00	T = .1582E+00	SIGMRC(MB)= 179.7978
L= 2.	T+= .6670E+00	T-= .1170E+00	T = .4470E+00	SIGMRC(MB)= 846.8315
L= 3.	T+= .1435E-02	T-= .8046E-03	T = .1165E-02	SIGMRC(MB)= 3.0894

SIGMA REACTION= 1294.39620839MILLIBARNS

SIGMA TOTAL = 2835.44003787MILLIBARNS

SHAPE EL. SIGMA= 1541.04382949MILLIBARNS

CMTETA	SIGMA SH.	SIGMA C.EL.	SIGMA T.EL.	SIGMA(TETA) EXP	DSIGMA EXP	POL(TETA)	POL(TETA) EXP	DPOL EXP
15.0	489.727	214.93317	704.66006	-0.00000	-0.000	-.07784	-0.00000	-0.0000
30.0	318.135	157.92507	476.05972	-0.00000	-0.000	-.15296	-0.00000	-0.0000
45.0	147.530	103.97631	251.50661	-0.00000	-0.000	-.19666	-0.00000	-0.0000
60.0	48.983	77.65463	126.63754	-0.00000	-0.000	-.10673	-0.00000	-0.0000
75.0	20.009	75.90070	95.90974	-0.00000	-0.000	.04228	-0.00000	-0.0000
90.0	14.747	78.96004	93.70746	-0.00000	-0.000	.00813	-0.00000	-0.0000
105.0	10.670	75.90070	86.57064	-0.00000	-0.000	.02253	-0.00000	-0.0000
120.0	38.973	77.65463	116.62736	-0.00000	-0.000	.25642	-0.00000	-0.0000
135.0	146.544	103.97630	250.51989	-0.00000	-0.000	.29906	-0.00000	-0.0000
150.0	329.738	157.92505	487.66317	-0.00000	-0.000	.20342	-0.00000	-0.0000
165.0	510.784	214.93316	725.71696	-0.00000	-0.000	.09871	-0.00000	-0.0000

COULOMB PHASES AND SCATTERING AMPLITUDES TABLE

L	J	CO.PHAS.	MOD U RES.AND	OPTIC.	REAL AND	IMAG.AMPL.	L	J	MOD U RES.AND	OPTIC.	REAL AND	IMAG.AMPL.
0	1/2	0.0000	.5490370	.5490370	.2230	.6600	0	0/2	0.0000000	0.0000000	0.0000	0.0000
1	3/2	0.0000	.9162153	.9162153	-.0682	.0470	1	1/2	.9200880	.9206238	-.1112	.0536
2	5/2	0.0000	.5770813	.7757432	.1738	.2697	2	3/2	.9396556	.9313056	.2845	.1261
3	7/2	0.0000	.9992822	.9992822	.0023	.0004	3	5/2	.9995976	.9995976	.0013	.0002