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EUROPEAN ATOMIC ENERGY COMMUNITY - EURATOM

RELATIVISTIC CALCULATIONS OF KINEMATIC PARAMETERS FOR NUCLEAR REACTIONS

by

H. HORSTMANN and H. LISKIEN

1968

Joint Nuclear Research Center
Geel Establishment - Belgium

Central Bureau for Nuclear Measurements - CBNM

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SUMMARY

A FORTRAN program for relativistic calculations of general kinematic parameters for nuclear reactions is described. The usefulness of the program is demonstrated by means of calculations for neutron-producing reactions.

KEYWORDS

FORTRAN
PROGRAMMING
NUCLEAR REACTIONS
REACTION KINETICS
COMPUTERS
RELATIVITY THEORY
KINETIC ENERGY
BEAMS
ANGULAR DISTRIBUTION
MASS
Q-VALUE

CONTENTS

RELATIVISTIC CALCULATIONS OF KINEMATIC PARAMETERS FOR NUCLEAR REACTIONS(+)

1. Relativistic Kinematics of Nuclear Reactions

1.1. Description of the Kinematic Problem

This report describes a FORTRAN II program for relativistic calculations of kinematic nuclear reaction parameters. The program has been written for the experimenters using the 3 MeV Van-de-Graaff accelerator of the CBNM as a source of fast neutrons, but is not restricted to neutron-producing reactions.

Fig. 1 explains the notation used for the description of nuclear reactions.

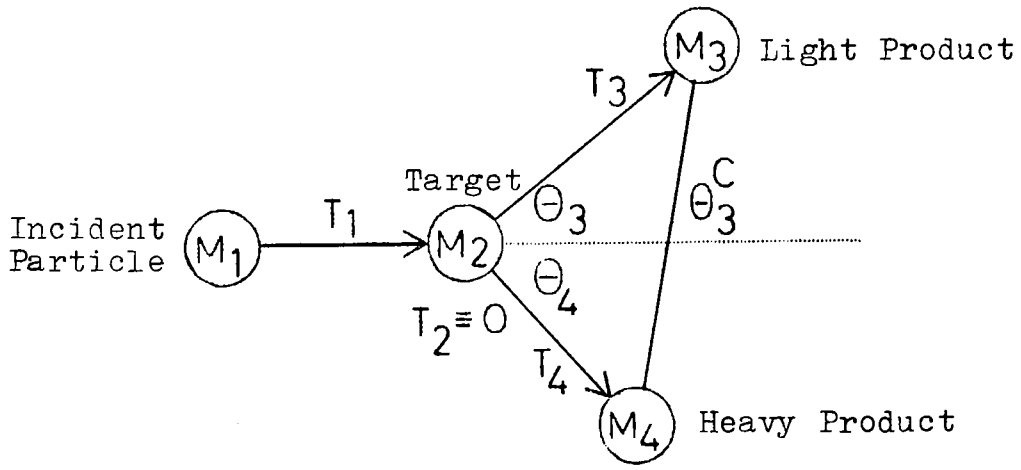


Fig. 1

For a nuclear reaction defined by

M_1 = rest energy of incident particle

M_2 = rest energy of target nucleus

M_3 = rest energy of light reaction product

M_4 = rest energy of heavy reaction product

$Q = M_1 + M_2 - M_3 - M_4$ = reaction energy in the centre-of-mass system (Q-value)

(+) Manuscript received on October 9, 1967.

and user-specified values for

T_1 = kinetic energy of incident particle in the laboratory system

and

Q_3 = angle of light reaction product in the laboratory system

the program performs the calculation of

T_3 = kinetic energy of light reaction product in the laboratory system

T_4 = kinetic energy of heavy reaction product in the laboratory system

Θ_3^c = angle of light reaction product in the centre-of-mass system

Θ_3^{max} = maximum angle of light reaction product in the laboratory system for the double-valued energy region $T_f < T_1 < T_b$

T_f = forward threshold

T_b = backward threshold

Θ_4 = angle of heavy reaction product in the laboratory system

$J = \frac{d\Omega}{d\Omega^c}$ = ratio of elements of solid angle in the laboratory and the centre-of-mass system.

$\frac{\partial T_3}{\partial T_1}$ and $\frac{\partial T_3}{\partial \Theta_3}$: These derivatives are of interest for calculating the neutron energy spread due to finite target thicknesses and finite detector or sample sizes. For both derivatives the non-relativistic approximations are used in the program.

1.2. Kinematic Formulas

The derivation of the kinematic formulas is based on the review article of Monahan [1]. However, some obvious misprints in the relativistic correction factors β_1 and β_3 have been corrected.

The following formulas are used in the program

$$T_3 = \frac{M_1 M_3}{(M_1+M_2)^2} T_1 \beta_1 (2\cos^2\theta_3 + z\beta_2 \pm 2\cos\theta_3 \sqrt{z\beta_3 + \cos^2\theta_3}) \qquad (1)$$

$\pm$ for $T_f < T_1 < T_b$ (Double-valued energy region)

$+$ for $T_1 > T_b$

$$T_4 = T_1 - T_3 + Q \qquad (2)$$

$$\cos\theta_4 = \frac{1}{\sqrt{M_4 T_4 (1+\frac{T_4}{2M_4})}} \left(\sqrt{M_1 T_1 (1+\frac{T_1}{2M_1})} - \sqrt{M_3 T_3 (1+\frac{T_3}{2M_3})}.\cos\theta_3 \right) \qquad (3)$$

$$\sin\theta_3^{max} = \sqrt{\frac{M_2 M_4}{M_1 M_3}(1-\frac{T_f}{T_1}) \frac{1+\frac{M_2 T_1}{2M_3 M_4}(1-\frac{T_f}{T_1})}{1+\frac{T_1}{2M_1}}} \qquad (4)$$

$$\cos\theta_3^c = \frac{-\gamma_o^2 k \sin^2\theta_3 \pm \cos\theta_3 \sqrt{\cos\theta_3 + \gamma_o^2 (1-k^2)\sin^2\theta_3}}{\cos^2\theta_3 + \gamma_o^2 \sin^2\theta_3} \qquad (5)$$

$\pm$ for $T_f < T_1 < T_b$ (Double-valued energy region)

$+$ for $T_1 > T_b$

$$J = \gamma^{o} \frac{1 + k \cos\theta_3^c}{(\sin^2\theta_3^c + \gamma_o^2(k+\cos\theta_3')^2)^{3/2}} \tag{6}$$

$$\frac{\partial T_3}{\partial T_1} = \frac{M_1 \cdot M_3}{(M_1+M_2)^2} \left(2\cos^2\theta_3 + z \pm 2\cos\theta_3 \sqrt{z+\cos^2\theta_3}\right) \tag{7}$$

$$+ \frac{M_2-M_3}{M_1+M_2} \cdot \frac{T_b}{T_1} \left(1 \pm \frac{\cos\theta_3}{\sqrt{z+\cos^2\theta_3}}\right)$$

$\pm$ for $T_f < T_1 < T_b$ (Double-valued energy region)

$+$ for $T_1 > T_b$

$$\frac{\partial T_3}{\partial \theta_3} = \mp T_3 \frac{2\sin\theta_3}{\sqrt{z+\cos^2\theta_3}} \tag{8}$$

$\mp$ for $T_f < T_1 < T_b$ (Double-valued energy region)

$-$ for $T_1 > T_b$

$$T_f = \frac{Q}{M_2} \left(M_1 + M_2 - \frac{Q}{2}\right) \tag{9}$$

$$T_b = -\frac{Q}{M_2-M_3} \left(M_2-M_3+M_1 - \frac{Q}{2}\right) \tag{10}$$

$$T_1^{*} = \frac{M_3 + \frac{Q}{2}}{M_1-M_3-Q} Q \tag{11}$$

(c.f. SUBRØUTINE KIN)

$$k = \sqrt{\frac{M_1 M_3}{M_2 M_4 (1 - \frac{T_f}{T_1})}} \cdot \sqrt{\frac{1 + \frac{T_1}{2M_1}}{1 + \frac{T_1 M_2}{2M_3 M_4}(1 - \frac{T_f}{T_1})}} \cdot \frac{(1 - \frac{Q}{M_1+M_2})(1 + \frac{M_2 T_1 (1 - \frac{T_f}{T_1})}{M_3(M_3+M_4)})}{1 + \frac{T_1}{M_1 M_2}} \qquad (12)$$

$$z = \frac{(M_1+M_2)(M_2-M_3)}{M_1 . M_3} (1 - \frac{T_b}{T_1}) \qquad (13)$$

$$\gamma_o = \frac{1 + \frac{T_1}{M_1+M_2}}{\sqrt{1 + \frac{2T_1 M_2}{(M_1+M_2)^2}}} \qquad (14)$$

$$\beta_1 = \frac{1 + \frac{T_1}{2M_1}}{1 + \frac{2T_1}{M_1+M_2}(1 - \frac{M_1 . \cos^2\theta_3}{M_1+M_2}) + \frac{T_1^2 . \sin^2\theta_3}{(M_1+M_2)^2}} \qquad (15)$$

$$\beta_2 = \frac{1 + \frac{T_1}{M_1+M_2}}{1 + \frac{T_1}{2M_1}} \qquad (16)$$

$$\beta_3 = \frac{1 + \frac{T_1}{M_1+M_2}(1 + \frac{M_2-M_3}{2M_3}(1 - \frac{T_b}{T_1}))}{1 + \frac{T_1}{2M_1}} \qquad (17)$$

2. Description of the Computer Program

2.1. Glossary of Symbols

Symbols used in the program	Symbols used in the formulas (cf. 1.2.)
A1	M_1
A2	M_2
A3	M_3
A4	M_4
B1	β_1
B2	β_2
B3	β_3
C	k
DTDTET	$\frac{\partial T_3}{\partial \Theta_3}$
DTDT1	$\frac{\partial T_3}{\partial T_1}$
FI1	J
FI2	$J.\frac{\partial T_3}{\partial \Theta_3}$
G	γ_o
Q	Q
T1	T_1
T1S	T_1^*
T3	T_3
T4	T_4
TB	T_b
TF	T_f
TET3	Θ_3
TET3E	Θ_3^{max}
TET3C	Θ_3^{c}
TET4	Θ_4
Z	z

Other symbols used in the program are explained in the list of input data and in the block diagrams. No special explanation is given for program symbols representing intermediate results calculated from program variables listed above.

2.2. Data Input

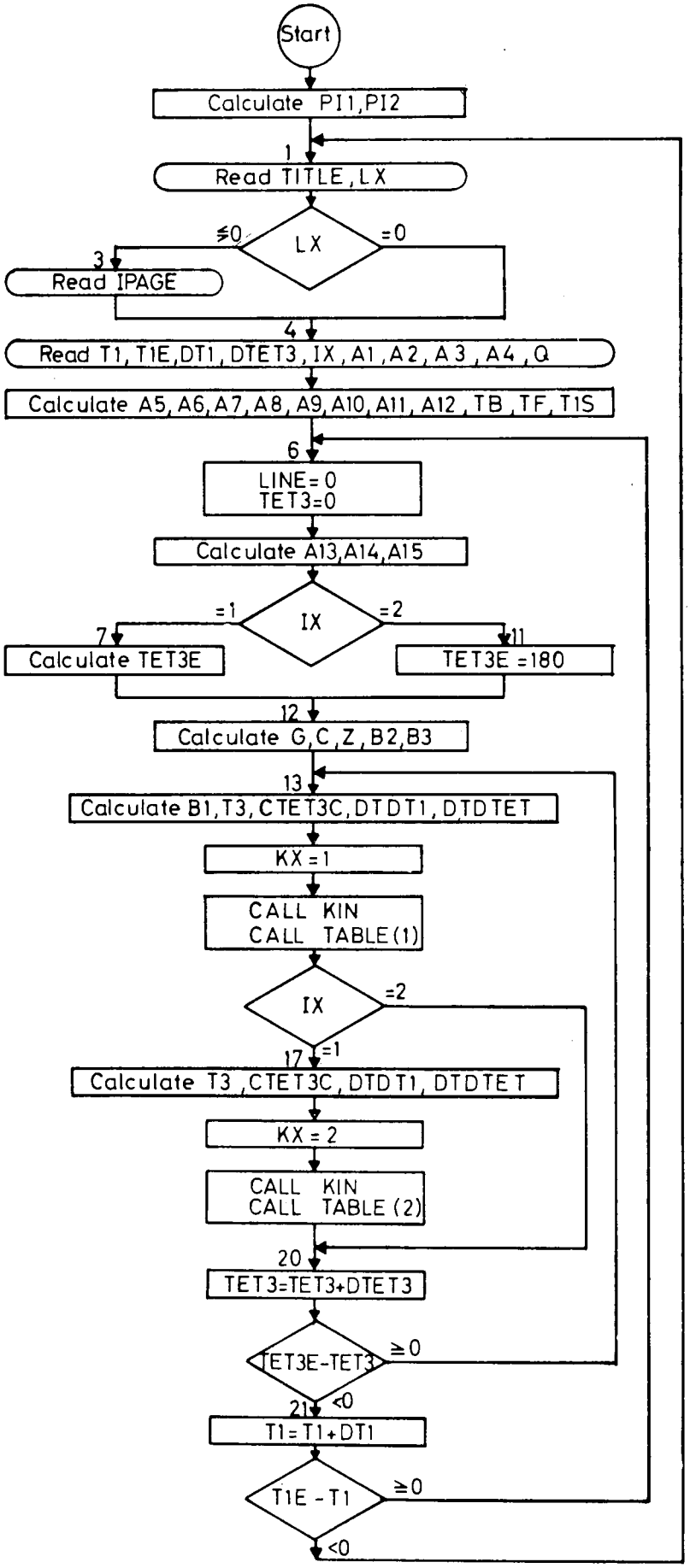
Card No.	Columns	FORMAT	Symbol	
1	1 - 36	6A6	TITLE	Name of nuclear reaction. TITLE is written in two lines as heading of the program output tables by SUBROUTINE TABLE, e.g. for $T(P,N)HE^3$ the first field of 18 columns contains the number 3 for the first line and the second field of 18 columns contains T(P,N)HE for the second line (cf. example of input data at the end of the symbolic program listing).
	37 - 42	I6	LX	Page number indicator. LX $\gtrless$ 0 indicates that the page number of the first output table of this run is determined by input data. LX=0 indicates that the page numbers of this run join those of the preceding run. (The input data of cards 1-3 define one run). For the first run LX should be $\neq$ 0.

Card No.	Columns	FORMAT	Symbol	
2	1 - 6	I6	IPAGE	Page number. IPAGE+1 is the page number of the first output table. If LX=0 this card is omitted.
3	1 - 5	F5.0	T1	Lower limit for the kinetic energy (in keV) of the incident particle in the laboratory system. T1 $\neq T_f, T_b$.
	6 - 10	F5.0	T1E	Upper limit for the kinetic energy (in keV) of the incident particle in the laboratory system. T1E $\neq T_b$.
	11 - 15	F5.0	DT1	Energy increment (in keV). Kinematic parameters are calculated at energy intervals DT1 between T1 and T1E.
	16 - 20	F5.0	DTET3	Increment of TET3 in degrees. For one value of T_1 kinematic parameters are calculated between TET3=0° and TET3=180° or Θ_3^{max} at intervals DTET3.
	21 - 22	I2	IX	Energy range indicator IX = 1 for $T_f < T_1 < T_b$, IX = 2 for $T_1 > T_b$.
	23 - 31	F9.0	A1	Rest energy (in keV) of the incident particle
	32 - 40	F9.0	A2	Rest energy (in keV) of the target nucleus

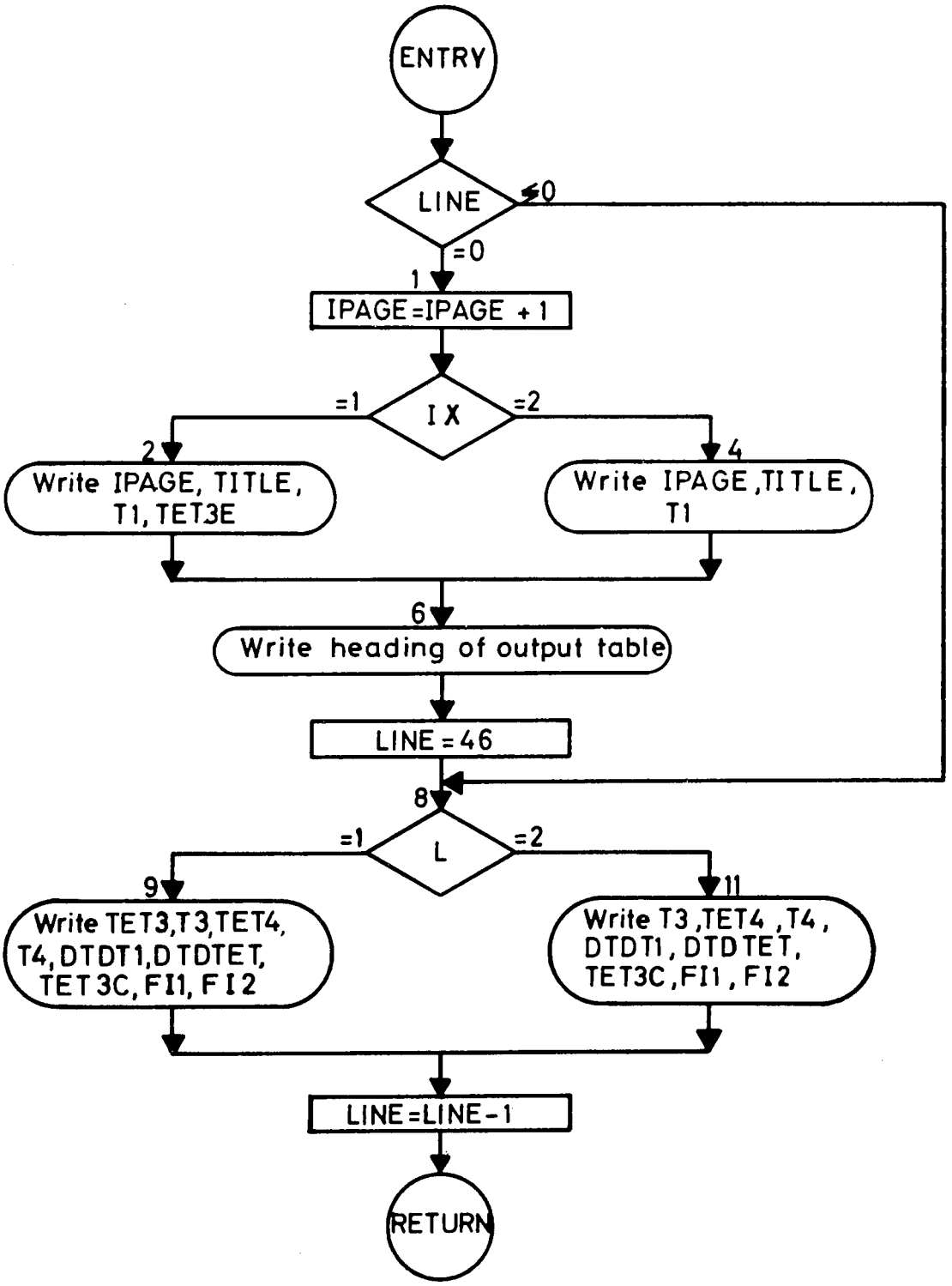
Card No.	Columns	FORMAT	Symbol	
3 (continued)	41 - 49	F9.0	A3	Rest energy (in keV) of the light reaction product
	50 - 58	F9.0	A4	Rest energy (in keV) of the heavy reaction product
	59 - 67	F9.0	Q	"Q"-value of the reaction (in keV)

2.3.BLOCK DIAGRAMS

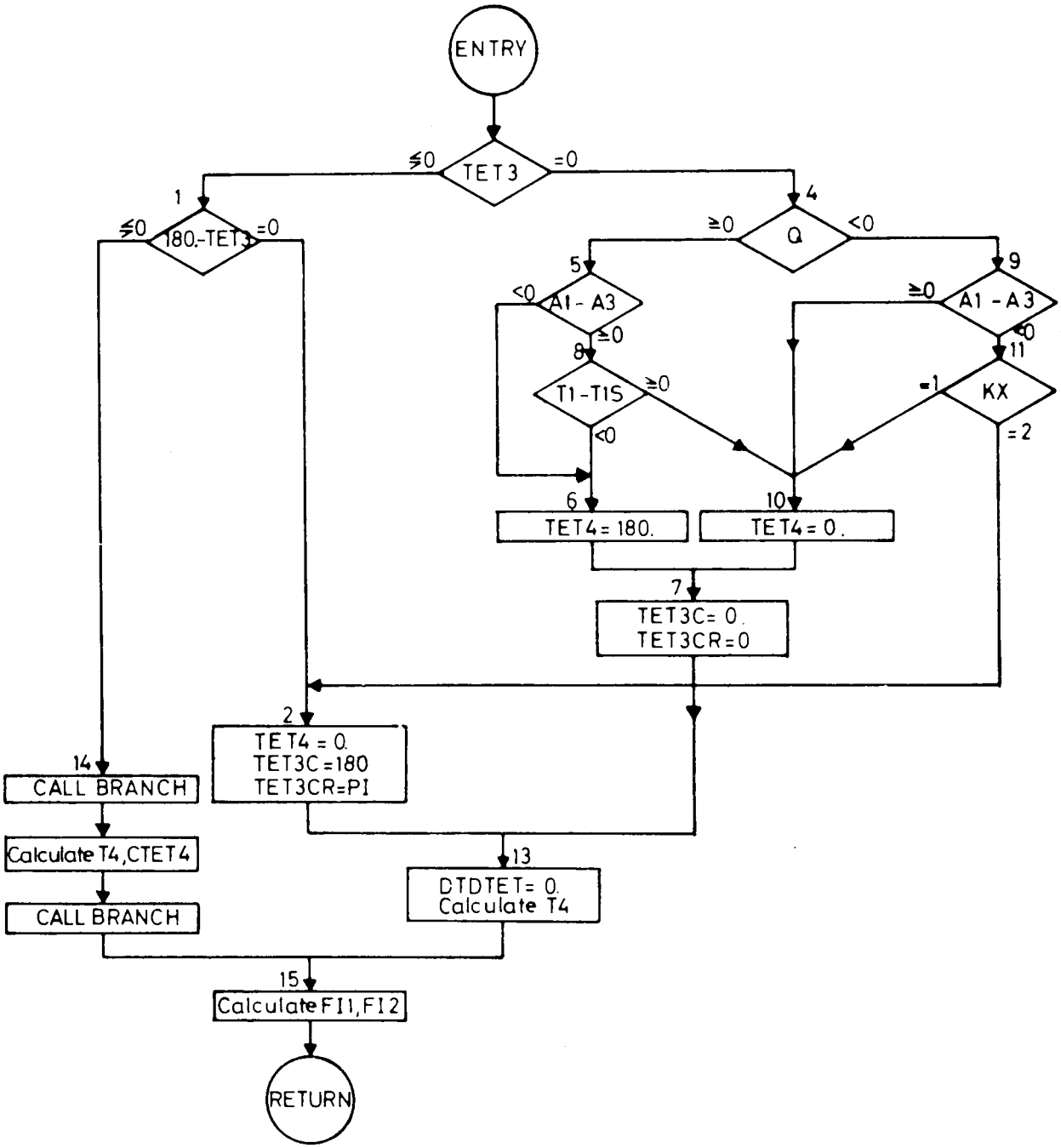
MAIN PROGRAM



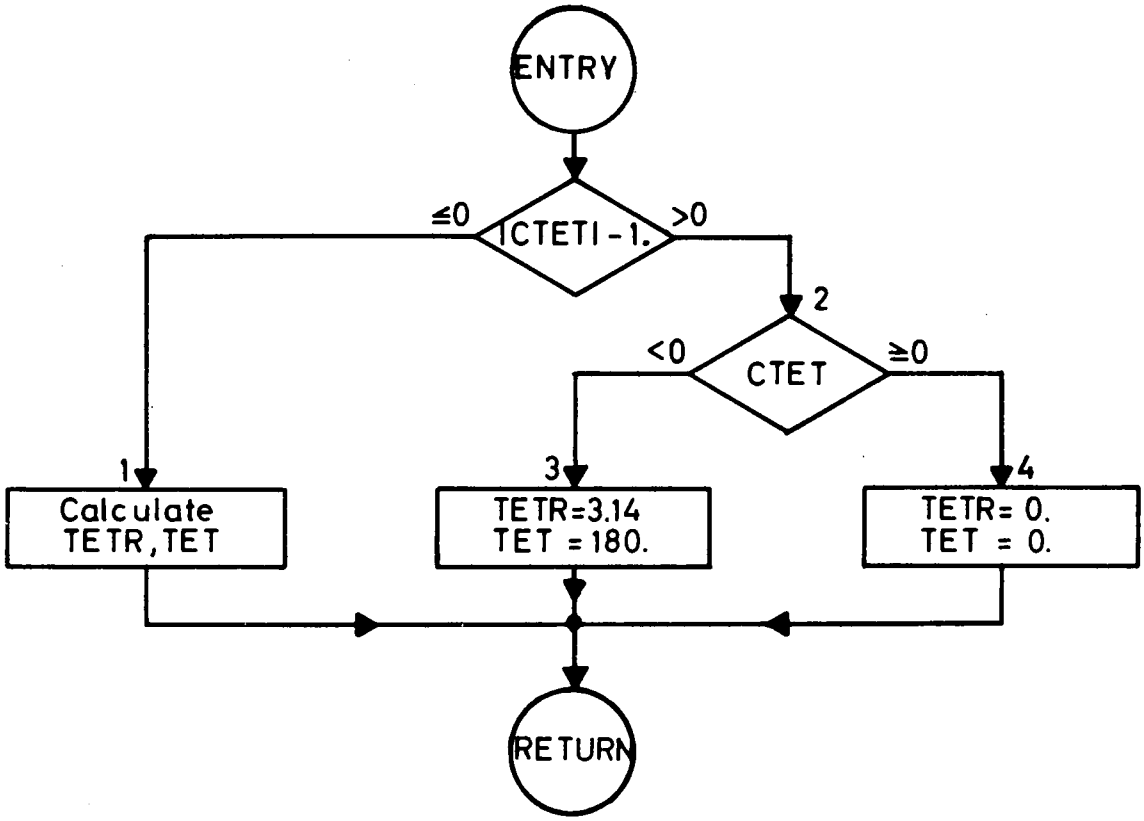
SUBROUTINE TABLE (L)



SUBROUTINE KIN



SUBROUTINE BRANCH(CTET, TETR, TET, PI1)



2.4. SYMBOLIC PROGRAM LISTING

```
C*******************************************************************************  TAB0010
C                                                                                   TAB0020
CTAB            TABULATION OF KINEMATIC PARAMETERS  FORTRAN 2  IBM 7090           TAB0030
C                                                                                   TAB0040
C*******************************************************************************  TAB0050
      DIMENSION TITLE(6)                                                            TAB0060
      COMMON TET3,T3,DTDT1,DTDTET,TET3C,FI1,FI2,LINE,TITLE,T1,IPAGE,CTET            TAB0070
     13C,T4,TET4,TET3E,IX,PI1,G,GG,C,A1,A3,A4,Q,CTET3,KX,T1S                        TAB0080
      PI=3.1415926                                                                  TAB0090
      PI1=180./PI                                                                   TAB0100
      PI2=PI/180.                                                                   TAB0110
    1 READ INPUT TAPE 5,2,TITLE,LX                                                  TAB0120
    2 FORMAT (6A6,I6)                                                               TAB0130
      IF(LX)3,4,3                                                                   TAB0140
    3 READ INPUT TAPE 5,31,IPAGE                                                    TAB0150
   31 FORMAT (I6)                                                                   TAB0160
    4 READ INPUT TAPE 5,5,T1,T1E,DT1,DTET3,IX,A1,A2,A3,A4,Q                         TAB0170
    5 FORMAT (4F5.0,I2,5F9.0)                                                       TAB0180
      A5=A1+A2                                                                      TAB0190
      A6=A5**2                                                                      TAB0200
      A7=A2-A3                                                                      TAB0210
      A8=A1*A3                                                                      TAB0220
      A9=A8/(A2*A4)                                                                 TAB0230
      A10=2.*A1                                                                     TAB0240
      A11=2.*A3                                                                     TAB0250
      A12=A2/(A11*A4)                                                               TAB0260
      TF=-Q/A2*(A5-Q/2.)                                                            TAB0270
      TB=-Q/A7*(A7+A1-Q/2.)                                                         TAB0280
      T1S=(A3+Q/2.)*Q/(A1-A3-Q)                                                     TAB0290
    6 LINE=0                                                                        TAB0300
      TET3=0.                                                                       TAB0310
      A13=1.-TF/T1                                                                  TAB0320
      A14=1.-TB/T1                                                                  TAB0330
      A15=1.+T1/A10                                                                 TAB0340
      GO TO (7,11),IX                                                               TAB0350
    7 CTET3E=SQRTF(1./A9*A13*(1.+A12*T1*A13)/A15)                                   TAB0360
   10 TET3E=ASINF(CTET3E)*PI1                                                       TAB0370
      GO TO 12                                                                      TAB0380
   11 TET3E=180.                                                                    TAB0390
   12 G=(1.+T1/A5)/SQRTF(1.+2.*T1*A2/A6)                                            TAB0400
      GG=G**2                                                                       TAB0410
      C=SQRTF(A9/A13*A15/(1.+T1*A12*A13))*(1.-Q/A5)*(1.+A2*T1*A13/(A3*(A            TAB0420
     13+A4)))/(1.+T1/A5)                                                            TAB0430
      Z=A5*A7*A14/A8                                                                TAB0440
      B2=(1.+T1/A5)/A15                                                             TAB0450
      B3=(1.+T1/A5*(1.+A7/A11*A14))/A15                                             TAB0460
   13 TET3R=TET3*PI2                                                                TAB0470
      CTET3=COSF(TET3R)                                                             TAB0480
```

```
      CTET3S=CTET3**2                                                    TAB0490
      STET3=SINF(TET3R)                                                  TAB0500
      STET3S=STET3**2                                                    TAB0510
      B1=A15/(1.+2.*T1/A5*(1.-A1*CTET3S/A5)+T1**2*STET3S/A6)             TAB0520
      T3A=A8/A6*T1*B1                                                    TAB0530
      T3B=2.*CTET3S+Z*B2                                                 TAB0540
      T3C=2.*CTET3*SQRTF(Z*B3+CTET3S)                                    TAB0550
      T3=T3A*(T3B+T3C)                                                   TAB0560
      TET3C1=-GG*C*STET3S                                                TAB0570
      TET3C2=CTET3*SQRTF(CTET3S+GG*(1.-C**2)*STET3S)                     TAB0580
      TET3C3=CTET3S+GG*STET3S                                            TAB0590
      CTET3C=(TET3C1+TET3C2)/TET3C3                                      TAB0600
   15 ROOT=SQRTF(Z+CTET3S)                                               TAB0610
      DTDT1A=A8/A6                                                       TAB0620
      DTDT1B=2.*CTET3S+Z                                                 TAB0630
      DTDT1C=2.*CTET3*ROOT                                               TAB0640
      DTDT1D=A7/A5*TB/T1                                                 TAB0650
      DTDT1E=CTET3/ROOT                                                  TAB0660
      DTDT1=DTDT1A*(DTDT1B+DTDT1C)+DTDT1D*(1.+DTDT1E)                    TAB0670
      FACTOR=2.*STET3/ROOT*PI2                                           TAB0680
      DTDTET=-T3*FACTOR                                                  TAB0690
      KX=1                                                               TAB0700
      CALL KIN                                                           TAB0710
      CALL TABLE(1)                                                      TAB0720
      GO TO (17,20),IX                                                   TAB0730
   17 T3=T3A*(T3B-T3C)                                                   TAB0740
      CTET3C=(TET3C1-TET3C2)/TET3C3                                      TAB0750
   19 DTDT1=DTDT1A*(DTDT1B-DTDT1C)+DTDT1D*(1.-DTDT1E)                    TAB0760
      DTDTET=T3*FACTOR                                                   TAB0770
      KX=2                                                               TAB0780
      CALL KIN                                                           TAB0790
      CALL TABLE(2)                                                      TAB0800
   20 TET3=TET3+DTET3                                                    TAB0810
      IF(TET3E-TET3)21,13,13                                             TAB0820
   21 T1=T1+DT1                                                          TAB0830
      IF(T1E-T1)1,6,6                                                    TAB0840
      END                                                                TAB0850
```

```
C*************************************************************************  TAB0860
C                                                                           TAB0870
      SUBROUTINE TABLE(L)                                                   TAB0880
C                                                                           TAB0890
C*************************************************************************  TAB0900
      DIMENSION TITLE(6)                                                    TAB0910
      COMMON TET3,T3,DTDT1,DTDTET,TET3C,FI1,FI2,LINE,TITLE,T1,IPAGE,CTET    TAB0920
     13C,T4,TET4,TET3E,IX                                                   TAB0930
      IF(LINE)8,1,8                                                         TAB0940
    1 IPAGE=IPAGE+1                                                         TAB0950
      GO TO (2,4),IX                                                        TAB0960
    2 WRITE OUTPUT TAPE 6,3,IPAGE,TITLE,T1,TET3E                            TAB0970
    3 FORMAT (1H1,103X,4HPAGE,I5///32X,3A6,35X,3HMAX/32X,3A6,7X,1HT,2X,1    TAB0980
     1H=,F6.0,1X,3HKEV,10X,4HTETA,4X,1H=,F6.1/58X,1H1,26X,1H3///)           TAB0990
      GO TO 6                                                               TAB1000
    4 WRITE OUTPUT TAPE 6,5,IPAGE,TITLE,T1                                  TAB1010
    5 FORMAT (1H1,103X,4HPAGE,I5///32X,3A6/32X,3A6,7X,1HT,2X,1H=,F6.0,1X    TAB1020
     1,3HKEV/58X,1H1///)                                                    TAB1030
    6 WRITE OUTPUT TAPE 6,7                                                 TAB1040
    7 FORMAT (85X,1HC/23X,4HTETA,7X,1HT,4X,4HTETA,7X,1HT,5X,6HDT /DT,6X,    TAB1050
     19HDT /DTETA,4X,4HTETA,8X,1HJ,7X,11HJ.DT /DTETA/27X,1H3,7X,1H3,7X,1    TAB1060
     2H4,7X,1H4,6X,1H3,3X,1H1,7X,1H3,6X,1H3,7X,1H3,19X,1H3,6X,1H3///)       TAB1070
      LINE=46                                                               TAB1080
    8 GO TO (9,11),L                                                        TAB1090
    9 WRITE OUTPUT TAPE6,10,TET3,T3,TET4,T4,DTDT1,DTDTET,TET3C,FI1,FI2      TAB1100
   10 FORMAT (23X,F5.0,F9.1,F7.1,F9.1,E13.4,E13.4,F7.1,E13.4,E13.4)         TAB1110
      GO TO 15                                                              TAB1120
   11 WRITE OUTPUT TAPE 6,12,T3,TET4,T4,DTDT1,DTDTET,TET3C,FI1,FI2          TAB1130
   12 FORMAT (28X,F9.1,F7.1,F9.1,E13.4,E13.4,F7.1,E13.4,E13.4)              TAB1140
   15 LINE=LINE-1                                                           TAB1150
      RETURN                                                                TAB1160
      END                                                                   TAB1170
```

```
C*************************************************************************  TAB1180
C                                                                           TAB1190
      SUBROUTINE KIN                                                        TAB1200
C                                                                           TAB1210
C*************************************************************************  TAB1220
      DIMENSION TITLE(6)                                                    TAB1230
      COMMON TET3,T3,DTDT1,DTDTET,TET3C,FI1,FI2,LINE,TITLE,T1,IPAGE,CTET    TAB1240
     13C,T4,TET4,TET3E,IX,PI1,G,GG,C,A1,A3,A4,Q,CTET3,KX,T1S                TAB1250
      IF(TET3)1,4,1                                                         TAB1260
    1 IF(180.-TET3)14,2,14                                                  TAB1270
    2 TET4=0.                                                               TAB1280
    3 TET3C=180.0                                                           TAB1290
      TET3CR=PI                                                             TAB1300
      GOTO 13                                                               TAB1310
    4 IF(Q)9,5,5                                                            TAB1320
    5 IF(A1-A3)6,8,8                                                        TAB1330
    6 TET4=180.0                                                            TAB1340
    7 TET3C=0.0                                                             TAB1350
      TET3CR=0.0                                                            TAB1360
      GOTO 13                                                               TAB1370
    8 IF(T1-T1S)6,10,10                                                     TAB1380
    9 IF(A1-A3)11,10,10                                                     TAB1390
   10 TET4=0.0                                                              TAB1400
      GOTO 7                                                                TAB1410
   11 CONTINUE                                                              TAB1420
   12 GOTO(10,2),KX                                                         TAB1430
   13 DTDTET=0.0                                                            TAB1440
      T4=T1-T3+Q                                                            TAB1450
      GOTO 15                                                               TAB1460
   14 CALLBRANCH(CTET3C,TET3CR,TET3C,PI1)                                   TAB1470
      T4=T1-T3+Q                                                            TAB1480
      DENOM=A4*T4*(1.+T4/(2.*A4))                                           TAB1490
      CTET4=SQRTF(A1*T1*(1.+T1/(2.*A1))/DENOM)-SQRTF(A3*T3*(1.+T3/(2.*A3    TAB1500
     1))/DENOM)*CTET3                                                       TAB1510
      CALL BRANCH(CTET4,TET4R,TET4,PI1)                                     TAB1520
   15 FI1=G*(1.+C*CTET3C)/(SINF(TET3CR)**2+GG*(C+CTET3C)**2)**1.5           TAB1530
      FI2=FI1*DTDTET                                                        TAB1540
      RETURN                                                                TAB1550
      END                                                                   TAB1560
```

```
C*********************************************************************  TAB1570
C                                                                       TAB1580
      SUBROUTINE BRANCH(CTET,TETR,TET,PI1)                              TAB1590
C                                                                       TAB1600
C*********************************************************************  TAB1610
      IF(ABSF(CTET)-1.)1,1,2                                            TAB1620
    1 TETR=ACOSF(CTET)                                                  TAB1630
      TET =TETR*PI1                                                     TAB1640
      GO TO 5                                                           TAB1650
    2 IF(CTET)3,4,4                                                     TAB1660
    3 TET=180.0                                                         TAB1670
      TETR=3.1415926                                                    TAB1680
      GO TO 5                                                           TAB1690
    4 TET=0.0                                                           TAB1700
      TETR=0.0                                                          TAB1710
    5 CONTINUE                                                          TAB1720
      RETURN                                                            TAB1730
      END                                                               TAB1740
```

```
*     DATA
        3          T(P,N)HE                11
      0
1020.1147.1.   2.     1938219.  2808761. 939512.   2808232.-764.
        3          T(P,N)HE
1148.1248.1.   2.     2938219.  2808761. 939512.   2808232.-764.
        3          T(P,N)HE
1250.3500.10.  2.     2938219.  2808761. 939512.   2808232.-764.
```

2.5. Example of Program Output

On the following four pages examples of the program output for the reaction $T(p,n)^3He$ will be found. For each value of the kinetic energy T_1 of the incident particle the kinematic parameters are calculated at intervals of 2 degrees between $\Theta_3 = 0°$ and $\Theta_3 = \Theta_3^{max}$ or between $\Theta_3 = 0°$ and $\Theta_3 = 180°$ depending on whether T_1 is in the double-valued energy region or not. All energies are given in keV, all angles in degrees, and $\frac{\partial T_3}{\partial \Theta_3}$ in keV/degree.

T(P,N)HE^3 T_1 = 1060. KEV $TETA_3^{MAX}$ = 35.9

$TETA_3$	T_3	$TETA_4$	T_4	DT_3/DT_1	$DT_3/DTETA_3$	$TETA_3^C$	J	$J.DT_3/DTETA_3$
0.	167.4	0.	128.6	0.1620E 01	0.	0.	0.1365E-00	0.
	11.4	0.	284.6	-0.3711E-00	0.	180.0	-0.2003E 01	-0.
2.	167.1	1.3	128.9	0.1621E 01	-0.3481E-00	5.4	0.1365E-00	-0.4752E-01
	11.4	0.2	284.6	-0.3722E-00	0.2382E-01	178.6	-0.1995E 01	-0.4753E-01
4.	166.0	2.6	130.0	0.1623E 01	-0.6951E 00	10.8	0.1367E-00	-0.9499E-01
	11.5	0.5	284.5	-0.3754E-00	0.4816E-01	177.2	-0.1972E 01	-0.9499E-01
6.	164.3	3.9	131.7	0.1627E 01	-0.1040E 01	16.3	0.1369E-00	-0.1423E-00
	11.6	0.7	284.4	-0.3808E-00	0.7360E-01	175.7	-0.1934E 01	-0.1423E-00
8.	161.9	5.1	134.1	0.1633E 01	-0.1382E 01	21.7	0.1371E-00	-0.1895E-00
	11.8	0.9	284.2	-0.3887E-00	0.1007E-00	174.3	-0.1881E 01	-0.1895E-00
10.	158.8	6.2	137.2	0.1641E 01	-0.1720E 01	27.2	0.1375E-00	-0.2365E-00
	12.0	1.2	284.0	-0.3993E-00	0.1303E-00	172.8	-0.1814E 01	-0.2365E-00
12.	155.0	7.2	141.0	0.1651E 01	-0.2054E 01	32.8	0.1378E-00	-0.2831E-00
	12.3	1.4	283.7	-0.4129E-00	0.1633E-00	171.2	-0.1734E 01	-0.2831E-00
14.	150.6	8.2	145.4	0.1664E 01	-0.2383E 01	38.4	0.1382E-00	-0.3294E-00
	12.7	1.7	283.3	-0.4302E-00	0.2008E-00	169.6	-0.1641E 01	-0.3295E-00
16.	145.5	9.0	150.5	0.1682E 01	-0.2708E 01	44.1	0.1386E-00	-0.3754E-00
	13.1	2.0	282.9	-0.4519E-00	0.2444E-00	167.9	-0.1536E 01	-0.3754E-00
18.	139.7	9.7	156.3	0.1704E 01	-0.3029E 01	49.8	0.1390E-00	-0.4208E-00
	13.7	2.3	282.3	-0.4792E-00	0.2963E-00	166.2	-0.1420E 01	-0.4209E-00
20.	133.4	10.3	162.6	0.1733E 01	-0.3348E 01	55.7	0.1391E-00	-0.4658E-00
	14.3	2.6	281.7	-0.5136E 00	0.3596E-00	164.3	-0.1296E 01	-0.4658E-00
22.	126.3	10.8	169.7	0.1771E 01	-0.3668E 01	61.7	0.1391E-00	-0.5102E 00
	15.1	2.9	280.9	-0.5576E 00	0.4390E-00	162.3	-0.1162E 01	-0.5102E 00
24.	118.7	11.1	177.3	0.1822E 01	-0.3997E 01	68.0	0.1386E-00	-0.5540E 00
	16.1	3.2	279.9	-0.6151E 00	0.5420E 00	160.0	-0.1022E 01	-0.5540E 00
26.	110.3	11.3	185.7	0.1893E 01	-0.4346E 01	74.4	0.1374E-00	-0.5972E 00
	17.3	3.6	278.7	-0.6929E 00	0.6816E 00	157.6	-0.8761E 00	-0.5972E 00
28.	101.3	11.3	194.7	0.1997E 01	-0.4737E 01	81.2	0.1350E-00	-0.6396E 00
	18.9	4.1	277.1	-0.8032E 00	0.8821E 00	154.8	-0.7252E 00	-0.6397E 00
30.	91.4	11.1	204.6	0.2159E 01	-0.5224E 01	88.6	0.1304E-00	-0.6814E 00
	20.9	4.6	275.1	-0.9727E 00	0.1196E 01	151.4	-0.5699E 00	-0.6814E 00
32.	80.3	10.8	215.7	0.2450E 01	-0.5946E 01	96.7	0.1215E-00	-0.7226E 00
	23.8	5.2	272.2	-0.1272E 01	0.1763E 01	147.3	-0.4098E-00	-0.7226E 00
34.	67.1	10.1	228.9	0.3169E 01	-0.7506E 01	106.6	0.1018E-00	-0.7638E 00
	28.5	6.1	267.5	-0.1999E 01	0.3184E 01	141.4	-0.2399E-00	-0.7638E 00

$T(P,N)HE^3$ $T_1 = 1061.$ KEV $TETA_3^{MAX} = 36.4$

$TETA_3$	T_3	$TETA_4$	T_4	DT_3/DT_1	$DT_3/DTETA_3$	$TETA_3^C$	J	$J.DT_3/DTETA_3$
0.	169.0	0.	128.0	0.1609E 01	0.	0.	0.1385E-00	0.
	11.0	0.	286.0	-0.3604E-00	0.	180.0	-0.2120E 01	-0.
2.	168.7	1.3	128.3	0.1610E 01	-0.3473E-00	5.4	0.1386E-00	-0.4812E-01
	11.1	0.2	285.9	-0.3614E-00	0.2279E-01	178.6	-0.2112E 01	-0.4813E-01
4.	167.6	2.6	129.4	0.1612E 01	-0.6936E 00	10.8	0.1387E-00	-0.9619E-01
	11.1	0.5	285.9	-0.3645E-00	0.4607E-01	177.2	-0.2088E 01	-0.9620E-01
6.	165.9	3.9	131.1	0.1616E 01	-0.1038E 01	16.2	0.1389E-00	-0.1441E-00
	11.3	0.7	285.7	-0.3697E-00	0.7037E-01	175.8	-0.2048E 01	-0.1442E-00
8.	163.5	5.1	133.5	0.1621E 01	-0.1379E 01	21.6	0.1392E-00	-0.1919E-00
	11.4	0.9	285.6	-0.3772E-00	0.9628E-01	174.4	-0.1993E 01	-0.1919E-00
10.	160.4	6.2	136.6	0.1628E 01	-0.1716E 01	27.0	0.1396E-00	-0.2395E-00
	11.6	1.2	285.4	-0.3872E-00	0.1245E-00	173.0	-0.1924E 01	-0.2395E-00
12.	156.6	7.3	140.4	0.1638E 01	-0.2048E 01	32.5	0.1400E-00	-0.2867E-00
	11.9	1.4	285.1	-0.4002E-00	0.1558E-00	171.5	-0.1840E 01	-0.2867E-00
14.	152.2	8.2	144.8	0.1651E 01	-0.2376E 01	38.1	0.1404E-00	-0.3336E-00
	12.3	1.7	284.7	-0.4165E-00	0.1914E-00	169.9	-0.1743E 01	-0.3336E-00
16.	147.1	9.1	149.9	0.1667E 01	-0.2698E 01	43.7	0.1409E-00	-0.3801E-00
	12.7	1.9	284.3	-0.4370E-00	0.2327E-00	168.3	-0.1634E 01	-0.3801E-00
18.	141.4	9.8	155.6	0.1688E 01	-0.3016E 01	49.4	0.1413E-00	-0.4262E-00
	13.2	2.2	283.8	-0.4627E-00	0.2815E-00	166.6	-0.1514E 01	-0.4262E-00
20.	135.1	10.4	161.9	0.1714E 01	-0.3332E 01	55.2	0.1416E-00	-0.4717E-00
	13.8	2.5	283.2	-0.4949E-00	0.3409E-00	164.8	-0.1384E 01	-0.4717E-00
22.	128.1	10.9	168.9	0.1750E 01	-0.3647E 01	61.2	0.1417E-00	-0.5167E 00
	14.6	2.8	282.4	-0.5360E 00	0.4149E-00	162.8	-0.1245E 01	-0.5167E 00
24.	120.5	11.2	176.5	0.1797E 01	-0.3968E 01	67.3	0.1414E-00	-0.5610E 00
	15.5	3.2	281.5	-0.5893E 00	0.5102E 00	160.7	-0.1100E 01	-0.5611E 00
26.	112.2	11.4	184.8	0.1861E 01	-0.4305E 01	73.7	0.1405E-00	-0.6047E 00
	16.6	3.5	280.4	-0.6606E 00	0.6381E 00	158.3	-0.9477E 00	-0.6047E 00
28.	103.3	11.4	193.7	0.1954E 01	-0.4678E 01	80.4	0.1385E-00	-0.6477E 00
	18.1	4.0	278.9	-0.7604E 00	0.8190E 00	155.6	-0.7909E 00	-0.6477E 00
30.	93.5	11.3	203.5	0.2096E 01	-0.5127E 01	87.5	0.1346E-00	-0.6900E 00
	20.0	4.5	277.0	-0.9101E 00	0.1095E 01	152.5	-0.6300E 00	-0.6900E 00
32.	82.6	11.0	214.4	0.2342E 01	-0.5760E 01	95.4	0.1270E-00	-0.7316E 00
	22.6	5.0	274.4	-0.1163E 01	0.1574E 01	148.6	-0.4648E-00	-0.7316E 00
34.	70.1	10.4	226.9	0.2884E 01	-0.6970E 01	104.6	0.1109E-00	-0.7729E 00
	26.6	5.8	270.4	-0.1713E 01	0.2646E 01	143.4	-0.2921E-00	-0.7729E 00
36.	52.3	9.0	244.7	0.6337E 01	-0.1414E 02	118.5	0.5830E-01	-0.8241E 00
	35.7	7.2	261.3	-0.5175E 01	0.9637E 01	133.5	-0.8551E-01	-0.8241E 00

$T(P,N)HE^3$ T_1 = 1250. KEV

$TETA_3$	T_3	$TETA_4$	T_4	DT_3/DT_1	$DT_3/DTETA_3$	$TETA_3^C$	J	$J.DT_3/DTETA_3$
0.	409.7	0.	76.3	0.1142E 01	0.	0.	0.3161E-00	0.
2.	409.3	2.7	76.7	0.1142E 01	-0.3883E 00	3.6	0.3163E-00	-0.1228E-00
4.	408.2	5.3	77.8	0.1141E 01	-0.7747E 00	7.1	0.3169E-00	-0.2455E-00
6.	406.2	7.8	79.8	0.1139E 01	-0.1158E 01	10.7	0.3178E-00	-0.3678E-00
8.	403.6	10.3	82.4	0.1136E 01	-0.1535E 01	14.2	0.3191E-00	-0.4898E-00
10.	400.1	12.5	85.9	0.1132E 01	-0.1905E 01	17.8	0.3208E-00	-0.6111E 00
12.	395.9	14.6	90.1	0.1128E 01	-0.2266E 01	21.3	0.3228E-00	-0.7317E 00
14.	391.0	16.5	95.0	0.1123E 01	-0.2617E 01	24.9	0.3253E-00	-0.8513E 00
16.	385.5	18.2	100.5	0.1117E 01	-0.2955E 01	28.4	0.3282E-00	-0.9700E 00
18.	379.2	19.7	106.8	0.1111E 01	-0.3280E 01	31.9	0.3315E-00	-0.1087E 01
20.	372.4	21.0	113.6	0.1103E 01	-0.3590E 01	35.4	0.3353E-00	-0.1204E 01
22.	364.9	22.1	121.1	0.1095E 01	-0.3882E 01	39.0	0.3396E-00	-0.1318E 01
24.	356.8	23.0	129.2	0.1087E 01	-0.4157E 01	42.5	0.3443E-00	-0.1431E 01
26.	348.3	23.8	137.7	0.1077E 01	-0.4413E 01	46.0	0.3496E-00	-0.1543E 01
28.	339.2	24.4	146.8	0.1067E 01	-0.4648E 01	49.4	0.3555E-00	-0.1652E 01
30.	329.7	24.8	156.3	0.1057E 01	-0.4862E 01	52.9	0.3619E-00	-0.1760E 01
32.	319.8	25.2	166.2	0.1046E 01	-0.5053E 01	56.4	0.3690E-00	-0.1865E 01
34.	309.5	25.4	176.5	0.1034E 01	-0.5222E 01	59.8	0.3768E-00	-0.1968E 01
36.	298.9	25.4	187.1	0.1021E 01	-0.5368E 01	63.2	0.3854E-00	-0.2069E 01
38.	288.0	25.4	198.0	0.1008E 01	-0.5489E 01	66.6	0.3947E-00	-0.2167E 01
40.	276.9	25.3	209.1	0.9949E 00	-0.5586E 01	70.0	0.4050E-00	-0.2262E 01
42.	265.7	25.2	220.3	0.9809E 00	-0.5658E 01	73.4	0.4162E-00	-0.2355E 01
44.	254.3	24.9	231.7	0.9663E 00	-0.5705E 01	76.7	0.4285E-00	-0.2445E 01
46.	242.9	24.6	243.1	0.9512E 00	-0.5729E 01	80.1	0.4419E-00	-0.2532E 01
48.	231.4	24.2	254.6	0.9356E 00	-0.5728E 01	83.3	0.4566E-00	-0.2615E 01
50.	220.0	23.8	266.0	0.9194E 00	-0.5703E 01	86.6	0.4728E-00	-0.2696E 01
52.	208.6	23.3	277.4	0.9028E 00	-0.5655E 01	89.8	0.4904E-00	-0.2773E 01
54.	197.4	22.8	288.6	0.8856E 00	-0.5584E 01	93.0	0.5099E 00	-0.2847E 01
56.	186.3	22.2	299.7	0.8680E 00	-0.5492E 01	96.2	0.5312E 00	-0.2918E 01
58.	175.4	21.6	310.6	0.8498E 00	-0.5380E 01	99.3	0.5548E 00	-0.2985E 01
60.	164.8	21.0	321.2	0.8311E 00	-0.5248E 01	102.4	0.5807E 00	-0.3048E 01
62.	154.4	20.4	331.6	0.8119E 00	-0.5099E 01	105.4	0.6094E 00	-0.3107E 01
64.	144.4	19.8	341.6	0.7922E 00	-0.4934E 01	108.4	0.6411E 00	-0.3163E 01
66.	134.7	19.1	351.3	0.7720E 00	-0.4754E 01	111.3	0.6763E 00	-0.3215E 01
68.	125.4	18.4	360.6	0.7512E 00	-0.4562E 01	114.2	0.7153E 00	-0.3263E 01
70.	116.4	17.8	369.6	0.7300E 00	-0.4359E 01	117.0	0.7586E 00	-0.3307E 01
72.	107.9	17.1	378.1	0.7082E 00	-0.4148E 01	119.8	0.8069E 00	-0.3347E 01
74.	99.9	16.4	386.1	0.6860E 00	-0.3930E 01	122.4	0.8607E 00	-0.3383E 01
76.	92.2	15.8	393.8	0.6634E 00	-0.3709E 01	125.1	0.9208E 00	-0.3415E 01
78.	85.0	15.1	401.0	0.6404E 00	-0.3485E 01	127.6	0.9879E 00	-0.3442E 01
80.	78.3	14.5	407.7	0.6170E 00	-0.3261E 01	130.0	0.1063E 01	-0.3466E 01
82.	72.0	13.8	414.0	0.5935E 00	-0.3039E 01	132.4	0.1147E 01	-0.3485E 01
84.	66.1	13.2	419.9	0.5698E 00	-0.2822E 01	134.7	0.1241E 01	-0.3500E 01
86.	60.7	12.6	425.3	0.5460E 00	-0.2610E 01	136.9	0.1345E 01	-0.3511E 01
88.	55.7	12.0	430.3	0.5224E 00	-0.2405E 01	139.1	0.1462E 01	-0.3517E 01
90.	51.1	11.4	434.9	0.4989E-00	-0.2209E 01	141.1	0.1593E 01	-0.3519E 01

$T(P,N)HE^3$ T_1 = 1250. KEV

$TETA_3$	T_3	$TETA_4$	T_4	DT_3/DT_1	$DT_3/DTETA_3$	$TETA_3^C$	J	$J.DT_3/DTETA_3$
92.	46.8	10.9	439.2	0.4757E-00	-0.2023E 01	143.1	0.1739E 01	-0.3517E 01
94.	43.0	10.3	443.0	0.4529E-00	-0.1847E 01	144.9	0.1901E 01	-0.3511E 01
96.	39.4	9.8	446.6	0.4307E-00	-0.1683E 01	146.7	0.2080E 01	-0.3500E 01
98.	36.2	9.4	449.8	0.4091E-00	-0.1529E 01	148.4	0.2279E 01	-0.3485E 01
100.	33.3	8.9	452.7	0.3883E-00	-0.1387E 01	150.0	0.2498E 01	-0.3466E 01
102.	30.7	8.4	455.3	0.3682E-00	-0.1257E 01	151.6	0.2740E 01	-0.3443E 01
104.	28.3	8.0	457.7	0.3491E-00	-0.1137E 01	153.0	0.3004E 01	-0.3415E 01
106.	26.1	7.6	459.9	0.3308E-00	-0.1027E 01	154.4	0.3293E 01	-0.3383E 01
108.	24.1	7.2	461.9	0.3135E-00	-0.9280E 00	155.8	0.3607E 01	-0.3347E 01
110.	22.4	6.9	463.6	0.2971E-00	-0.8380E 00	157.0	0.3947E 01	-0.3307E 01
112.	20.8	6.5	465.2	0.2817E-00	-0.7565E 00	158.2	0.4313E 01	-0.3263E 01
114.	19.4	6.2	466.6	0.2673E-00	-0.6831E 00	159.3	0.4707E 01	-0.3215E 01
116.	18.1	5.9	467.9	0.2538E-00	-0.6169E 00	160.4	0.5128E 01	-0.3163E 01
118.	16.9	5.6	469.1	0.2411E-00	-0.5574E 00	161.4	0.5575E 01	-0.3108E 01
120.	15.8	5.3	470.2	0.2294E-00	-0.5039E 00	162.4	0.6049E 01	-0.3048E 01
122.	14.9	5.0	471.1	0.2184E-00	-0.4558E-00	163.3	0.6549E 01	-0.2985E 01
124.	14.0	4.7	472.0	0.2083E-00	-0.4125E-00	164.2	0.7073E 01	-0.2918E 01
126.	13.2	4.5	472.8	0.1989E-00	-0.3737E-00	165.0	0.7620E 01	-0.2847E 01
128.	12.5	4.2	473.5	0.1901E-00	-0.3387E-00	165.8	0.8189E 01	-0.2774E 01
130.	11.9	4.0	474.1	0.1821E-00	-0.3072E-00	166.6	0.8777E 01	-0.2696E 01
132.	11.3	3.8	474.7	0.1746E-00	-0.2788E-00	167.3	0.9382E 01	-0.2616E 01
134.	10.7	3.6	475.3	0.1677E-00	-0.2532E-00	168.1	0.1000E 02	-0.2532E 01
136.	10.3	3.4	475.7	0.1614E-00	-0.2300E-00	168.7	0.1063E 02	-0.2445E 01
138.	9.8	3.2	476.2	0.1555E-00	-0.2089E-00	169.4	0.1127E 02	-0.2355E 01
140.	9.4	3.0	476.6	0.1502E-00	-0.1899E-00	170.0	0.1192E 02	-0.2262E 01
142.	9.1	2.8	476.9	0.1452E-00	-0.1725E-00	170.6	0.1256E 02	-0.2167E 01
144.	8.7	2.6	477.3	0.1407E-00	-0.1566E-00	171.2	0.1321E 02	-0.2069E 01
146.	8.4	2.5	477.6	0.1365E-00	-0.1421E-00	171.8	0.1385E 02	-0.1968E 01
148.	8.2	2.3	477.8	0.1327E-00	-0.1288E-00	172.4	0.1448E 02	-0.1865E 01
150.	7.9	2.1	478.1	0.1292E-00	-0.1166E-00	172.9	0.1509E 02	-0.1760E 01
152.	7.7	2.0	478.3	0.1260E-00	-0.1053E-00	173.4	0.1569E 02	-0.1652E 01
154.	7.5	1.8	478.5	0.1231E-00	-0.9484E-01	174.0	0.1627E 02	-0.1543E 01
156.	7.3	1.7	478.7	0.1205E-00	-0.8511E-01	174.5	0.1682E 02	-0.1432E 01
158.	7.1	1.5	478.9	0.1182E-00	-0.7602E-01	175.0	0.1735E 02	-0.1319E 01
160.	7.0	1.4	479.0	0.1161E-00	-0.6749E-01	175.4	0.1784E 02	-0.1204E 01
162.	6.9	1.2	479.1	0.1142E-00	-0.5946E-01	175.9	0.1829E 02	-0.1088E 01
164.	6.8	1.1	479.2	0.1126E-00	-0.5185E-01	176.4	0.1871E 02	-0.9702E 00
166.	6.7	0.9	479.3	0.1112E-00	-0.4462E-01	176.9	0.1909E 02	-0.8515E 00
168.	6.6	0.8	479.4	0.1099E-00	-0.3769E-01	177.3	0.1942E 02	-0.7318E 00
170.	6.5	0.7	479.5	0.1089E-00	-0.3102E-01	177.8	0.1970E 02	-0.6112E 00
172.	6.5	0.5	479.5	0.1081E-00	-0.2457E-01	178.2	0.1994E 02	-0.4899E-00
174.	6.4	0.4	479.6	0.1074E-00	-0.1828E-01	178.7	0.2012E 02	-0.3679E-00
176.	6.4	0.3	479.6	0.1070E-00	-0.1212E-01	179.1	0.2025E 02	-0.2455E-00
178.	6.4	0.1	479.6	0.1067E-00	-0.6041E-02	179.6	0.2034E 02	-0.1228E-00
180.	6.4	0.	479.6	0.1066E-00	0.	180.0	0.2036E 02	0.

3. Tabulation of Kinematic Parameters for Neutron-Producing Nuclear Reactions.

For the experimenters at the Van-de-Graaff accelerator of the CBNM numerous tables of kinematic parameters for neutron-producing reactions have been prepared (cf. 2.5. for example of program output). On the following two pages those nuclear reactions, energy regions, and angular ranges are specified for which kinematic calculations have been made. The nuclear masses and Q-values used are those quoted by König, Mattauch, and Wapstra [2].

REACTION TYPE	REGION FOR T_1 (KEV)	INCREMENT FOR T_1 (KEV)	INCREMENT FOR THETA 3 (DEG.)	REST ENERGY M_1 (KEV)	REST ENERGY M_2 (KEV)	REST ENERGY M_3 (KEV)	REST ENERGY M_4 (KEV)	Q (KEV)
$D(D,N)HE^3$	500-3500	10	2	1875506	1875506	939512	2808232	+3268
$T(P,N)HE^3$	1020-1147	1	2	938219	2808761	939512	2808232	-764
	1148-1248	1	2	938219	2808761	939512	2808232	-764
	1250-3500	10	2	938219	2808761	939512	2808232	-764
$T(D,N)HE^4$	500-3500	10	2	1875506	2808761	939512	3727167	+17568
$LI^7(P,N)BE^7$	1881-1919	1	2	938219	6533462	939512	6533813	-1644
	1920-2021	1	2	938219	6533462	939512	6533813	-1644
	2030-3500	10	2	938219	6533462	939512	6533813	-1644
$LI^7(P,N)BE^{7*}$	2374-2423	1	2	938219	6533462	939512	6534244	-2075
	2424-2524	1	2	938219	6533462	939512	6534244	-2075
	2530-3500	10	2	938219	6533462	939512	6534244	-2075
$BE^9(A,N)C^{12}$	500-3500	10	2	3727167	8392275	939512	11174226	+5704
$BE^9(A,N)C^{12*}$	500-3500	10	2	3727167	8392275	939512	11178659	+1271
$C^{14}(D,N)N^{15}$	500-3500	10	2	1875506	13040128	939512	13968139	+7983

REACTION TYPE	REGION FOR T_1 (KEV)	INCREMENT FOR T_1 (KEV)	INCREMENT FOR THETA 3 (DEG.)	REST ENERGY M_1 (KEV)	REST ENERGY M_2 (KEV)	REST ENERGY M_3 (KEV)	REST ENERGY M_4 (KEV)	Q (KEV)
$C^{14}(D,N)N^{15*}$	500-3500	10	2	1875506	13040128	939512	13973415	+2707
$N^{14}(D,N)O^{15}$	500-3500	10	2	1875506	13039461	939512	13970388	+5067
$N^{14}(D,N)O^{15*}$	500-3500	10	2	1875506	13039461	939512	13975583	-128
$N^{15}(D,N)O^{16}$	500-3500	10	2	1875506	13968139	939512	14894232	+9901
$N^{15}(D,N)O^{16*}$	500-3500	10	2	1875506	13968139	939512	14900288	+3845
$SC^{45}(P,N)TI^{45}$	2906-3006	1	5	938219	41863055	939512	41864602	-2840
$V^{51}(P,N)CR^{51}$	1565-1665	1	5	938219	47439557	939512	47439798	-1534
$CU^{65}(P,N)ZN^{65}$	2164-2264	1	5	938219	60461583	939512	60462420	-2130

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2) L.A.König, J.H.E.Mattauch, A.H.Wapstra, Nucl.Phys. 31, 18 (1962).

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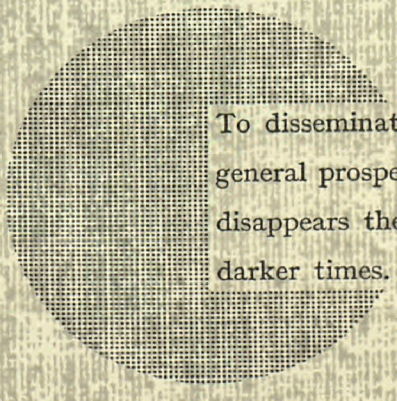

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Alfred Nobel

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