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Neutron Physics Division

DEFENSE NUCLEAR AGENCY WORKING CROSS SECTION LIBRARY: DESCRIPTION AND CONTENTS

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OAK RIDGE NATIONAL LABORATORY

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NUCLEAR DIVISION

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June 27, 1974

RADIATION SHIELDING INFORMATION CENTER
TELEPHONE: 615 - 483-8611, EXT. 3-6944

TO: Distribution

SUBJECT: Update of ORNL-RSIC-34, "The Defense Nuclear Agency Working Cross Section Library: Description and Contents."

The purpose of this memo is to update ORNL-RSIC-34 to define the status of the DNA Library as of May 6, 1974.

The evaluated data in the DNA Working Cross Section Library are subject to revision whenever, in the evaluator's opinion, new information warrants such a change. Many changes have been made to the library since ORNL-RSIC-34 was first distributed and subsequently revised in February 1973. Each change was reported in the monthly RSIC Newsletter. Users of the DNA Library are urged to keep aware of these modifications.

The material enclosed should be used to update your copy of ORNL-RSIC-34. Since the changes are rather extensive, we are providing a complete set of pages which should be used to replace entirely the contents of the existing version of ORNL-RSIC-34.

You will note that information is given in Section 3, "History of the Modifications to the DNA Working Cross Section Library," which relates the particular MAT and MOD numbers for evaluations which were submitted for inclusion in ENDF/B-IV. Also note that a Section 6 has been added which lists reports documenting some of the evaluation work for the DNA materials.

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DEFENSE NUCLEAR AGENCY WORKING CROSS SECTION LIBRARY: DESCRIPTION AND CONTENTS

1. INTRODUCTION

The Radiation Shielding Information Center (RSIC) serves as a repository for the Defense Nuclear Agency (DNA) cross-section library. This is a working library in ENDF[1] format whose content can be modified and revised whenever the evaluator deems such changes to be necessary. The key to this approach is a selected evaluator, the person responsible for making the original evaluation for a particular element or elements. He is then responsible for authorizing changes in evaluations for those elements. The evaluated data are for those materials of interest to DNA, whose cross-section values are in a state of rapid flux, and emphasis is placed on neutron energies up to 20 MeV and on secondary gamma-ray production. Evaluations of interest to DNA which are not in a state of rapid change are found in the ENDF/B library, which is available from the National Neutron Cross Section Center at Brookhaven National Laboratory.

The clearinghouse for the program is RSIC. Initial versions of evaluations are received, processed through checking codes to eliminate obvious format errors, and modified as necessary in collaboration with the evaluator. Next, DNA Phase I data testing is performed whereby selected reviewers will be provided with listings, output from checking codes, graphics, etc., and asked to review the data and feed back their comments. These will be relayed to the evaluator and, upon his instruction, appropriate changes will be made.

The data, along with available documentation, are distributed upon request. The users are asked to feed back any comments they have through using the data.

The official DNA library will be maintained at RSIC. Changes to it will be initiated only by the evaluator and each change will be documented so that users can, at any time refer to an identifiable data set when reporting results of their calculations.

Because the data are apt to be revised with some frequency, each evaluation is designated by a DNA MAT number and a MOD number. The DNA MAT number is a unique identification number for an evaluation and is equal to ENDF MAT number plus three thousand for those evaluations which are submitted for inclusion in the ENDF/B library. The MOD number designates the number of times the DNA evaluation has been modified since its initial availability through RSIC.

The current contents of the library are given in Table 1. The format used for designating the MOD number for DNA evaluations is described in Section 2. A history of the modifications to the evaluations is summarized in Section 3. Section 4 contains the listings of file 1 information on the tapes. This is the Evaluator's description of his effort and much useful information can be found therein.

Table 1.

Material	Evaluators	DNA MAT	MOD	Date of MOD
Nitrogen	Young, Foster - LASL	4133	3	2-72
Oxygen	Young, Foster - LASL	4134	1	2-72
Aluminum	Foster, Young - LASL	4135	2	2-72
Lead	Fu, Perey - ORNL	4136	2	4-72
Hydrogen	Stewart, LaBauve, Young - LASL	4148	1	2-72
Silicon	Drake, Kinsey - BNL	4151	1	2-72
Calcium	Fu, Perey - ORNL	4152	2	5-72
Beryllium	Howerton, Perkins - LLL	4154	0	2-72
Sodium	Paik, Pitterle, Perey - WARD, ORNL	4156	0	2-72
Tantalum	Howerton, Perkins, MacGregor - LLL	4179	0	2-72
Iron	Penny, Kinney, Wright, Perey, Fu - ORNL	4180	0	3-72
U-238	Howerton, MacGregor - LLL	4187	0	7-72
U-235	Howerton, MacGregor - LLL	4188	0	7-72

1. M. K. Drake, Editor, "Data Formats and Procedures for the ENDF Neutron Cross Section Library," BNL-50274 (ENDF-102, Vol. I), October 1970, and D. J. Dudziak, Compiler, "ENDF Formats and Procedures for Photon Production and Interaction Data," LA-4549 (ENDF-102, Vol. II), July 1971.

2. FORMAT FOR DESIGNATION OF MOD NUMBER FOR DEFENSE NUCLEAR AGENCY EVALUATION

The data formats and procedures to be used for the DNA Working Cross Section Library are essentially the same as those used for the ENDF/B. All processing codes, such as CHECKER[2], SUPERTOG[3], AMPX[4], will be able to read the data tape regardless of whether the tape is a DNA or ENDF/B data type. The only difference between the two tapes is a flag in the HEAD record of the first section, MT = 451, in File 1. Also the first part of the Hollerith information (first two BCD card image records) will have an artificial structure.

This structure allows the specification of the DNA MOD number in a particular format. Thus, a computer code operating on a DNA evaluation can read the MOD number and use that information to identify more precisely the cross section data being processed.

The modified structure is an adaptation of a format allowed for ENDF/A data which is described in Appendix H of "Data Formats and Procedures for the ENDF Neutron Cross Section Library," BNL 50274, ENDF-102, Vol. 1, Edited by M. K. Drake.

The structure is as follows:

[MAT, 1, 451/ZA, AWR, LRP, LFI, NTY, NXC] HEAD
[MAT, 1, 451/0.0, 0.0, LDD, LFP, NWD, 0/
AID, ALAB, DATE1, AUTH
REF, DATE2, MOD, DATE3, /H(N)] LIST
[MAT, 1, 451/0.0, 0.0, MF_1, MT_1, NC_1, 0] CØNT

[MAT, 1, 451/0.0, 0.0, MF_{NXC}, MT_{NXC}, NC_{NXC}, 0] CØNT
[MAT, 1, 0/0.0, 0.0, 0, 0, 0, 0] SEND

where

NTY is flag to indicate the type of data tape.

If NTY = 0 or blank - ENDF/B tape.

= 6 - DNA tape,

The first part of the Hollerith information (first two BCD card image records) has the structure:

Field	Cols.	Name	Description
		(First Card)	
1	2-11	AID	Material name (left adjusted)
2	12-22	ALAB	Originating Laboratory (left adjusted)
3	23-33	DATE1	Date of evaluation (left adjusted)
4	34-66	AUTH	Author of evaluation (left adjusted)
		(Second card)	
1	2-22	REF	Reference (left adjusted)
2	23-33	DATE2	Original distribution date (left adjusted)
3	34-39	MOD	Latest modification number (format is 3X,I2)
4	40-44	DATE3	Date of latest modification (left adjusted)

NWD has the same meaning as an ENDF/B tape, i.e., NWD is the count of the number of elements in the Hollerith section (for the BCD card image tapes.) NWD is the number of card images used to describe the data set of this material. NWD includes the count of the first two BCD card images.

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2. Odelli Ozer, Editor, "Description of the ENDF/B Processing Codes and Retrieval Subroutines," BNL 50300 (ENDF-110). Revised June 1971.

3. R. Q. Wright, N. M. Greene, Jr., J. L. Lucius, and C. W. Craven, Jr., "SUPERTOG: A Program to Generate Fine Group Constants and P_n Scattering Matrices for ENDF/B," ORNL-TM-2679, September, 1969.

4. N. M. Greene et al., "AMPX: Multigroup Coupled Neutron-Gamma Cross-Section Generator," Neutron Physics Division Annual Progress Report for Period Ending May 31, 1972, ORNL-4800.

3. HISTORY OF THE MODIFICATIONS TO THE DNA LIBRARY

A brief history of the modifications made to DNA evaluations is given below.

1. Nitrogen - MAT 4133
   a. MOD 0* - February 1971

   b. MOD 1 - April 1971
      Minor clerical errors were corrected, elastic scattering Legendre coefficients were adjusted to agree with Wick's limit, normalization errors were corrected for the (n,2n) reaction, and some capture gamma ray energies were corrected.

   c. MOD 2 - July 1971
      Minor clerical errors were corrected and information to designate the decay mode of inelastic levels was added to file 3.

   d. MOD 3 - February 1972
      Modification consisted of using the ENDF/B III version** of nitrogen (MAT 1133), as the current DNA version. In addition RSIC added ENDF/B file 23 photon interaction data to the evaluation, using the RSIC data library DLC-7D.

2. Oxygen - MAT 4134
   a. MOD 0 - September 1971

   b. MOD 1 - February 1972
      Modified to be the same as ENDF/B-III oxygen (MAT 1134). Also, file 23 data added from DLC-7D.

3. Aluminum - MAT 4135
   a. MOD 0 - July 1971

   b. MOD 1 - July 1971
      Information was added to designate the decay mode of inelastic levels and the threshold energy for the (n,n'p) reaction was corrected.

   c. MOD 2 - February 1972
      Modified to conform to ENDF/B-III aluminum (MAT 1135). Also, file 23 data added from DLC-7D.

4. Lead - MAT 4136
   a. MOD 0 - September 1971

   b. MOD 1 - February 1972
      Modified to conform to ENDF/B-III lead (MAT 1136).

c. MOD 2 - April 1972
The capture cross section from 1 keV to 1 MeV was reevaluated based on recent measurements by B. J. Allen et al., of ORNL. Corresponding changes have been made in the elastic and non-elastic scattering cross sections.

5. Hydrogen - MAT 4148
a. MOD 0 - February 1971

b. MOD 1 - February 1972
Modified to conform to ENDF/B-III hydrogen (MAT 1148) and file 23 data added from DLC-7D.

6. Silicon - MAT 4151
a. MOD 0 - September 1971

b. MOD 1 - February 1972
Modified to conform to ENDF/B-III silicon (MAT 1151) and file 23 data added from DLC-7D.

7. Calcium - MAT 4152
a. MOD 0 - September 1971

b. MOD 1 - February 1972
Modified to conform to ENDF/B-III calcium (MAT 1152).

c. MOD 2 - May 1972
The lower limit of the energy range was extended from 0.001 to 0.00001 eV. File 3 cross sections for (n,n'), (n,p), (n,α), (n,n'p) and (n,n'α) were reevaluated above 9 MeV. The file 5 energy distributions of secondary neutrons were reevaluated. In file 12, gamma-ray production multiplicities for (n,α), (n,n'), (n,p) and (n,α), which were previously combined, are now given separately. Also, multiplicities are now given for (n,n'p) and (n,n'α).

8. Beryllium-9 - MAT 4154

MOD 0 - February 1972. Note that this is the same as ENDF/B-III beryllium-9 (MAT 1154)

9. Sodium - MAT 4156

MOD 0 - February 1972. Note that this is the same as ENDF/B-III sodium (MAT 1156).

10. Tantalum-181 - MAT 4179

MOD 0 - February 1972. Note that this is <u>not</u> in ENDF/B-III. It became available after Version III was released.

11. Iron - MAT 4180

MOD 0 - March 1972. Note that this is the same as ENDF/B-III iron (MAT 1180). Note also that this supersedes DNA MAT 4124 iron, which has the following history.

a. MOD 0 - September 1970

b. MOD 1 - September 1971
Multilevel Breit-Wigner resonance parameters used for the energy range 1 to 60 keV, direct interaction reactions for inelastic scatter were corrected, and the number of energy points and angular distributions were reduced.

c. MOD 2 - December 1971. Note that this is essentially the same as DNA MAT 4180 MOD 0.
The minimum in the total cross section at 24 keV was reduced to 425 mb and the gamma-ray production data were made consistent with the data of Hoot and Orphan, GRT.

12. Uranium-238 - MAT 4187

MOD 0 - July 1972

13. Uranium-235 - MAT 4188

MOD 0 - July 1972

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* MOD 0 denotes the original version maintained by RSIC

**DNA evaluations were submitted to NNCSC and accepted by CSEWG for ENDF/B-III. However, NNCSC made minor adjustments to the data to conform to their special needs. For consistency, the corresponding DNA evaluations were modified to be the same as in ENDF/B-III.

4. ACKNOWLEDGEMENTS

The Defense Nuclear Agency Working Cross Section Library resulted from concepts developed by Captain Dean C. Kaul of the Defense Nuclear Agency. We are grateful for his support of the RSIC work associated with the DNA library. We acknowledge the help and cooperation of the cross section evaluators at various installations in reviewing the contents of the data.

Our sincere appreciation is extended to Mrs. Juanita B. Wright of the RSIC staff for her continuing efforts in all phases of checking, updating, and maintaining the library.

5. LISTINGS OF FILE 1 OF THE DNA LIBRARY TAPES

There follows the listings of file 1 from each tape in the DNA Working Cross Section Library. The evaluation effort is summarized therein. Much useful information is given.

TAPE NUMBEF = 1

NITROGEN-14 MOD 3 FEB. 1972 YOUNG, FOSTER, JR.

```
     N-14        LASL       EVAL-JAN71 P.G.YOUNG AND D.G.FOSTER,JR
MATERIAL= 4133   ZA=  7014.   AWR =  13.8830      FILE=  1   SECTION= 451

                          DIST-FEB71 MOD 3-FEB72

*****************   DNA 4133 MOD 3   ***************************

          THIS MODIFICATION WAS MADE TO ENABLE THE CURRENT
          DNA LIBRARY TO CONFORM TO THE ENDF/B-III LIBRARY
          AND TO ADD PHOTON INTERACTION DATA

          THE DATA CORRESPONDS TO THE ENDF/B-III EVALUATION
          WITH THE MAT NUMBER HAVING THE SAME LAST 3 DIGITS.

          FILE 23 DATA - PHOTON INTERACTION - TAKEN FROM RSIC
          DATA LIBRARY (DLC-7 D) IS BASED ON DATA FROM
          UCRL-50174 SEC. II, REV. 1969 BY MCMASTER ET AL.
          AND UCRL-50400, VOL. VI BY PLECHATY AND TERRALL.

*****************************************************************


*********       MAT=4133  NITROGEN MOD.2 7-30-71      *********

 MF=1              ONE ERROR IN THE BIBLIOGRAPHY WAS CORRECTED.

 MF=2              EH CHANGED FROM 1.0E+30 TO 1.0E+03.
 MF=3,MT=60-82     MODIFIED TO INCLUDE INFORMATION DESIGNATING
                   DECAY OF THE INELASTIC LEVELS BY PROTON OR
                   ALPHA EMISSION, AS PROVIDED FOR AT THE LAST
                   CSEWG MEETING.

 MF=4,MT=2,51-62   HAVE BEEN THINNED SOMEWHAT.

*********       MAT=4133  NITROGEN MOD.1  4-6-71      *********

  MF = 1      SEVERAL CORRECTIONS AND ADDITIONS WERE MADE.

   MT = 3     TWO MINOR CLERICAL ERRORS IN MT=700 WHICH
              PROPOGATED INTO MT=103, 3, AND 2 WERE CORRECTED.

   MT = 4     THE ELASTIC LEGENDRE COEFFICIENTS (MT=2)
              ABOVE ABOUT 13 MEV WERE ADJUSTED SOMEWHAT
        TO PRODUCE AGREEMENT WITH WICKS LIMIT.  IN ADDITION,
              AN ERROR IN THE NORMALIZATION OF THE FIRST
              (N,2N) ANGULAR DISTRIBUTION (MT=16) WAS
              CORRECTED.

   MT = 5     THE ORIGINAL (N,2N) ENERGY DISTRIBUTION
              (MT=16) WERE ERRONEOUSLY GIVEN IN UNITS OF
              MEV-1, THESE WERE REDUCED BY A FACTOR OF
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     N-14        LASL      EVAL-JAN71 P.G.YOUNG AND D.G.FOSTER,JR
MATERIAL= 4133   ZA=  7014.   AWR =  13.8830      FILE=  1   SECTION= 451

                 10E+6 TO GIVE THE RESULTS IN EV-1.

       MT = 12   SOME OF THE CAPTURE (MT=102) GAMMA-RAY ENERGIES
                 WERE ORIGINALLY IN ERROR BY AS MUCH 7 PER CENT,
                 THESE WERE CORRECTED.

    ************************************************************

     *         *         *         *         *         *         *
    N-14 FREE ATOM   EVAL. JAN.1971   P.G.YOUNG,D.G.FOSTER,JR.   (LASL)
    MF=2 ---- RESONANCE PARAMETERS -----
      MT=151  EFFECTIVE SCATTERING RADIUS = 0.89014E-12 CM
    MF=3 ----- SMOOTH CROSS SECTIONS -----
        THE 2200 M/S CROSS SECTIONS ARE AS FOLLOWS,
            MT=1    SIGMA=11.851 BARNS
            MT=2    SIGMA= 9.957 BARNS
            MT=3    SIGMA= 1.894 BARNS
            MT=102  SIGMA= 0.075 BARNS
            MT=103  SIGMA= 1.819 BARNS
      MT=1   TOTAL CROSS SECTION
        ZERO TO 1 EV, SIGT = 9.957+0.3013/SQRT(E) BARNS, FROM ABSORP-
            TION OF 1.894 B AT 2200 M/S AND ME49 DATA ABOVE 1 EV.
         1  EV TO 10 KEV, FROM DATA OF ME49.
        10 KEV TO .5 MEV, FROM HI52, BI59, HU61, AND BI62 WITH ENERGY
            SCALES ADJUSTED TO MATCH, NORMALIZED SEPARATELY TO JOIN
            TIME-OF-FLIGHT DATA SMOOTHLY AT 0.5 MEV.
        .5 MEV TO 20 MEV, FROM CA70, HE70, AND FO71 USING CA70 ALONE
            AT SHARP RESONANCES.
        SMOOTHED BY APPROPRIATE FITS. LOG-LOG INTERPOLATION IS GOOD TO
            1.3 PCT TO 0.4 MEV, LINEAR INTERPOLATION IS GOOD TO 0.5
            PCT FROM 0.4 TO 20 MEV. ABSOLUTE ERROR LESS THAN 1 PCT
            ABOVE 0.75 MEV, MAY RISE TO 5 PCT IN EV REGION.
      MT=2   ELASTIC SCATTERING CROSS SECTION
        ZERO TO 10 MEV, SUBTRACTED EVALUATED NON-ELASTIC FROM THE
            EVALUATED TOTAL, ALTHOUGH DIRECT ELASTIC MEASUREMENTS OF
            FO55,FO66,BO57,CH61,BA67,PH61,NE70 WERE CONSIDERED.
        10 TO 12 MEV, TRANSITION REGION.
        12 TO 20 MEV, BASED UPON DATA OF CH61,BA67,NE70,BA63,BO68.
      MT= 4  SUM OF MT=51-82 CROSS SECTIONS.
      MT=16  (N,2N) CROSS SECTION
        BASED UPON DATA OF FE60,BR61,BO65,PR60, ESTIMATE +-30 PCT ERR.
      MT=51-62 INELASTIC CROSS SECTION TO DISCRETE STATES
            MT=51 Q=-2.313 MEV  MT=55 Q=-5.691 MEV  MT=59 Q=-7.028 MEV
               52   -3.945         56   -5.834         60   -7.966
               53   -4.913         57   -6.198         61   -8.061
               54   -5.106         58   -6.444         62   -8.489
        THRESHOLD TO 15 MEV, FROM (N,NG) DATA OF DI69,OR69,CL69,BU69,
            NY69,CO68.
        ABOVE 15 MEV, SMOOTH E.TRAPOLATIONS.
      MT=63-82 INELASTIC CROSS SECTION TO GROUPS OF DISCRETE STATES IN
```

BANDS CENTERED ABOUT THE Q-VALUES THAT ARE GIVEN.

MT=63	Q=- 9.25 MEV	MT=70	Q=-12.75 MEV	MT=77	Q=-16.25 MEV
64	- 9.75	71	-13.25	78	-16.75
65	-10.25	72	-13.75	79	-17.25
66	-10.75	73	-14.25	80	-17.75
67	-11.25	74	-14.75	81	-18.25
68	-11.75	75	-15.25	82	-18.75
69	-12.25	76	-15.75		

THE INTEGRATED CROSS SECTION OVER THESE BANDS WAS ADJUSTED SUCH THAT THE DIFFERENCE BETWEEN THE TOTAL AND NON-ELASTIC CROSS SECTIONS AGREED WITH ELASTIC DATA (SEE MT=2). THE DIVISION OF THE CROSS SECTION AMONG THE BANDS IS BASED ON HAUSER-FESHBACH AND NUCLEAR TEMPERATURE CALCULATIONS.

****PLEASE NOTE THAT MOST OF THE CROSS SECTION TO THESE BANDS
****SUBSEQUENTLY RESULTS IN PROTON EMISSION. SINCE THESE DATA
****ARE NOT INCLUDED E.PLICITLY AS (N,NP) REACTIONS, IT IS
****IMPORTANT THAT THE USER INVOLVED IN CERTAIN CALCULATIONS
****(E.G., LOCAL HEATING) BE AWARE OF THIS INFORMATION.

MT=102 (N,GAMMA) CROSS SECTION
ZERO TO 0.25 MEV, 1/V FROM 75 MB (+-10PCT) AT THERMAL (JU63).
.25 TO 1 MEV, TRANSITION REGION.
1 TO 20 MEV, DEDUCED FROM N14(P,G)O15 DATA OF KU70,ASSUMING CHARGE INDEPENDENCE. ENERGY SCALE ADJUSTED TO MATCH FOOT-HILLS OF (P,G) GIANT RESONANCE TO RESONANCE CLUSTERS OB-SERVED IN N15 COMPOUND NUCLEUS.

MT=103 SUM OF MT=700-704 CROSS SECTIONS.
MT=104 SUM OF MT=720-723 CROSS SECTIONS.
MT=105 SUM OF MT=740-741 CROSS SECTIONS.
MT=107 SUM OF MT=780-790 CROSS SECTIONS.
MT=108 (N,2ALPHA) CROSS SECTION.
BASED ON LI52,MO67 AND HAUSER-FESHBACH CALCULATION.

MT=700 (N,P) CROSS SECTION TO C14 GROUND STATE.
ZERO TO 4 MEV, FROM DATA OF JO50 AND GA59.
4 TO 13 MEV, FROM INVERSE REACTION DATA OF WO67.
13 TO 20 MEV, SMOOTH E.TRAPOLATION.

MT=701-704 (N,P) CROSS SECTIONS TO C14 E.CITED STATES.

MT=701	Q=-5.468 MEV	E.=6.095 MEV (6.58,6.89 MEV LEVEL E.CITATION CROSS SECTIONS ARE ALSO INCLUDED)
MT=702	Q=-6.102 MEV	E.=6.728 MEV
703	-6.385	7.012
704	-6.711	7.337

THRES.TO 15 MEV, FROM (N,PG) DATA OF OR69,DI69,CL69,BU69,NY69.
15 TO 20 MEV, SMOOTH E.TRAPOLATIONS.

MT=720 (N,D) CROSS SECTION TO C13 GROUND STATE.
THRES.TO 15 MEV, FROM INVERSE CROSS SECTION DATA OF CH61,BE63 NEAR THRES.AND DIRECT DATA OF MI68,FE67,CA57,ZA63 AT 14MEV
15 TO 20 MEV, SMOOTH E.TRAPOLATIONS.

MT=721-723 (N,D) CROSS SECTION TO E.CITED C13 LEVELS
MT=721 Q=-8.411 MEV E.=3.086 MEV

```
            722    -9.009          3.684
            723    -9.179          3.854
      THRES.TO 15 MEV, DIRECT DATA OF FE67,ZA63,CA57 AND (N,DG) DATA
          OF OR69 AND DI69 BELOW 13 MEV.
      15 TO 20 MEV, SMOOTH E.TRAPOLATIONS.
    MT=740-741 (N,T) CROSS SECTIONS TO C12 GROUND AND 4.439 MEV E.-
          CITED STATE.
      THRES.TO 15 MEV, DIRECT DATA OF GA59,SC66,RE67,FE67.
       15 TO 20 MEV, SMOOTH E.TRAPOLATIONS.
    MT=780-790  (N,ALPHA) CROSS SECTION TO DISCRETE B11 STATES.
          MT=780  Q=-0.157 MEV  E.=0.000 MEV
            781    -2.282          2.124
            782    -4.602          4.444
            783    -5.176          5.019
            784    -6.900          6.743
            785    -6.950          6.793
            786    -7.453          7.296
            787    -8.153          7.996
            788    -8.723          8.566
            789    -9.082          8.925
            790    -9.342          9.185
      THRES.TO 6 MEV, FROM DIRECT DATA OF JO50,GA59,SC66.
      6 TO 15 MEV, USED ABOVE DIRECT DATA, TOGETHER WITH (N,AG) DATA
          OF HA59,DI69,OR69,NY69,BU69. NEAR 14 MEV, DIRECT (N,A)
          DATA OF LI52,BA68,LE68,MA68 WERE ALSO USED.
      15 TO 20 MEV, SMOOTH E.TRAPOLATIONS.
  MF=4 ----- SECONDARY NEUTRON ANGULAR DISTRIBUTIONS -----
    MT=2  ELASTIC ANGULAR DISTRIBUTIONS
      ZERO TO 8 MEV, BASED UPON RESONANCE THEORY ANALYSIS OF DATA OF
          FO55,FO66,BO57,CH61,BA67, USING PARAMETERS FROM TOTAL AND
          PARTIAL CROSS SECTION ANALYSES AND AJ70.
      8 TO 15 MEV, BASED UPON DATA OF CH61,BA67,NE70,BA63
      15 TO 20 MEV,BASED UPON OPTICAL MODEL CALCULATION.
    MT=16  ANGULAR DISTRIBUTION  FOR (N,2N) REACTION
      IN THE ABSENCE OF DATA, ISOTROPY IN THE CM SYSTEM IS ASSUMED,
          AND THE CORRESPONDING 3-BODY PHASE-SPACE TRANSFORMED TO
          THE LAB SYSTEM IS GIVEN. FOR ANY REASONABLE CM DISTRIBU-
          TION THE STRONG FORWARD PEAKING OF THE TRANSFORMATION
          WILL DOMINATE. NORMALIZED FOR TRAPEZOIDAL INTEGRATION.
    MT=51 TO 62  ANGULAR DISTRIBUTIONS FOR INELASTIC SCATTERING
      ABOVE 7 MEV TAKEN FROM PROTON DATA OF DO64, HA70, AND OD60
          ASSUMING CHARGE SYMMETRY, AND NEUTRON DATA OF BA63.
          THRESHOLD SHAPES MODELED AFTER HAUSER-FESHBACH CALCS.
    MT=63-82  ANGULAR DISTRIBUTIONS FOR INELASTIC SCATTERING.
      ASSUMED ISOTROPIC IN CM AT ALL ENERGIES.
  MF=5 ----- ENERGY DISTRIBUTION OF SECONDARY NEUTRONS -----
    MT=16  SPECTRUM OF (N,2N) SECONDARY NEUTRONS
      IN THE ABSENCE OF DATA, ONLY THE 3-BODY PHASE-SPACE DISTRIBU-
          TION IS GIVEN. NORMALIZED FOR TRAPEZOIDAL INTEGRATION.
  MF=12 ----- PHOTON MULTIPLICITIES -----
```

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     N-14        LASL       EVAL-JAN71 P.G.YOUNG AND D.G.FOSTER,JR
MATERIAL= 4133   ZA=  7014.   AWR =  13.8830      FILE=  1   SECTION= 451

      MT=102  (N,GAMMA) MULTIPLICITIES
        ZERO TO 0.25 MEV, THERMAL SPECTRUM BASED PRIMARILY UPON MEA-
            SUREMENTS OF TH67,JO69,GR68, AND MO62.
        .25 TO 1 MEV, TRANSITION REGION WHERE THERMAL SPECTRUM IS
            PHASED INTO SINGLE GROUND-STATE TRANSITION.
        1 TO 20 MEV, DEDUCED FROM N14(P,G)O15 DATA OF KU70,WHO OB-
            SERVED NO SIGNIFICANT TRANSITIONS E.CEPT TO GROUND STATE.
            ENERGY VARIATION OF THIS SINGLE PHOTON IS APPRO.IMATED BY
            PHASING IN AND OUT FICTITIOUS PHOTONS CORRESPONDING TO
            NEUTRONS OF 0.4, 1.0, 2.5, 4.6, 10, 15, AND 20 MEV.
    MF=13 ----- PHOTON-PRODUCTION CROSS SECTIONS -----
        ALL (N,.G) CROSS SECTIONS AGREE WITH THE E.CITATION CROSS
            SECTIONS IN MF=3 VIA THE RELEVANT DECAY SCHEME (AJ68,AJ70)
            HOWEVER, MT=104,105 INCLUDE CONTRIBUTIONS FROM (N,NPG) AND
            (N,NDG).
      MT=4  (N,NG) CROSS SECTION
        FROM DATA OF HA59,DI69,OR69,CL69,BU69,NY69,CO68.
      MT=103  (N,PG) CROSS SECTION
        FROM DATA OF DI69,OR69,BU69,NY69,CL69.
      MT=104  (N,DG)+(N,NPG) CROSS SECTION
        FROM DATA OF DI69,OR69,BU69,NY69,CL69.
      MT=105  (N,TG)+(N,NDG) CROSS SECTION
        (N,TG) ESTIMATED FROM (N,T) AS DISCUSSED UNDER MF=3,MT=741.
            (N,NDG) ESTIMATED FROM MT=63-82.
      MT=107  (N,AG) CROSS SECTION
        FROM (N,A) DATA OF GA59,SC66 AND (N,AG) DATA OF HA59,DI69,
            NY69,OR69,BU69.
    MF=14 ----- PHOTON ANGULAR DISTRIBUTIONS -----
      DATA ON 9 STRONGEST LINES FROM INELASTIC SCATT. AND PARTICLE
        REACTIONS TAKEN FROM MO64.
      MT=  4  INEL. SCATT. TO N14,  1.63 AND 4.91 MEV ANISOTROPIC
      MT=102  (N,GAMMA) ANGULAR DISTRIBUTIONS
        ZERO TO 0.4 MEV, ALL PHOTONS ARE ISOTROPIC.
        .4 TO 20 MEV, ANISOTROPIC DISTRIBUTION FOR THE SINGLE GROUND
            STATE TRANSITION IS BASED UPON N14(P,GO)O15 DATA BY KU70.
      MT=103          (N,P) TO C14,  ALL ISOTROPIC
      MT=104  (N,NP)+(N,D) TO C13,  3.85 MEV ANISOTROPIC
      MT=105  (N,ND)+(N,T) TO C12,  ALL ISOTROPIC
      MT=107      (N,ALPHA) TO B11,  ALL ISOTROPIC
         ----- REFERENCES -----
    AJ68  F.AJZENBERG-SELOVE+T.LAURITSEN (HAV), NUCL.PHYS.A114,1(1968)
    AJ70  F.AJZENBERG-SELOVE (PEN), NUCL.PHYS.A152,1 (1970)
    BA63  R.W.BAUER ET AL.(LRL), NUCL. PHYS. 47, 241 (1963)
    BA67  R.W.BAUER ET AL.(LRL), NUCL.PHYS.A93, 673 (1967).
    BA68  R.BACHINGER+M.UHL (IRK), NUCL.PHYS.A116, 673 (1968).
    BE63  R.E.BENENSON+R.YARAMIS (COL), PHYS.REV.129, 720 (1963).
    BI59  E.G.BILPUCH ET AL.(DKE), PRIV. COMM. TO BNL (1959)
    BI62  E.G.BILPUCH ET AL.(DKE), PRIV. COMM. TO R.J.HOWERTON (1962)
    BO57  N.A.BOSTROM ET AL.(TNC), WADC-TR-57-446, (1957).
    BO65  M.BORMANN ET AL.(HAM), NUCL.PHYS.63, 438 (1965).
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BO68 F.BORELI ET AL.(TE.), PHYS.REV.174, 1221 (1968).
BR61 O.D.BRILL ET AL.(PUS), SOV.PHYS.-DOKL.6, 24 (1961).
BU69 P.S.BUCHANAN (TNC), PRIV.COMM., (1969).
CA57 R.R.CARLSON (LAS), PHYS.REV.107, 1094 (1957).
CA70 A.D.CARLSON, R.J.CERBONE (GGA), NUCL. SCI. ENG. 42,28,(1970)
CH61 L.F.CHASE ET AL.(LOK), AFSWC-TR-61-15, (1961).
CL69 G.CLAYEU.+G.GRENIER (FR), CEA-R-3807, (1969).
CO68 H.CONDE ET AL.(SWD), NEUT.CROSS SECT.AND TECH.CONF., WASH., D.C., P763 (1968).
DI69 J.K.DICKENS+F.G.PEREY (ORL), NUCL.SCI.ENG.36, 280 (1969).
DO64 D.F.DONOVAN ET AL.(BNL), PHYS. REV. 133, B113 (1964)
FE60 J.M.FERGUSON+W.E.THOMPSON (NRD), PHYS.REV.118, 228 (1960).
FE67 P.FESSENDEN+D.R.MA.SON (BRN), PHYS.REV.158, 948 (1967).
FO55 J.L.FOWLER+C.H.JOHNSON (ORL), PHYS.REV.98, 728 (1955).
FO66 J.L.FOWLER ET AL.(ORL), NEUT.CROSS SECT.AND TECH.CONF., WASH.,D.C., P653 (1968).
FO71 D.G.FOSTER,JR.+D.W.GLASGOW (PNL), PHYS.REV.(TO BE PUB.,1971)
GA59 F.GABBARD ET AL.(RIC), NUCL.PHYS.14,277(1959).
GR68 R.C.GREENWOOD (MTR), PHYS. LETT. 27B, 274 (1968)
HA59 H.E.HALL+T.W.BONNER (RIC), NUCL.PHYS.14, 295 (1959).
HA70 L.HANSEN (LRL), PRIVATE COMMUNICATION (1970)
HE70 H.T.HEATON ET AL.(NBS), BULL. AM. PHYS. SOC. 15, 568 (1970) AND PRIVATE COMMUNICATION FROM R.B.SCHWARTZ (1970)
HI52 J.J.HINCHEY ET AL.(MIT), PHYS. REV. 86, 483 (1952)
HU61 C.M.HUDDLESTON, F.P.MOORING (ANL), ANL-6376, P.13 (1961)
JO50 C.H.JOHNSON+H.H.BARSCHALL (WIS), PHYS.REV.80, 818 (1950).
JO69 L.JONSSON, R.HARDELL (SWD), SYMPOSIUM ON NEUTRON CAPTURE GAMMA RAYS, STUDSVIK (1969)
JU63 E.T.JURNEY, H.T.MOTZ (LAS), ANL-9797, P. 241 (1963)
KU70 H.M.KUAN ET AL.(STF), NUCL. PHYS. A151, 129 (1970)
LE68 B.LEROU. ET AL.(FR), NUCL.PHYS.A116, 196 (1968).
LI52 A.B.LILLIE (RIC), PHYS.REV.87, 716 (1952).
MA68 D.R.MA.SON ET AL.(BRN), NUCL.PHYS.A110, 609 (1968).
ME49 E.MELKONIAN (COL), PHYS. REV. 76, 1750 (1949)
MI68 D.MILJANIC ET AL.(YUG), NUCL.PHYS.A106, 401 (1968).
MO62 H.T.MOTZ ET AL.(LAS), PILE NEUTRON RESEARCH IN PHYSICS (IAEA, VIENNA, 1962), P. 225
MO64 I.L.MORGAN ET AL.(TNC), TNC NUCL.PHYS.DIV.ANN.RPT.(AUG.1964)
MO67 J.MOSNER ET AL.(GER), NUCL.PHYS.A103, 238 (1967).
NE70 D.O.NELLIS (TNC), PRIV.COMM., (1970).
NY69 K.NYBERG (SWD), PRIV.COMM.TO L.STEWART, (1969).
OD60 Y.ODA ET AL.(TOK), J. PHYS. SOC. JAPAN 15, 760 (1960)
OR69 V.J.ORPHAN ET AL. (GGA), GA-8006, (1969).
PH61 D.D.PHILLIPS (LAS), PRIV.COMM.TO R.J.HOWERTON, (1961).
PR60 J.T.PRUDHOMME ET AL.(TNC),AFSWC-TR-60-30, (1960).
RE67 D.RENDIC (YUG), NUCL.PHYS.A91, 604 (1967).
SC66 W.SCOBEL ET AL.(HAM), Z.PHYSIK 197, 124(1966).
TH67 G.E.THOMAS ET AL.(ANL), NUCL. INSTR. METH. 56, 325 (1967)
WO67 C.WONG ET AL.(LRL), PHYS.REV.160, 769 (1967).
ZA63 M.R.ZATZICK+D.R.MA.SON (BRN), PHYS.REV.129, 1728 (1963).

N-14 LASL EVAL-JAN71 P.G.YOUNG AND D.G.FOSTER,JR
MATERIAL= 4133 ZA= 7014. AWR = 13.8830 FILE= 1 SECTION= 451

FILE	SECTION	DESCRIPTION	NO OF CARDS
1	451	DESCRIPTIVE	425
2	151	RESONANCE	4
3	1	TOTAL	348
3	2	ELASTIC	346
3	3	NON-ELASTIC	344
3	4	(N,N*) TOTAL	67
3	16	(N,2N)	11
3	51	(N,N*) LEVEL	67
3	52	(N,N*) LEVEL	63
3	53	(N,N*) LEVEL	59
3	54	(N,N*) LEVEL	57
3	55	(N,N*) LEVEL	54
3	56	(N,N*) LEVEL	53
3	57	(N,N*) LEVEL	50
3	58	(N,N*) LEVEL	49
3	59	(N,N*) LEVEL	46
3	60	(N,N*) LEVEL	41
3	61	(N,N*) LEVEL	40
3	62	(N,N*) LEVEL	38
3	63	(N,N*) LEVEL	37
3	64	(N,N*) LEVEL	34
3	65	(N,N*) LEVEL	32
3	66	(N,N*) LEVEL	30
3	67	(N,N*) LEVEL	28
3	68	(N,N*) LEVEL	26
3	69	(N,N*) LEVEL	25
3	70	(N,N*) LEVEL	23
3	71	(N,N*) LEVEL	21
3	72	(N,N*) LEVEL	20
3	73	(N,N*) LEVEL	18
3	74	(N,N*) LEVEL	17
3	75	(N,N*) LEVEL	15
3	76	(N,N*) LEVEL	14
3	77	(N,N*) LEVEL	12
3	78	(N,N*) LEVEL	11
3	79	(N,N*) LEVEL	9
3	80	(N,N*) LEVEL	8
3	81	(N,N*) LEVEL	6
3	82	(N,N*) LEVEL	5
3	102	(N,GAMMA)	32
3	103	(N,P)	233
3	104	(N,D)	24
3	105	(N,T)	29
3	107	(N,ALPHA)	203
3	108	(N,2ALPHA)	16
3	251	MU BAR	108
3	252	XI	108
3	253	GAMMA	108
3	700	(N,P) LEVEL	233
3	701	(N,P) LEVEL	23

N-14 LASL EVAL-JAN71 P.G.YOUNG AND D.G.FOSTER,JR
MATERIAL= 4133 ZA= 7014. AWR = 13.8830 FILE= 1 SECTION= 451

FILE	SECTION	DESCRIPTION	NO OF CARDS
3	702	(N,P) LEVEL	21
3	703	(N,P) LEVEL	20
3	704	(N,P) LEVEL	20
3	720	(N,D) LEVEL	24
3	721	(N,D) LEVEL	16
3	722	(N,D) LEVEL	13
3	723	(N,D) LEVEL	13
3	740	(N,T) LEVEL	29
3	741	(N,T) LEVEL	14
3	780	(N,A) LEVEL	203
3	781	(N,A) LEVEL	158
3	782	(N,A) LEVEL	66
3	783	(N,A) LEVEL	56
3	784	(N,A) LEVEL	15
3	785	(N,A) LEVEL	18
3	786	(N,A) LEVEL	16
3	787	(N,A) LEVEL	13
3	788	(N,A) LEVEL	11
3	789	(N,A) LEVEL	11
3	790	(N,A) LEVEL	11
4	2	ELASTIC	695
4	16	(N,2N)	46
4	51	(N,N*) LEVEL	80
4	52	(N,N*) LEVEL	60
4	53	(N,N*) LEVEL	44
4	54	(N,N*) LEVEL	30
4	55	(N,N*) LEVEL	44
4	56	(N,N*) LEVEL	54
4	57	(N,N*) LEVEL	48
4	58	(N,N*) LEVEL	20
4	59	(N,N*) LEVEL	18
4	60	(N,N*) LEVEL	18
4	61	(N,N*) LEVEL	14
4	62	(N,N*) LEVEL	10
4	63	(N,N*) LEVEL	8
4	64	(N,N*) LEVEL	8
4	65	(N,N*) LEVEL	8
4	66	(N,N*) LEVEL	8
4	67	(N,N*) LEVEL	8
4	68	(N,N*) LEVEL	8
4	69	(N,N*) LEVEL	8
4	70	(N,N*) LEVEL	8
4	71	(N,N*) LEVEL	8
4	72	(N,N*) LEVEL	8
4	73	(N,N*) LEVEL	8
4	74	(N,N*) LEVEL	8
4	75	(N,N*) LEVEL	8
4	76	(N,N*) LEVEL	8
4	77	(N,N*) LEVEL	8
4	78	(N,N*) LEVEL	8

N-14 LASL EVAL-JAN71 P.G.YOUNG AND D.G.FOSTER,JR
MATERIAL= 4133 ZA= 7014. AWR = 13.8830 FILE= 1 SECTION= 451

FILE	SECTION	DESCRIPTION	NO OF CARDS
4	79	(N,N*) LEVEL	8
4	80	(N,N*) LEVEL	8
4	81	(N,N*) LEVEL	8
4	82	(N,N*) LEVEL	8
5	16	(N,2N)	65
7	4	(N,N*) TOTAL	4
12	102	(N,GAMMA)	204
13	4	(N,N*) TOTAL	636
13	103	(N,P)	161
13	104	(N,D)	79
13	105	(N,T)	14
13	107	(N,ALPHA)	633
14	4	(N,N*) TOTAL	32
14	102	(N,GAMMA)	119
14	103	(N,P)	1
14	104	(N,D)	13
14	105	(N,T)	1
14	107	(N,ALPHA)	1
23	501	TOTAL PHOTON	17
23	502	COHERENT	17
23	504	INCOHERENT	17
23	516	PAIR PRD TOT	9
23	602	PHOTOELECTRC	17

TAPE NUMBER = 1

OXYGEN-16 MOD 1 FEB. 1972 YOUNG, FOSTER, JR.

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O-16        LASL      EVAL-AUG71 P.G.YOUNG AND D.G.FOSTER,JR
MATERIAL= 4134   ZA=  8016.   AWR =  15.8580      FILE=  1   SECTION= 451

                        DIST-SEP71 MOD 1-FEB72

*****************   DNA 4134 MOD 1   ***************************

          THIS MODIFICATION WAS MADE TO ENABLE THE CURRENT
          DNA LIBRARY TO CONFORM TO THE ENDF/B-III LIBRARY
          AND TO ADD PHOTON INTERACTION DATA

          THE DATA CORRESPONDS TO THE ENDF/B-III EVALUATION
          WITH THE MAT NUMBER HAVING THE SAME LAST 3 DIGITS.

          FILE 23 DATA - PHOTON INTERACTION - TAKEN FROM RSIC
          DATA LIBRARY (DLC-7 D) IS BASED ON DATA FROM
          UCRL-50174 SEC. II, REV. 1969 BY MCMASTER ET AL.
          AND UCRL-50400, VOL. VI BY PLECHATY AND TERRALL.

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O-16 FREE ATOM EVAL. - AUG.1971 - P.G.YOUNG,D.G.FOSTER,JR. (LASL)
MF=2 -------- RESONANCE PARAMETERS ---------
  MT=151      EFFECTIVE SCATTERING RADIUS = 0.5429E-12 CM.
MF=3 -------- SMOOTH CROSS SECTIONS --------
    THE 2200 M/S CROSS SECTIONS ARE AS FOLLOWS,
        MT=1    SIGMA = 3.704 BARNS
        MT=2    SIGMA = 3.704 BARNS
        MT=3    SIGMA = 0.178 MILLIBARNS
        MT=102  SIGMA = 0.178 MILLIBARNS
  MT=1        TOTAL CROSS SECTION
    0.0 TO 0.1 KEV, SIGT = 3.704 + 2.83E-6/SQRT(E) BARNS, FROM
         AD49,JO48,ME49, AND JU64.
    0.1 TO 700 KEV, FIT TO CK55 NORMALIZED TO ADJACENT REGIONS.
    0.7 TO   4 MEV, FROM SC71 WITH VERY NARROW PEAKS FROM
              JO67 AND FO70.
     4  TO  12 MEV, FROM SC71 WITH INSERTS OF CI68 (NORMALIZED TO
         SC71) WHERE NEEDED TO PRESERVE STRUCTURE.
    12  TO  20 MEV, COMPOSITE OF SC71 AND CI68.
    SMOOTHED BY SLIDING POLYNOMIAL FITS BETWEEN NARROW RESONANCES
         ABOVE 0.7 MEV. LINEAR INTERPOLATION IS GOOD TO ABOUT
         1 PCT AT ALL ENERGIES. ABSOLUTE ACCURACY 1 PCT ABOVE
         0.7 MEV, RISES TO 4 PCT BELOW 442-KEV RESONANCE.
  MT=2   ELASTIC SCATTERING CROSS SECTION
    0.0 TO 20 MEV, SUBTRACTED NONELASTIC FROM TOTAL. ELASTIC DATA
        OF NE71, CH61, BA63, BE67, AND MC66 WERE USED IN
        ESTABLISHING THE NONELASTIC.
  MT=3   NONELASTIC CROSS SECTION
    0.0 TO 20 MEV, SUM OF MT=4,102,103,104,107.
  MT=4   INELASTIC CROSS SECTION
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     O-16        LASL      EVAL-AUG71 P.G.YOUNG AND D.G.FOSTER,JR
MATERIAL= 4134   ZA=  8016.   AWR =  15.8580      FILE=  1   SECTION= 451

        THRES. TO 20 MEV, SUM OF MT=51-89.
      MT=51-70    INELASTIC CROSS SECTION TO DISCRETE STATES
        MT=51 Q=-6.052 MEV   MT=58 Q=-10.354 MEV  MT=65 Q=-11.63 MEV
           52   -6.131          59   -10.952          66   -12.053
           53   -6.917          60   -11.080          67   -12.442
           54   -7.119          61   -11.096          68   -12.528
           55   -8.872          62   -11.26           69   -12.795
           56   -9.597          63   -11.44           70   -12.967
           57   -9.847          64   -11.521
        THRES. TO 20 MEV, MT=52-55,59,60 ARE BASED MAINLY ON (N,NG)
            DATA OF DI70,OR70,DR70,BU69,NY69,CL69,EN64 BELOW 15 MEV
            AND WERE E.TRAPOLATED TO 20 MEV WITH COMPOUND NUCLEUS
            REACTION THEORY CALCULATIONS. THE REMAINING MT NUMBERS
            ARE BASED ON COMPD. NUC. CALCULATIONS NORMALIZED TO GIVE
            AN MT=3 IN AGREEMENT WITH ELASTIC DATA OF BA63,BE67,MC66.
      MT=71-89    INELASTIC CROSS SECTION TO 0.3-MEV BANDS CENTERED
        ABOUT Q-VALUES GIVEN (EQUIVALENT TO CONTINUUM).
        MT=71 Q=-13.15 MEV   MT=78 Q=-15.25 MEV   MT=85 Q=-17.35 MEV
           72   -13.45          79   -15.55          86   -17.65
           73   -13.75          80   -15.85          87   -17.95
           74   -14.05          81   -16.15          88   -18.25
           75   -14.35          82   -16.45          89   -18.55
           76   -14.65          83   -16.75
           77   -14.95          84   -17.05
        THRES. TO 20 MEV, INTEGRATED CROSS SECTION ADJUSTED TO GIVE
            AN MT=3 IN AGREEMENT WITH OPTICAL MODEL CALC. USING
            PARAMETERS FROM FIT OF 14 MEV ELASTIC DATA OF BA63 AND
            TOTAL ./S. CROSS SECTION DIVIDED AMONG BANDS ACCORDING
            TO A  NUCLEAR TEMPERATURE CALCULATION USING T=2 MEV.
    ****PLEASE NOTE THAT MUCH OF THE CROSS SECTION TO LEVELS ABOVE
    ****9 MEV SUBSEQUENTLY RESULTS IN CHARGED PARTICLE EMISSION.
    ****MT=56-58,61-66,68-70,72-73,75,77-78,80,82-83,85,87,89, ARE
    ****FLAGGED AS DECAYING BY ALPHA EMISSION. THIS CHOICE LEADS TO
    ****A TOTAL ALPHA EMISSION ./S SIMILAR TO DATA OF LI52,DA68,BO66
    ****BELOW 17 MEV. THE REMAINING MT NUMBERS ABOVE MT=66 ARE
    ****FLAGGED AS BEING PROTON EMITTERS.
      MT=102 (N,GAMMA) CROSS SECTION
        1/V VARIATION FROM 178 MICROBARNS AT 2200 M/S, FROM JU64.
      MT=103 (N,P) CROSS SECTION
        THRES. TO 15 MEV, USED EVALUATED DATA OF SI65.
        15 TO 20 MEV, BASED ON E.PERIMENTAL DATA OF BO66,SE62,DE62,
            AND MA54.
      MT=104 (N,D) CROSS SECTION
        THRES. TO 20 MEV, COMPD. NUC. REACT. THEORY CALC. NORM. TO
            SINGLE DATUM POINT OF LI52 AT 14 MEV.
      MT=107 (N,ALPHA) CROSS SECTION
        THRES. TO 20 MEV, SUM OF MT=780-783.
      MT=780  (N,A) CROSS SECTION TO C13 GROUND STATE
        THRES. TO 6.3 MEV, USED EVALUATED DATA OF SI65.
        6.3 TO 20 MEV, BASED ON DATA OF DA63, DA68, SI68 AND
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          COMPOSITE OF MC66A, MA68, AND LE68 AT 14 MEV.
    MT=781-783   (N,A) CROSS SECTION TO E.CITED LEVELS OF C13.
      THRES. TO 15 MEV, USED (N,A) DATA OF DA63 AND (N,AG) DATA OF
          DI70, OR70, CL69, NY69, EN64, AND BU69.
      15 TO 20 MEV, BASED ON DATA OF SI68.
  MF=4 --- NEUTRON ANGULAR DISTRIBUTIONS ---
    MT=2   ELASTIC ANGULAR DISTRIBUTIONS
      0.0 TO 5 MEV, USED EVALUATED DATA OF SL65.
      5.0 TO 14 MEV, FROM SMOOTH CURVE THROUGH COEFFICIENTS DERIVED
          FROM FITS TO ELASTIC DATA OF PH61, NE71, CH61, BA63, BE67
          AND MC66.
      14.0 TO 20 MEV, FROM OPTICAL MODEL CALC. USING PARAMETERS
          FROM FIT OF 14 MEV DATA OF BA63, ADJUSTED TO GIVE CORRECT
          TOTAL ./S UP TO 20 MEV.
    MT=51-89  INELASTIC ANGULAR DISTRIBUTIONS
      ASSUMED ISOTROPIC IN CM.
  MF=12 ------- PHOTON MULTIPLICITIES --------
    MT=102 RADIATIVE CAPTURE, PRIVATE COMMUNICATION FROM JU64.
  MF=13 --- GAMMA RAY SMOOTH CROSS SECTIONS ---
    MT=4   (N,NG) CROSS SECTIONS
      THRES. TO 15 MEV, BASED MAINLY ON DATA OF DI70, OR70, DR70,
          BU69, NY69, CL69, EN64.
      15 TO 20 MEV, BASED ON E.TRAPOLATION OF MT=51-60 USING
          COMPOUND NUCLEUS REACTION THEORY.
  ****NOTE THAT THE FIRST E.CITED LEVEL OF C16 AT 6.052 MEV IS
  ****ASSUMED TO DECAY WITH EMISSION OF TWO 0.51 MEV GAMMA RAYS
    MT=22   (N,NAG) CROSS SECTIONS
      THRES. TO 20 MEV, SMOOTH CURVE BASED CRUDELY ON (N,NA) CROSS
          SECTION AND KNOWN LEVELS IN C12, ADJUSTED TO AGREE WITH
          COMPOSITE OF 14 MEV DATA OF CL69, OR70.
    MT=103  (N,PG) CROSS SECTIONS
      THRES. TO 20 MEV, BASED ON CRUDE DIVISION OF MF=3, MT=103 ./S
          AMONG AVAILABLE LEVELS ACCORDING TO (2*J+1).
    MT=107 (N,AG) CROSS SECTIONS
      THRES. TO 15 MEV, BASED MAINLY ON (N,AG) DATA OF DI70, OR70,
          CL69, NY69, EN64, BU69, AND (N,A) DATA OF DA63.
      15 TO 20 MEV, BASED ON DATA OF SI68.
  MF=14 --- GAMMA RAY ANGULAR DISTRIBUTIONS ---
    MT=4   (N,NG) ANGULAR DISTRIBUTIONS
      ASSUMED ISOTROPIC.
    MT=22  (N,NAG) ANGULAR DISTRIBUTIONS
      ASSUMED ISOTROPIC.
    MT=103  (N,PG) ANGULAR DISTRIBUTIONS
      ASSUMED ISOTROPIC.
    MT=107 (N,AG) ANGULAR DISTRIBUTIONS
      ASSUMED ISOTROPIC.
  ---------------------------- REFERENCES ---------------------------
  AD49   R.K.ADAIR ET AL., PHYS. REV. 75, 1124 (1949)
  BA63   R.W.BAUER ET AL., NUCL. PHYS. 47, 241 (1963)
  BE67   R.L.BEACH ET AL., PHYS. REV. 156, 1201 (1967)
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O-16 LASL EVAL-AUG71 P.G.YOUNG AND D.G.FOSTER,JR
MATERIAL= 4134 ZA= 8016. AWR = 15.8580 FILE= 1 SECTION= 451

BO66 M.BORMANN ET AL., PROC. IAEA CONF. NUCL. DATA, PARIS (1966), P.225
BU69 P.S.BUCHANAN, PRIVATE COMMUNICATION (1969)
CH61 L.F.CHASE ET AL., AFSWC-TR-61-15 (1961)
CI68 S.CIERJACKS ET AL., KFK-1000 (1968)
CL69 G.CLAYEU.+G.GRENIER, CEA-R-3807 (1969)
DA63 E.A.DAVIS ET AL., NUCL. PHYS. 48, 169 (1963)
DA68 D.DANDY ET AL., AWRE O60/68 (1968)
DE62 J.A.DEJUREN ET AL., PHYS. REV. 127, 1229 (1962)
DI70 J.K.DICKENS+F.G.PERRY, NUCL. SCI. ENG. 40, 283 (1970)
DR70 D.M.DRAKE ET AL., NUCL. SCI. ENG. 40, 294 (1970)
EN64 F.C.ENGESSER+W.E.THOMPSON, J. NUCL. ENG. 21, 487 (1967)
FO70 J.L.FOWLER AND C.H.JOHNSON, PHYS. REV. C 2, 124 (1970)
JO48 W.B.JONES,JR., PHYS. REV. 74, 364 (1948)
JO67 C.H.JOHNSON AND J.L.FOWLER, PHYS. REV. 162, 890 (1967)
JU64 E.T.JURNEY AND H.T.MOTZ, BULL.AM.PHYS.SOC. 9, 176 (1964)
LE68 B.LEROU. ET AL., NUCL. PHYS. A116, 196 (1968)
LI52 A.B.LILLIE, PHYS. REV. 87, 716 (1952)
MA54 H.C.MARTIN, PHYS. REV. 93, 498 (1954)
MA68 D.R.MA.SON + R.D.MURPHY, NUCL. PHYS. A110, 555 (1968)
MC66 W.J.MCDONALD ET AL., NUCL. PHYS. 75, 353 (1966)
MC66A W.N.MCDICKEN + W.JACK, NUCL. PHYS. 88, 457 (1966)
ME49 E.MELKONIAN, PHYS. REV. 76, 1750 (1949)
NE71 D.O.NELLIS+P.S.BUCHANAN, PRIVATE COMMUNICATION (1971)
NY69 K.NYBERG, PRIV. COMM. TO LEONA STEWART (1969)
OK55 A.OKAZAKI, PHYS. REV. 99, 55 (1955)
OR70 V.J.ORPHAN ET AL., NUCL. SCI. ENG. 42, 352 (1970)
PH61 D.D.PHILLIPS, PRIVATE COMMUNICATION TO BNL (1961)
SC71 R.B.SCHWARTZ, PRIVATE COMMUNICATION (1971)
SE62 K.W.SEEMANN+W.E.MOORE, KAPL-2214 (1962)
SI68 VON I. SICK ET AL., HELV. PHYS. ACTA 41, 573 (1968)
SL65 E.L.SLAGGIE+J.T.REYNOLDS, KAPL-M-6452 (1965)

O-16 LASL EVAL-AUG71 P.G.YOUNG AND D.G.FOSTER,JR
MATERIAL= 4134 ZA= 8016. AWR = 15.8580 FILE= 1 SECTION= 451

FILE	SECTION	DESCRIPTION	NO OF CARDS
1	451	DESCRIPTIVE	295
2	151	RESONANCE	4
3	1	TOTAL	342
3	2	ELASTIC	342
3	3	NON-ELASTIC	342
3	4	(N,N*) TOTAL	59
3	51	(N,N*) LEVEL	59
3	52	(N,N*) LEVEL	59
3	53	(N,N*) LEVEL	53
3	54	(N,N*) LEVEL	51
3	55	(N,N*) LEVEL	39
3	56	(N,N*) LEVEL	36
3	57	(N,N*) LEVEL	35
3	58	(N,N*) LEVEL	31
3	59	(N,N*) LEVEL	28
3	60	(N,N*) LEVEL	28
3	61	(N,N*) LEVEL	27
3	62	(N,N*) LEVEL	27
3	63	(N,N*) LEVEL	26
3	64	(N,N*) LEVEL	25
3	65	(N,N*) LEVEL	25
3	66	(N,N*) LEVEL	24
3	67	(N,N*) LEVEL	23
3	68	(N,N*) LEVEL	22
3	69	(N,N*) LEVEL	21
3	70	(N,N*) LEVEL	21
3	71	(N,N*) LEVEL	20
3	72	(N,N*) LEVEL	19
3	73	(N,N*) LEVEL	18
3	74	(N,N*) LEVEL	17
3	75	(N,N*) LEVEL	16
3	76	(N,N*) LEVEL	15
3	77	(N,N*) LEVEL	14
3	78	(N,N*) LEVEL	13
3	79	(N,N*) LEVEL	12
3	80	(N,N*) LEVEL	11
3	81	(N,N*) LEVEL	11
3	82	(N,N*) LEVEL	10
3	83	(N,N*) LEVEL	9
3	84	(N,N*) LEVEL	8
3	85	(N,N*) LEVEL	7
3	86	(N,N*) LEVEL	7
3	87	(N,N*) LEVEL	6
3	88	(N,N*) LEVEL	5
3	89	(N,N*) LEVEL	4
3	102	(N,GAMMA)	4
3	103	(N,P)	22
3	104	(N,D)	11
3	107	(N,ALPHA)	93
3	251	MU BAR	95

O-16 LASL EVAL-AUG71 P.G.YOUNG AND D.G.FOSTER,JR
MATERIAL= 4134 ZA= 8016. AWR = 15.8580 FILE= 1 SECTION= 451

FILE	SECTION	DESCRIPTION	NO OF CARDS
3	252	XI	95
3	253	GAMMA	95
3	780	(N,A) LEVEL	93
3	781	(N,A) LEVEL	55
3	782	(N,A) LEVEL	47
3	783	(N,A) LEVEL	46
4	2	ELASTIC	621
4	51	(N,N*) LEVEL	8
4	52	(N,N*) LEVEL	8
4	53	(N,N*) LEVEL	8
4	54	(N,N*) LEVEL	8
4	55	(N,N*) LEVEL	8
4	56	(N,N*) LEVEL	8
4	57	(N,N*) LEVEL	8
4	58	(N,N*) LEVEL	8
4	59	(N,N*) LEVEL	8
4	60	(N,N*) LEVEL	8
4	61	(N,N*) LEVEL	8
4	62	(N,N*) LEVEL	8
4	63	(N,N*) LEVEL	8
4	64	(N,N*) LEVEL	8
4	65	(N,N*) LEVEL	8
4	66	(N,N*) LEVEL	8
4	67	(N,N*) LEVEL	8
4	68	(N,N*) LEVEL	8
4	69	(N,N*) LEVEL	8
4	70	(N,N*) LEVEL	8
4	71	(N,N*) LEVEL	8
4	72	(N,N*) LEVEL	8
4	73	(N,N*) LEVEL	8
4	74	(N,N*) LEVEL	8
4	75	(N,N*) LEVEL	8
4	76	(N,N*) LEVEL	8
4	77	(N,N*) LEVEL	8
4	78	(N,N*) LEVEL	8
4	79	(N,N*) LEVEL	8
4	80	(N,N*) LEVEL	8
4	81	(N,N*) LEVEL	8
4	82	(N,N*) LEVEL	8
4	83	(N,N*) LEVEL	8
4	84	(N,N*) LEVEL	8
4	85	(N,N*) LEVEL	8
4	86	(N,N*) LEVEL	8
4	87	(N,N*) LEVEL	8
4	88	(N,N*) LEVEL	8
4	89	(N,N*) LEVEL	8
12	102	(N,GAMMA)	16
13	4	(N,N*) TOTAL	401
13	22	(N,N*)ALPHA	10
13	103	(N,P)	47

O-16 LASL EVAL-AUG71 P.G.YOUNG AND D.G.FOSTER,JR
MATERIAL= 4134 ZA= 8016. AWR = 15.8580 FILE= 1 SECTION= 451

FILE	SECTION	DESCRIPTION	NO OF CARDS
13	107	(N,ALPHA)	277
14	4	(N,N*) TOTAL	1
14	22	(N,N*)ALPHA	1
14	102	(N,GAMMA)	1
14	103	(N,P)	1
14	107	(N,ALPHA)	1
23	501	TOTAL PHOTON	17
23	502	COHERENT	17
23	504	INCOHERENT	17
23	516	PAIR PRD TOT	9
23	602	PHOTOELECTRC	17

TAPE NUMBER = 1

ALUMINUM-27 MOD 2 FEB. 1972 FOSTER, JR, YOUNG

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     AL-27       LASL       EVAL-APR71 D.G.FOSTER,JR AND P.G.YOUNG
MATERIAL= 4135   ZA= 13027.   AWR =  26.7500      FILE=  1   SECTION= 451

                          DIST-JUL71 MOD 2-FEB72

     *****************   DNA 4135 MOD 2   ***************************

              THIS MODIFICATION WAS MADE TO ENABLE THE CURRENT
              DNA LIBRARY TO CONFORM TO THE ENDF/B-III LIBRARY
              AND TO ADD PHOTON INTERACTION DATA

              THE DATA CORRESPONDS TO THE ENDF/B-III EVALUATION
              WITH THE MAT NUMBER HAVING THE SAME LAST 3 DIGITS.

              FILE 23 DATA - PHOTON INTERACTION - TAKEN FROM RSIC
              DATA LIBRARY (DLC-7 D) IS BASED ON DATA FROM
              UCRL-50174 SEC. II, REV. 1969 BY MCMASTER ET AL.
              AND UCRL-50400, VOL. VI BY PLECHATY AND TERRALL.

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     *********    MAT=4135  ALUMINUM MOD. 1  7-30-71       **********

      MF=3,MT=75-90     MODIFIED TO INCLUDE INFORMATION DESIGNATING
                        DECAY OF THE INELASTIC LEVELS BY PROTON OR
                        ALPHA EMISSION

      MF=13,MT=28       THE THRESHOLD ENERGY WAS CHANGED FROM
                        14.0E+6 TO 13.093E+6 EV

     ***************************************************************
     *         *         *         *         *         *         *
     AL-27 FREE ATOM EVAL., APR.1971, D.G.FOSTER,JR.,P.G.YOUNG (LASL)
     MF=2 --- RESONANCE PARAMETERS ---
       MT=151 EFFECTIVE SCATTERING RADIUS = 0.3468E-12 CM
     MF=3 --- NEUTRON SMOOTH CROSS SECTIONS ---
         THE 2200 M/S CROSS SECTIONS ARE AS FOLLOWS,
             MT=1     SIGMA = 1.743 BARNS
             MT=2     SIGMA = 1.511 BARNS
             MT=3     SIGMA = 0.232 BARNS
             MT=102   SIGMA = 0.232 BARNS
       MT=1   TOTAL CROSS SECTION
         ABOVE .46 MEV, TAKEN FROM CI68 NORMALIZED TO AVERAGE OF CA67,
           SC70, AND FO71. PROBABLY GOOD TO 1.5 PCT.
         BELOW .45 MEV, MAINLY FROM ME52 AND HI59, USING GA65 FOR
           SHARP STRUCTURE. GAP AT .45-.46 MEV BRIDGED WITH CH66, AND
           NORMALIZATION CONTINUED DOWNWARDS FROM MEV RANGE THROUGH
           CH66 AND HI59 TO ME52. MAY BE 5 PCT HIGH IN EV REGION.
         BELOW 1 EV, SYNTHESIZED FROM 1/V CAPTURE CROSS SECTION OF
           232 MB AT THERMAL AND SCATTERING CROSS SECTION ABOVE 1 EV.
         NARROW RESONANCES SMOOTHED BY APPRO.IMATE FITS, REMAINDER BY
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SLIDING POLYNOMIAL FIT. FLUCTUATIONS PRESERVED BELOW 3 MEV, DELIBERATELY SMOOTHED OVER ABOVE 3 MEV.

MT=2 ELASTIC SCATTERING CROSS SECTION

BELOW 5 MEV, SUBTRACTED NONELASTIC FROM TOTAL.

5 TO 16 MEV, MAINLY BASED ON ELASTIC DATA OF HO69, ST59, KI70, ST65, CO58, CO59, BE58, MI68, BE56 TOGETHER WITH THE EVAL. TOTAL AND THE NONELASTIC MEASUREMENTS LISTED BELOW.

16 TO 20 MEV, SMOOTH E.TRAPOLATION TO 1/2 THE TOTAL AT 20 MEV

MT=3 NONELASTIC CROSS SECTION

BELOW 9 MEV, BASED ON THE NONELASTIC MEASUREMENTS OF BA58, BE56, TA55, DE65, ON THE SUM OF MT=4,102,103,107, AND ON THE DIFFERENCE BETWEEN THE EVALUATED TOTAL AND THE ELASTIC MEASUREMENTS OF HO69, KI70, BE56, MI68.

9 TO 16 MEV, BASED ON NONELASTIC MEASUREMENTS OF BA58, TA55, GE55, PH52, MA57, DE61, FL56, CH67, AND ON THE DIFFERENCE BETWEEN MT=1 AND ELASTIC MEASUREMENTS OF ST59, ST65, CO58, CO59, BE58.

16 TO 20 MEV, DIFFERENCE BETWEEN MT=1 AND MT=2

MT=4 INELASTIC CROSS SECTION

THRES. TO 5 MEV, SUM OF MT=51-63.

5 TO 9 MEV, BASED ON (N,NPRIME) DATA OF TH63, TO67, THE EVAL. (N,NPRIME) DATA OF DI71 WHICH INCLUDES CONSIDERATION OF SEVERAL OTHER MEASUREMENTS, AND THE (N,NG) DATA OF DI71.

9 TO 20 MEV, THE DIFFERENCE BETWEEN MT=1 AND THE SUM OF MT=2,16,102,103,104,105,107.

MT=16 (N,2N) CROSS SECTION

THRES. TO 20 MEV, ESTIMATED USING A NUCLEAR TEMP. CALCULATION ASSUMING THAT HIGHLY E.CITED STATES IN AL-27 DECAY 50 PER CENT BY NEUTRON EMISSION.

MT=51-63 INELASTIC CROSS SECTION TO DISCRETE STATES

MT=51	Q=-0.843 MEV	MT=56	Q=-3.001 MEV	MT=60	Q=-4.409 MEV
52	-1.013	57	-3.678	61	-4.508
53	-2.210	58	-3.956	62	-4.580
54	-2.732	59	-4.055	63	-4.811
55	-2.980				

THRES. TO 5 MEV, BASED ON THE (N,NPRIME) DATA OF TO62, WI63, IS61, AND THE (N,NG) DATA OF CH68, MA65.

5 TO 9 MEV, BASED ON AN EVALUATION OF SEVERAL MEASUREMENTS GIVEN IN DI71 (TABLE B1).

9 TO 20 MEV, SMOOTH E.TRAPOLATION PASSING THROUGH 14 MEV DATA OF ST65, BO65A.

MT=64-90 INELASTIC CROSS SECTION TO GROUPS OF DISCRETE STATES IN BANDS CENTERED ABOUT THE Q-VALUES GIVEN BELOW,

MT=64	Q=- 5.25 MEV	MT=73	Q=- 9.75 MEV	MT=82	Q=-14.25 MEV
65	- 5.75	74	-10.25	83	-14.75
66	- 6.25	75	-10.75	84	-15.25
67	- 6.75	76	-11.25	85	-15.75
68	- 7.25	77	-11.75	86	-16.25
69	- 7.75	78	-12.25	87	-16.75
70	- 8.25	79	-12.75	88	-17.375

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     AL-27       LASL       EVAL-APR71 D.G.FOSTER,JR AND P.G.YOUNG
MATERIAL= 4135   ZA= 13027.   AWR =  26.7500       FILE=  1   SECTION= 451

          71   - 8.75          80   -13.25          89   -18.125
          72   - 9.25          81   -13.75          90   -18.875
        THRES. TO 20 MEV, INTEGRATED CROSS SECTION OVER BANDS
          OBTAINED BY SUBTRACTING MT=51-63 FROM MT=4. CROSS SECTION
          DIVIDED AMONG BANDS ACCORDING TO A NUCLEAR TEMPERATURE
          CALCULATION USING TEMP. BASED ON (N,NPRIME) DATA OF TH63,
          GR53.
     ****PLEASE NOTE THAT MUCH OF THE CROSS SECTION TO BANDS ABOVE E.=
     ****9 MEV SUBSEQUENTLY RESULTS IN CHARGED PARTICLE EMISSION.
     ****SINCE THESE DATA ARE NOT INCLUDED E.PLICITLY AS (N,N.) REAC-
     ****TIONS, IT IS IMPORTANT THAT USERS INVOLVED IN CERTAIN CALCU-
     ****LATIONS (E.G., LOCAL HEATING) BE AWARE OF THIS INFORMATION.
       MT=102 (N,GAMMA) CROSS SECTION
         BELOW 1 KEV, 1/V FROM THERMAL VALUE OF 232 MB (GO71).
         1 TO 140 KEV, FROM BL68. 6-KEV RESONANCE HAS WIDTH DEDUCED
           FROM TOTAL .-SECT. SMALL RESONANCES NEARBY ALSO FROM TOTAL.
         ABOVE 140 KEV, MAINLY FROM HE50, HE53, AND CA62.
       MT=103 (N,P) CROSS SECTION
         THRES. TO 5 MEV, EVALUATION OF JO64 USED.
         5 TO 20 MEV, SMOOTH CURVE THROUGH DATA OF GR67, GA62, MA60,
           FE67, BO59, AS WELL AS SEVERAL 14 MEV POINTS.
       MT=104 (N,D) CROSS SECTION
         THRES. TO 20 MEV, SMOOTH CURVE THROUGH SINGLE DATUM OF GL61.
       MT=105 (N,T) CROSS SECTION
         THRES. TO 20 MEV, SMOOTH CURVE WITH SAME SHAPE AS MT=104,
           REACHING MA.IMUM OF 15 MB AT 20 MEV.
       MT=107 (N,ALPHA) CROSS SECTION
         THRES. TO 20 MEV, SMOOTH CURVE THROUGH DATA OF GR67, SC61,
           GR58, BA61, PA65, MA60,GA62, IM64, KE59, AS WELL AS SEVERAL
           14 MEV POINTS.
     MF=4 --- NEUTRON ANGULAR DISTRIBUTIONS ---
       MT=2   ELASTIC ANGULAR DISTRIBUTIONS
         FROM SMOOTH CURVES THROUGH PLOTS OF COEFFICIENTS FROM FITS
           TO ALL AVAILABLE DATA ABOVE .25 MEV, WITHOUT EVALUATION
           OF MEASUREMENTS. MAINLY FROM LA57, CH66, TO62, TS61, KI70,
           BE58, WITH OPTICAL-MODEL BRIDGE TO ST62. SOME OF DATA
           AUGMENTED BEFORE FITTING BY ZERO-DEGREE POINT SLIGHTLY
           ABOVE WICK LIMIT, AND COEFFICIENTS ADJUSTED EMPIRICALLY
           AFTERWARDS TO OBEY WICK LIMIT, BUT ONLY BARELY AT HIGHER
           ENERGIES.
       MT=16  (N,2N) ANGULAR DISTRIBUTIONS
         ASSUMED ISOTROPIC IN CM, USING 2-BODY KINEMATICS TO ESTIMATE
           TRANSFORMATION TO LAB SYSTEM.
       MT=51-90  INELASTIC ANGULAR DISTRIBUTIONS
         ASSUMED ISOTROPIC IN CM.
     MF=5 --- NEUTRON ENERGY DISTRIBUTIONS ---
       MT=16  (N,2N) ENERGY DISTRIBUTIONS
         BASED ON STATISTICAL THEORY CALCULATION.
     MF=12 --- GAMMA RAY MULTIPLICITIES ---
       MT=102 (N,G) CAPTURE MULTIPLICITIES
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ENERGIES FROM RA70, INTENSITIES FROM BA67. BA67 DECAY SCHEME DOES NOT ACCOUNT FOR INTENSITY OF LOW-ENERGY TRANSITIONS, EVEN AFTER REVISION. LINES IN RA70 BELOW 1 MEV ARE SPURIOUS (JU71) AND HAVE BEEN DROPPED.

MF=13 --- GAMMA RAY SMOOTH CROSS SECTIONS ---

MT=4 (N,NG) CROSS SECTIONS

THRES. TO 5 MEV, CALCULATED FROM MT=51-63 IN MF=3 VIA AL-27 DECAY SCHEME.

5 TO 20 MEV, MAINLY FROM (N,NG) DATA OF DI71, DR70, PE64, BE66, CL69, EN67, BO65, MA68, CA60, PR60, SUPPLEMENTED BY STATISTICAL THEORY CALCULATION.

MT=28 (N,NPG) CROSS SECTIONS

THRES. TO 20 MEV, 1.809 MEV GAMMA BASED ON DATA OF EN67, PR60, CL69, BE66, BO65 TOGETHER WITH STAT. THEORY CALC. REMAINING LINES AND CONTINUUM BASED ONLY ON CALCULATION.

MT=103 (N,PG) CROSS SECTIONS

THRES. TO 9 MEV, USED DATA OF DI71.

9 TO 20 MEV, SMOOTH E.TRAPOLATION.

MF=14 --- GAMMA RAY ANGULAR DISTRIBUTIONS ---

MT=4 (N,NG) ANGULAR DISTRIBUTIONS

ASSUMED ISOTROPIC.

MT=28 (N,NPG) ANGULAR DISTRIBUTIONS

ASSUMED ISOTROPIC.

MT=103 (N,PG) ANGULAR DISTRIBUTIONS

ASSUMED ISOTROPIC.

MF=15 --- GAMMA RAY ENERGY DISTRIBUTIONS ---

MT=4 (N,NG) ENERGY DISTRIBUTIONS

BASED ON STATISTICAL THEORY CALCULATION.

MT=28 (N,NPG) ENERGY DISTRIBUTIONS

BASED ON STATISTICAL THEORY CALCULATION.

MT=102 (N,G) CAPTURE ENERGY DISTRIBUTIONS

FROM WEAK LINES AND CONTINUUM OF RA70.

---------- REFERENCES ----------

BA58 W.P.BALL ET AL.(LRL), PHYS.REV.110,1392 (1958).
BA61 B.P.BAYHURST+R.J.PRESTWOOD (LAS),PHYS.REV.121,1438 (1961).
BA67 G.A.BARTHOLOMEW ET AL., NUCL. DATA A3, 367 (1967)
BE55 J.R.BEYSTER ET AL.(LAS), PHYS.REV.98,1216 (1955).
BE56 J.R.BEYSTER ET AL.(LAS), PHYS.REV.104,1319 (1956).
BE58 S.BERKO ET AL., NUCL. PHYS. 6, 210 (1958)
BE66 V.M.BEZOTOSNYI ET AL.(RUS),SOV.J.NUCL.PHYS.3,632 (1966).
BL68 R.C.BLOCK, PRIVATE COMMUNICATION TO R.J.HOWERTON (1968)
BO59 N.A.BOSTROM ET AL.(TNC), WADC-TN-59-107 (1959).
BO65 V.N.BOCHKAREV+V.V.NEFEDOV (LEB),SOV.J.NUCL.PHYS.1,574(1965)
BO65A G.C.BONAZZOLA ET AL.(TUR), PHYS.REV.140,835 (1965).
CA60 R.L.CALDWELL ET AL.(SOC),NUCL.SCI.ENG.8,173 (1960).
CA62 G.CALVI ET AL., NUCL. PHYS. 39, 621 (1962)
CA67 A.D.CARLSON AND H.H.BARSCHALL, PHYS. REV. 158, 1142 (1967)
CH66 J.P.CHIEN AND A.B.SMITH, NUCL. SCI. ENG. 26, 500 (1966)
CH67 A.CHATTERJEE+A.M.GHOSE(BOS), PHYS.REV.161,1181 (1967).
CH68 K.C.CHUNG ET AL.(KTY),NUCL.PHYS.68,476 (1968).

CI68 S.CIERJACKS ET AL., KFK-1000 (1968)
CL69 G.CLAYEU.+G.GRENIER (FR),CEA-R-3807,(1969).
CO58 J.H.COON ET AL.(LAS), PHYS.REV. 111,250 (1958).
CO59 J.H.COON (LAS),PRIVATE COMMUNICATION TO R.J.HOWERTON (1959)
DE61 YU.G.DEGTYAREV+V.G.NADTOCHII (RUS), SOV.J.AT.ENERGY 11,1043 (1961).
DE65 YU.G.DEGTYAREV (RUS), J.NUCL.ENERGY 20,818 (1965).
DI71 J.K.DICKENS (ORL), ORNL-TM-3284, 1971.
DR70 D.M.DRAKE ET AL. (LAS), NUCL.SCI.ENG.40,294 (1970).
EN67 F.C.ENGESSER+W.E.THOMPSON (NRD),J.NUCL.ENERGY 21,487 (1967)
FE67 J.M.FERGUSON+J.C.ALBERGOTTI (NRD),NUCL.PHYS.98,65 (1967).
FL56 N.N.FLEROV+V.M.TALYZIN (RUS),ATOMNAYA ENERGIYA 1,155 (1956)
FO71 D.G.FOSTER JR. AND D.W.GLASGOW, PHYS. REV. C 3, 576 (1971)
GA62 F.GABBARD+B.D.KERN(KTY), PHYS.REV.128,1276 (1962).
GA65 J.B.GARG ET AL., PRIV. COMM. TO R.J.HOWERTON (1965)
GL61 R.N.GLOVER+E.WIEGOLD (CBR),NUCL.PHYS.24,630 (1961).
GO71 D.T.GOLDMAN, UNPUBLISHED EVALUATION (1971)
GR53 E.R.GRAVES+L.ROSEN(LAS),PHYS.REV.89,343 (1953).
GR55 E.R.GRAVES+R.W.DAVIS(LAS), PHYS.REV.97, 1205(1955).
GR58 J.A.GRUNDL ET AL.(LAS),PHYS.REV.109,425 (1958).
GR67 J.A.GRUNDL (LAS), NUCL.SCI.ENG.30,69 (1967).
HE50 R.L.HENKEL AND H.H.BARSCHALL, PHYS. REV. 80, 145 (1950)
HE53 R.L.HENKEL, PRIV. COMM. TO SIGMA CENTER (1953)
HI59 C.T.HIBDON, PHYS. REV. 114, 179 (1959)
HO69 B.HOLMQVIST+T.WIEDLING (AE), AE-366 (1969).
IM64 W.L.IMHOF (LOK),PRIVATE COMMUNICATION TO BNL SIGMA CENTER (1964).
JO64 G.D.JOANOU+C.A.STEVENS (GA), GA-5884 (1964).
JU71 E.T.JURNEY, PRIVATE COMMUNICATION (1971)
KE59 B.D.KERN ET AL.(NRD), NUCL.PHYS.10,226 (1959).
KI70 W.E.KINNEY+F.G.PEREY (ORL),ORNL-4516,(1970).
LA57 A.LANGSDORF ET AL., PHYS. REV. 107, 1077 (1957)
MA57 M.H.MACGREGOR ET AL.(LRL), PHYS.REV.108,726(1957).
MA60 G.S.MANI ET AL.(HAR),NUCL.PHYS.19,535 (1960).
MA65 S.C.MATHUR ET AL.(TNC),NUCL.PHYS.73,561 (1965).
MA68 G.N.MASLOV ET AL.(RUS),SOV.J.AT.ENERGY 24,704 (1968).
ME52 A.W.MERRISON AND E.R.WIBLIN, PROC.RCY.SOC.(L) 215,278(1952)
MI68 A.MITTLER ET AL.(KTY), BULL.AM.PHYS.SOC.13,1420 (1968).
PA65 A.PAULSEN+H.LISKIEN (GEL),J.NUCL.ENERGY 19,907 (1965).
PE64 J.L.PERKIN (ALD),NUCL.PHYS.60,561 (1964).
PH52 D.D.PHILLIPS ET AL.(LAS), PHYS.REV.88,600 (1952).
PR60 J.T.PRUDHOMME ET AL.(TNC),AFSWC-TR-60-30 (1960).
RA70 N.C.RASMUSSEN ET AL., GA-10248 (1970)
SC61 H.W.SCHMITT+J.HALPERIN(ORL),PHYS.REV.121,827 (1961).
SC70 R.B.SCHWARTZ, PRIVATE COMMUNICATION (1970)
ST59 C.ST.PIERRE ET AL.(MON), PHYS.REV.115,999 (1959).
ST62 T.P.STUART ET AL., PHYS. REV. 125, 276 (1962)
ST65 P.H.STELSON+R.L.ROBINSON (ORL), NUCL.PHYS.68,97 (1965).
TA55 H.L.TAYLOR ET AL.(RIC), PHYS.REV.100,174 (1955).
TH63 D.B.THOMPSON (LAS),PHYS.REV.129,1649 (1963).

AL-27 LASL EVAL-APR71 D.G.FOSTER,JR AND P.G.YOUNG
MATERIAL= 4135 ZA= 13027. AWR = 26.7500 FILE= 1 SECTION= 451

TO62 J.H.TOWLE AND W.B.GILBOY, NUCL. PHYS. 39, 300 (1962)
TO67 J.H.TOWLE+R.O.OWENS(ALD),NUCL.PHYS.A100,257 (1967).
TS61 K.TSUKADA ET AL., PHYSICS OF FAST AND INTERMEDIATE REACTORS, VIENNA (1961).
WI63 D.WINTERHALTER (ZAG), NUCL.PHYS.43,339(1963).

AL-27 LASL EVAL-APR71 D.G.FOSTER,JR AND P.G.YOUNG
MATERIAL= 4135 ZA= 13027. AWR = 26.7500 FILE= 1 SECTION= 451

FILE	SECTION	DESCRIPTION	NO OF CARDS
1	451	DESCRIPTIVE	371
2	151	RESONANCE	4
3	1	TOTAL	457
3	2	ELASTIC	457
3	3	NON-ELASTIC	457
3	4	(N,N*) TOTAL	60
3	16	(N,2N)	15
3	51	(N,N*) LEVEL	60
3	52	(N,N*) LEVEL	58
3	53	(N,N*) LEVEL	54
3	54	(N,N*) LEVEL	51
3	55	(N,N*) LEVEL	50
3	56	(N,N*) LEVEL	50
3	57	(N,N*) LEVEL	47
3	58	(N,N*) LEVEL	46
3	59	(N,N*) LEVEL	45
3	60	(N,N*) LEVEL	44
3	61	(N,N*) LEVEL	43
3	62	(N,N*) LEVEL	42
3	63	(N,N*) LEVEL	41
3	64	(N,N*) LEVEL	39
3	65	(N,N*) LEVEL	37
3	66	(N,N*) LEVEL	35
3	67	(N,N*) LEVEL	33
3	68	(N,N*) LEVEL	32
3	69	(N,N*) LEVEL	31
3	70	(N,N*) LEVEL	30
3	71	(N,N*) LEVEL	28
3	72	(N,N*) LEVEL	27
3	73	(N,N*) LEVEL	26
3	74	(N,N*) LEVEL	25
3	75	(N,N*) LEVEL	24
3	76	(N,N*) LEVEL	22
3	77	(N,N*) LEVEL	21
3	78	(N,N*) LEVEL	20
3	79	(N,N*) LEVEL	19
3	80	(N,N*) LEVEL	18
3	81	(N,N*) LEVEL	16
3	82	(N,N*) LEVEL	15
3	83	(N,N*) LEVEL	14
3	84	(N,N*) LEVEL	13
3	85	(N,N*) LEVEL	12
3	86	(N,N*) LEVEL	10
3	87	(N,N*) LEVEL	9
3	88	(N,N*) LEVEL	8
3	89	(N,N*) LEVEL	6
3	90	(N,N*) LEVEL	5
3	102	(N,GAMMA)	40
3	103	(N,P)	45
3	104	(N,D)	22

AL-27 LASL EVAL-APR71 D.G.FOSTER,JR AND P.G.YOUNG
MATERIAL= 4135 ZA= 13027. AWR = 26.7500 FILE= 1 SECTION= 451

FILE	SECTION	DESCRIPTION	NO OF CARDS
3	105	(N,T)	14
3	107	(N,ALPHA)	28
3	251	MU BAR	15
3	252	XI	15
3	253	GAMMA	15
4	2	ELASTIC	126
4	16	(N,2N)	28
4	51	(N,N*) LEVEL	8
4	52	(N,N*) LEVEL	8
4	53	(N,N*) LEVEL	8
4	54	(N,N*) LEVEL	8
4	55	(N,N*) LEVEL	8
4	56	(N,N*) LEVEL	8
4	57	(N,N*) LEVEL	8
4	58	(N,N*) LEVEL	8
4	59	(N,N*) LEVEL	8
4	60	(N,N*) LEVEL	8
4	61	(N,N*) LEVEL	8
4	62	(N,N*) LEVEL	8
4	63	(N,N*) LEVEL	8
4	64	(N,N*) LEVEL	8
4	65	(N,N*) LEVEL	8
4	66	(N,N*) LEVEL	8
4	67	(N,N*) LEVEL	8
4	68	(N,N*) LEVEL	8
4	69	(N,N*) LEVEL	8
4	70	(N,N*) LEVEL	8
4	71	(N,N*) LEVEL	8
4	72	(N,N*) LEVEL	8
4	73	(N,N*) LEVEL	8
4	74	(N,N*) LEVEL	8
4	75	(N,N*) LEVEL	8
4	76	(N,N*) LEVEL	8
4	77	(N,N*) LEVEL	8
4	78	(N,N*) LEVEL	8
4	79	(N,N*) LEVEL	8
4	80	(N,N*) LEVEL	8
4	81	(N,N*) LEVEL	8
4	82	(N,N*) LEVEL	8
4	83	(N,N*) LEVEL	8
4	84	(N,N*) LEVEL	8
4	85	(N,N*) LEVEL	8
4	86	(N,N*) LEVEL	8
4	87	(N,N*) LEVEL	8
4	88	(N,N*) LEVEL	8
4	89	(N,N*) LEVEL	8
4	90	(N,N*) LEVEL	8
5	16	(N,2N)	104
12	102	(N,GAMMA)	103
13	4	(N,N*) TOTAL	840

AL-27 LASL EVAL-APR71 D.G.FOSTER,JR AND P.G.YOUNG
MATERIAL= 4135 ZA= 13027. AWR = 26.7500 FILE= 1 SECTION= 451

FILE	SECTION	DESCRIPTION	NO OF CARDS
13	28	(N,N*) P	92
13	103	(N,P)	71
14	4	(N,N*) TOTAL	1
14	28	(N,N*) P	1
14	102	(N,GAMMA)	1
14	103	(N,P)	1
15	4	(N,N*) TOTAL	153
15	28	(N,N*) P	66
15	102	(N,GAMMA)	32
23	501	TOTAL PHOTON	18
23	502	COHERENT	18
23	504	INCOHERENT	18
23	516	PAIR PRD TOT	9
23	602	PHOTOELECTRC	18

TAPE NUMBER = 1

LEAD MOD 1 FEB. 1972 C. Y. FU, F. G. PEREY

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     LEAD        ORNL       EVAL-JUL71 C.Y.FU AND F.G.PEREY
MATERIAL= 4136   ZA= 82000.   AWR = 205.4300      FILE=  1   SECTION= 451

                          DIST-SEP71 MOD 2-APR72

*****************   DNA 4136 MOD 2   ***************************

          THE CAPTURE CROSS SECTIONS FROM 1 KEV TO 1 MEV
          HAVE BEEN COMPLETELY REEVALUATED BASED PRIMARILY
          ON A RECENT HIGH-RESOLUTION MEASUREMENT OF CAPTURE
          CROSS SECTIONS FOR THE LEAD ISOTOPES 204, 206,
          207 AND 208 BY B. J. ALLEN ET AL. OF ORNL.
          APPROXIMATELY 75 PER CENT OF THE CAPTURE CROSS
          SECTIONS IN THE RANGE FROM 1 KEV TO 200 KEV WERE
          GIVEN EXPLICITLY AS RESONANCES.  CORRELATION OF
          THESE RESONANCES WITH THE TOTAL CROSS SECTIONS
          ENABLES US TO REFINE THE RESONANCE WIDTHS AND
          AREAS OF THE TOTAL CROSS SECTIONS AS WELL.
          CORRESPONDING CHANGES HAVE BEEN MADE IN THE
          ELASTIC-SCATTERING AND NON-ELASTIC CROSS SECTIONS.

          DETAILS OF THE ABOVE MODIFICATIONS HAVE BEEN
          DESCRIBED IN AN ADDENDUM OF THE REPORT, EVALUATION
          OF NEUTRON AND GAMMA-RAY-PRODUCTION CROSS SECTIONS
          FOR LEAD, ORNL-4746, C. Y. FU AND F. G. PEREY.


*****************   DNA 4136 MOD 1   ***************************

          THIS DATA IS FROM ENDF/B-III, MAT#1136    %BNL<

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*         *         *         *         *         *         *
                                                            *
DATA MODIFIED JAN.1972
LOW ENERGY RADIATIVE CAPTURE CROSS SECTION CHANGED TO CONFORM TO
THE CSEWG NORMALIZATION AND STANDARDS SUBCOMMITTEE RECOMMENDED
2200 M/SEC VALUE OF 0.178 BARNS
ALSO LOW ENERGY SCATTERING CROSS SECTION CHANGED TO REPRESENT
FREE ATOM SCATTERING
*         *         *         *         *         *         *
NATURAL LEAD, JULY 1971, C. Y. FU AND F. G. PEREY OF ORNL
FILE 1 GENERAL INFORMATION
  SECTION 451 DISCRIPTIVE DATA AND DICTIONARY
FILE 2 RESONANCE PARAMETERS
  SECTION 151 GENERAL DESIGNATION FOR RESONANCE INFORMATION
    ONLY EFFECTIVE SCATTERING LENGTH GIVEN.  TAKEN FROM BNL-325.
FILE 3 NEUTRON CROSS SECTIONS
  SECTION 1 TOTAL INTERACTION
    0.00001 EV TO 1 KEV FROM BNL-325
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     LEAD        ORNL       EVAL-JUL71 C.Y.FU AND F.G.PERRY
MATERIAL= 4136   ZA= 82000.   AWR = 205.4300      FILE=  1   SECTION= 451

        1 KEV TO 0.47 MEV MOSTLY FROM W. M. GOOD OF ORNL.
        0.47 MEV TO 20.0 MEV FROM F. B. SCHWARTZ OF NBS.
      SECTION 2 ELASTIC SCATTERING
        DERIVED BY SUBTRACTING THE NON-ELASTIC CROSS SECTION FROM THE
        TOTAL CROSS SECTION
      SECTION 3 NON-ELASTIC INTERACTION
        CALCULATED, VERY GOOD AGREEMENT WITH E.PERIMENT
      SECTION 4 TOTAL INELASTIC SCATTERING
        CALCULATED, VERY GOOD AGREEMENT WITH E.PERIMENT
      SECTION 16  N,2N< REACTION
        CALCULATED, E.PERIMENTAL DATA AVAILABLE ONLY NEAR 14 MEV
      SECTION 17  N,3N< REACTION
        CALCULATED, NO DATA AVAILABLE
      SECTION 51 THROUGH 85  INELASTIC SCATTERING E.CITING LEVELS
        CALCULATED, COMPARED FAVORABLY WITH E.PERIMENT.
        48 LEVELS IN 206, 49 LEVELS IN 207 AND 22 LEVELS IN 208 ARE
        MERGED TO FORM 35 LEVELS IN NATURAL LEAD
      SECTION 91 INELASTIC SCATTERING E.CITING CONTINUUM
        DERIVED BY SUBTRACTING THE LEVEL CONTRIBUTION FROM THE TOTAL
        INELASTIC CROSS SECTION.
      SECTION 102 RADIATIVE CAPTURE
        0.00001 EV TO 10 EV--1/V DEPENDENCE ASSUMED WITH 0.198 BARNS
        AT 0.0253 EV.  CURVE DRAWN THROUGH LIMITED DATA FOR HIGHER E
      SECTION 251 MU BAR
        DERIVED FROM ELASTIC ANGULAR DISTRIBUTIONS AND KINEMATICS
        USING THE COMPUTER PROGRAM SAD.
      SECTION 252 .I
        SEE SECTION 251.
      SECTION 253 GAMMA
        SEE SECTION 251.
    FILE 4 ANGULAR DISTRIBUTION OF SECONDARY NEUTRONS
        ALL DISTRIBUTIONS ARE GIVEN IN THE LEGENDRE POLYNOMIAL
        REPRESENTATIONS.
      SECTION 2 ELASTIC SCATTERING
        0.00001 EV TO 5 MEV--COEFFICIENTS OBTAINED BY FITTING DATA
        5 MEV TO 20 MEV--OPTICAL MODEL CALCULATION.  OPTICAL MODEL
        PARAMETERS BEST FIT DATA AT 7 AND 14 MEV.
        REPRESENTATION IS IN CENTER OF MASS SYSTEM.
        TRANSFORMATION MATRI. IS GIVEN
      SECTION 51 THROUGH 85  INELASTIC SCATTERING E.CITING LEVELS
        CALCULATED AND COMPARED FAVORABLY WITH DATA.
        REPRESENTATION IS IN CENTER OF MASS SYSTEM.
      SECTION 91 INELASTIC SCATTERING E.CITING CONTINUUM
        ASSUMED ISOTROPIC.
    FILE 5 ENERGY DISTRIBUTION OF SECONDARY NEUTRONS
      SECTION 16  N,2N< REACTION
        MA.WELLIAN DISTRIBUTIONS WITH TEMPERATURES DERIVED FROM
        LEVEL DENSITIES AND LE COUTEUR THERY.
      SECTION 17  N,3N< REACTION
        MA.WELLIAN DISTRIBUTIONS WITH TEMPERATURES DERIVED FROM
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LEVEL DENSITIES AND LE COUTEUR THERY.
SECTION 91 INELSTIC SCATTERING EXCITING THE CONTINUUM
EVAPORATION SPECTRA WITH TEMPERATURES DERIVED FROM LEVEL
DENSITIES, COMPARED FAVORABLY WITH RATHER SCARCE DATA.
FILE 12 MULTIPLICITIES OF GAMMA RAYS PRODUCED BY NEUTRON REACTION
SECTION 3 NON-ELASTIC SCATTERING
COMBINED FROM CONTRIBUTIONS FROM RADIATIVE CAPTURE, INELASTIC
SCATTERING, N,2N<, AND N,3N< REACTIONS.
FILE 14 ANGULAR DISTRIBUTIONS OF SECONDARY GAMMA RAYS
SECTION 3 NON-ELASTIC SCATTERING
ASSUMED ISOTROPIC.
FILE 15 ENERGY DISTRIBUTION OF SECONDARY GAMMA RAYS
SECTION 3 NON-ELASTIC SCATTERING
0.00001 EV TO 10 EV--ONE SINGLE SPECTRUM RESULTING FROM
THERMAL NEUTRON CAPTURE IS ASSUMED VALID.
1 KEV TO 573 KEV--ONE SINGLE SPECTRUM IS ASSUMED VALID WHICH
WAS DERIVED FROM RATHER LIMITED RESONANCE CAPTURE DATA.
10 EV TO 1 KEV--LINEAR INTERPOLATION BETWEEN ABOVE TWO SPECTRA
573 KEV TO 20 MEV--CALCULATED SPECTRA RESULTING FROM
INELASTIC, N,2N< AND N,3N< REACTIONS, GIVEN FOR INTERVALS
VARYING FROM 0.25 TO 1.0 MEV, COMPARED FAVORABLY WITH DATA.
FILE 23 PHOTON INTERACTION CROSS SECTION
FROM W. H. MCMASTER ET AL.,UCRL-50400 1968<
SECTION 501 TOTAL INTERACTION
SECTION 502 COHERENT SCATTERING
SECTION 504 INCOHERENT SCATTERING
SECTION 516 PAIR PRODUCTION PLUS TRIPLET PRODUCTION
SECTION 602 PHOTOELECTRIC INTERACTION

LEAD ORNL EVAL-JUL71 C.Y.FU AND F.G.PEPEY
MATERIAL= 4136 ZA= 82000. AWR = 205.4300 FILE= 1 SECTION= 451

FILE	SECTION	DESCRIPTION	NO OF CARDS
1	451	DESCRIPTIVE	228
2	151	RESONANCE	4
3	1	TOTAL	209
3	2	ELASTIC	209
3	3	NON-ELASTIC	78
3	4	(N,N*) TOTAL	13
3	16	(N,2N)	9
3	17	(N,3N)	6
3	51	(N,N*) LEVEL	11
3	52	(N,N*) LEVEL	12
3	53	(N,N*) LEVEL	11
3	54	(N,N*) LEVEL	10
3	55	(N,N*) LEVEL	10
3	56	(N,N*) LEVEL	10
3	57	(N,N*) LEVEL	10
3	58	(N,N*) LEVEL	11
3	59	(N,N*) LEVEL	9
3	60	(N,N*) LEVEL	9
3	61	(N,N*) LEVEL	10
3	62	(N,N*) LEVEL	9
3	63	(N,N*) LEVEL	9
3	64	(N,N*) LEVEL	10
3	65	(N,N*) LEVEL	10
3	66	(N,N*) LEVEL	10
3	67	(N,N*) LEVEL	9
3	68	(N,N*) LEVEL	8
3	69	(N,N*) LEVEL	8
3	70	(N,N*) LEVEL	9
3	71	(N,N*) LEVEL	8
3	72	(N,N*) LEVEL	7
3	73	(N,N*) LEVEL	8
3	74	(N,N*) LEVEL	8
3	75	(N,N*) LEVEL	8
3	76	(N,N*) LEVEL	8
3	77	(N,N*) LEVEL	8
3	78	(N,N*) LEVEL	7
3	79	(N,N*) LEVEL	8
3	80	(N,N*) LEVEL	7
3	81	(N,N*) LEVEL	8
3	82	(N,N*) LEVEL	7
3	83	(N,N*) LEVEL	7
3	84	(N,N*) LEVEL	8
3	85	(N,N*) LEVEL	8
3	91	(N,N*) CONT	8
3	102	(N,GAMMA)	66
3	251	MU BAR	11
3	252	XI	11
3	253	GAMMA	11
4	2	ELASTIC	143
4	16	(N,2N)	8

LEAD ORNL EVAL-JUL71 C.Y.FU AND F.G.PEREY
MATERIAL= 4136 ZA= 82000. AWR = 205.4300 FILE= 1 SECTION= 451

FILE	SECTION	DESCRIPTION	NO OF CARDS
4	17	(N,3N)	8
4	51	(N,N*) LEVEL	51
4	52	(N,N*) LEVEL	75
4	53	(N,N*) LEVEL	51
4	54	(N,N*) LEVEL	54
4	55	(N,N*) LEVEL	45
4	56	(N,N*) LEVEL	47
4	57	(N,N*) LEVEL	40
4	58	(N,N*) LEVEL	66
4	59	(N,N*) LEVEL	42
4	60	(N,N*) LEVEL	35
4	61	(N,N*) LEVEL	40
4	62	(N,N*) LEVEL	35
4	63	(N,N*) LEVEL	39
4	64	(N,N*) LEVEL	54
4	65	(N,N*) LEVEL	54
4	66	(N,N*) LEVEL	54
4	67	(N,N*) LEVEL	32
4	68	(N,N*) LEVEL	30
4	69	(N,N*) LEVEL	30
4	70	(N,N*) LEVEL	48
4	71	(N,N*) LEVEL	27
4	72	(N,N*) LEVEL	26
4	73	(N,N*) LEVEL	24
4	74	(N,N*) LEVEL	24
4	75	(N,N*) LEVEL	24
4	76	(N,N*) LEVEL	39
4	77	(N,N*) LEVEL	39
4	78	(N,N*) LEVEL	22
4	79	(N,N*) LEVEL	22
4	80	(N,N*) LEVEL	20
4	81	(N,N*) LEVEL	36
4	82	(N,N*) LEVEL	20
4	83	(N,N*) LEVEL	18
4	84	(N,N*) LEVEL	33
4	85	(N,N*) LEVEL	33
4	91	(N,N*) CONT	8
5	16	(N,2N)	9
5	17	(N,3N)	8
5	91	(N,N*) CONT	9
12	3	NON-ELASTIC	18
14	3	NON-ELASTIC	1
15	3	NON-ELASTIC	869
23	501	TOTAL PHOTON	23
23	502	COHERENT	23
23	504	INCOHERENT	23
23	516	PAIR PRD TOT	9
23	602	PHOTOELECTRC	23

TAPE NUMBER = 1

HYDROGEN-1 MOD 1 FEB. 1972 STEWART, LABAUVE, YOUNG

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     H-1          LASL       EVAL-AUG70 L.STEWART,R.J.LABAUVE,P.G.YOUNG
MATERIAL= 4148   ZA=  1001.   AWR =   0.9992       FILE=  1   SECTION= 451

                          DIST-FEB71 MOD 1-FEB72

*****************   DNA 4148 MOD 1   ***************************

          THIS MODIFICATION WAS MADE TO ENABLE THE CURRENT
          DNA LIBRARY TO CONFORM TO THE ENDF/B-III LIBRARY
          AND TO ADD PHOTON INTERACTION DATA

          THE DATA CORRESPONDS TO THE ENDF/B-III EVALUATION
          WITH THE MAT NUMBER HAVING THE SAME LAST 3 DIGITS.

          FILE 23 DATA - PHOTON INTERACTION - TAKEN FROM RSIC
          DATA LIBRARY (DLC-7 D) IS BASED ON DATA FROM
          UCRL-50174 SEC. II, REV. 1969 BY MCMASTER ET AL.
          AND UCRL-50400, VOL. VI BY PLECHATY AND TERRALL.

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*         *         *         *         *         *         *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                                                             *
* CROSS SECTION STANDARD        HYDROGEN TOTAL CROSS SECTION  *
*                                                             *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                                                             *
* THE TOTAL CROSS SECTION HAS BEEN RECOMMENDED AS A STANDARD  *
*                                                             *
* BY THE CSEWG NORMALIZATION AND STANDARDS SUBCOMMITTEE FOR THE *
*                                                             *
* ENERGY RANGE FROM 1.0-5 EV TO 20.0 MEV                      *
*                                                             *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

  HYDROGEN FREE ATOM CROSS SECTIONS
     ENTRY BY L. STEWART, R.J. LABAUVE, AND P.G. YOUNG
     LOS ALAMOS SCIENTIFIC LABORATORY
     LOS ALAMOS,NEW ME.ICO 87544
     OCTOBER 20,1970

 MF=1

   MT=451, ATOMIC MASS=1.007825

 MF=2

   MT=151, SCATTERING LENGTH=1.2756E-12 CM.

 MF=3
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H-1 LASL EVAL-AUG70 L.STEWART,R.J.LABAUVE,P.G.YOUNG
MATERIAL= 4148 ZA= 1001. AWR = 0.9992 FILE= 1 SECTION= 451

MT= 1, TOTAL CROSS SECTIONS --- THE TOTAL CROSS SECTIONS ARE OBTAINED BY ADDING THE ELASTIC SCATTERING AND RADIATIVE CAPTURE CROSS SECTIONS AT ALL ENERGIES.
1.0E-05 EV TO 20 MEV.

MT= 2, ELASTIC SCATTERING --- FROM AN E.TENSIVE THEORETICAL TREATMENT OF FAST NEUTRON MEASUREMENTS BY J. C. HOPKINS(LASL) AND G. BREIT(STATE UNIVERSITY OF NEW YORK).
1.0E-05 EV TO 20 MEV.

MT=102, RADIATIVE CAPTURE --- THESE CROSS SECTIONS ARE TAKEN FROM THE 1966 PUBLICATION OF A. HORSLEY WHERE A VALUE OF 332 MB WAS ADOPTED FOR THE THERMAL VALUE.
1.0E-05 EV TO 20 MEV.

MT=251, AVERAGE VALUE OF COSINE OF SCATTERING ANGLE IN LAB SYSTEM.
1.0E-05 EV TO 20 MEV.

MT=252, AVERAGE LOGARITHMIC ENERGY CHANGE PER COLLISON, TAKEN AS 1, FROM 1.0E-05 EV TO 20 MEV.

MT=253, GAMMA, TAKEN AS 1, FROM 1.0E-05 EV TO 20 MEV.

MF=4

MT= 2, NEUTRON ELASTIC SCATTERING ANGULAR DISTRIBUTIONS IN THE CENTER OF MASS SYSTEM--GIVEN AS NORMALIZED POINTWISE PROBABILITIES.

MF=7

MT= 4, .00001 TO 5 EV FREE GAS SIGMA=20.449 BARNS.

MF=12

MT=102, GAMMA RAY MULTIPLICITIES --- MULTIPLICITY, (REFERRED TO MT=102, MF=3), IS UNITY AT ALL NEUTRON ENERGIES. SI.TEEN ENERGY BANDS ARE GIVEN FROM .2 MEV TO 20 MEV, AND THE AVERAGE GAMMA RAY ENERGY, EAG, IS DETERMINED FROM THE AVERAGE NEUTRON ENERGY, EAN, IN THE BAND BY EAG=2.225E+06+EAN/2., RECOIL ENERGY IGNORED.

MF=14

MT=102, GAMMA RAY ANGULAR DISTRIBUTION --- ASSUMED ISOTROPIC AT ALL NEUTRON ENERGIES.

H-1 LASL EVAL-AUG70 L.STEWART,R.J.LABAUVE,P.G.YOUNG
MATERIAL= 4148 ZA= 1001. AWR = 0.9992 FILE= 1 SECTION= 451

FILE	SECTION	DESCRIPTION	NO OF CARDS
1	451	DESCRIPTIVE	120
2	151	RESONANCE	4
3	1	TOTAL	48
3	2	ELASTIC	48
3	102	(N,GAMMA)	48
3	251	MU BAR	8
3	252	XI	4
3	253	GAMMA	4
4	2	ELASTIC	88
7	4	(N,N*) TOTAL	4
12	102	(N,GAMMA)	70
14	102	(N,GAMMA)	1
23	501	TOTAL PHOTON	17
23	502	COHERENT	17
23	504	INCOHERENT	17
23	516	PAIR PRD TOT	9
23	602	PHOTOELECTRC	17

TAPE NUMBER = 1

SILICON-NAT MOD 1 FEB. 1972 DRAKE, YOUNG, WRIGHT

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     SI-NAT      BNL        EVAL-AUG71 DRAKE,YOUNG,WRIGHT,KINSEY
MATERIAL= 4151   ZA= 14000.   AWR =  27.8440       FILE=  1   SECTION= 451

                          DIST-SEP71 MOD 1-FEB72

*****************   DNA 4151 MOD 1   ***************************

          THIS MODIFICATION WAS MADE TO ENABLE THE CURRENT
          DNA LIBRARY TO CONFORM TO THE ENDF/B-III LIBRARY
          AND TO ADD PHOTON INTERACTION DATA

          THE DATA CORRESPONDS TO THE ENDF/B-III EVALUATION
          WITH THE MAT NUMBER HAVING THE SAME LAST 3 DIGITS.

          FILE 23 DATA - PHOTON INTERACTION - TAKEN FROM RSIC
          DATA LIBRARY (DLC-7 D) IS BASED ON DATA FROM
          UCRL-50174 SEC. II, REV. 1969 BY MCMASTER ET AL.
          AND UCRL-50400, VOL. VI BY PLECHATY AND TERRALL.

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SILICON (NATURAL) NEUTRON AND GAMMA RAY PRODUCTION CROSS SECTIONS
DATA TAKEN FROM AN EVALUATION BY M.K.DRAKE GULF GENERAL ATOMIC
REPORT GA-8628 (MAY, 1968)
TOTAL AND PARTIAL NEUTRON CROSS SECTIONS GIVEN FOR NEUTRON
ENERGIES FROM 0.00001 EV TO 20.0 MEV
REVISED FOR FORMAT CHANGES BY P.G.YOUNG, LASL, 6/2/70
***** SILICON REVISED BY R. Q. WRIGHT, ORNL, 2-05-71
                *** FILE 3 ***
        TOTAL CROSS SECTION REVISED  1.80-3.62 MEV
        ELASTIC CROSS SECTION REVISED  1.80-3.62 MEV
        NON-ELASTIC CROSS SECTION ADDED
        INELASTIC CROSS SECTION REVISED 1.85-3.53 MEV
        MT 52 CROSS SECTION REVISED 1.85-3.53 MEV
                *** FILE 4 ***
        ELASTIC ANGULAR DIST. GIVEN AS LEGENDRE COEFF.
**** REVISED BY R. R. KINSEY, BNL, 1-15-72
                      *** FILE 3 ***
          SECTIONS 251,252, AND 253 ADDED
                      *** FILE 12 ***
          REEVALUATION OF CAPTURE GAMMA RAYS
                      *** FILE 13 ***
          1.78 MEV GAMMA RAY CHANGED TO AGREE WITH MODIFICATION
          OF MT 52 IN MF 3 BY R. Q. WRIGHT
                      ***********
DESCRIPTION OF EVALUATION BASED ON GA-8628 AND INCLUDING REVISION
          FILE 3 - NEUTRON CROSS SECTIONS
SECTION 3 - TOTAL
 EN 1.E-5EV TO 5KEV  SUM OF CONSTANT SCATTERING AND 1/V RADIATIVE
                     CAPTURE
 EN 5 TO 100 KEV     REF. 1
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    SI-NAT      BNL        EVAL-AUG71 DRAKE,YOUNG,WRIGHT,KINSEY
MATERIAL= 4151   ZA= 14000.   AWR =  27.8440      FILE=  1   SECTION= 451

     EN 100 TO 500 KEV   REF. 2
     EN .5 TO 1.2 MEV    REF. 4
     EN 1.2 TO 1.8 MEV   REF. 5
     EN 1.8 TO 3.62 MEV  REF. 3
     EN 3.62 TO 5 MEV    REF. 6
     EN 5 TO 14 MEV      REF. 7 AS ADJUSTED AS RECOMMENDED BY REF. 8
     EN 14 TO 20 MEV     REF. 9 AND 10
    SECTION 2 - ELASTIC
     EN 1.E-5 EV TO 5KEV 2.15B BASED ON REF.12
     EN 5 KEV TO 20 MEV  SUBTRACTED NONELASTIC FROM THE TOTAL
    SECTION 3 - NONELASTIC
     EN 1.E-5 EV TO 9MEV SUM OF SECTIONS 4,102,103,AND 107
     EN 9 TO 20 MEV      OPTICAL MODE CODE
    SECTION 4 - INELASTIC (TOTAL)
     EN 1.E-5 EV TO 9MEV SUM OF DISCRETE E.CITATION LEVELS SEC.51-71
     EN 9 TO 20 MEV      SUBTRACTED THE SUM OF SECTIONS 16,102,103,
                         AND 107 FROM THE NONELASTIC
    SECTION 16 - (N,2N)
        THE SI-29 AND SI-30 CROSS SECTIONS WERE CALCULATED WITH A
     STATISTICAL MODEL AND COMBINED WITH THE MEASURED SI-28 CROSS
     SECTION (REF.13) TO OBTAIN ESTIMATED (N,2N) CROSS SECTION.
    SECTION 28 - (N,NP)
     THRESHOLD AND A VALUE AT 14 MEV (REF.14) WERE USED FOR ESTIMATE
    SECTIONS 51-71 - INELASTIC E.CITATION OF DISCRETE LEVELS
     1.78(2+)MEV LEVEL SI-28
       EN 1.85 TO 3.53 MEV REF.15
       EN 3.53 TO 7.5 MEV  AVAILABLE DATA
       EN 7.5 TO 20 MEV    DECREASING CURVE FROM .43B AT 7.5 (REF.16)
                           THRU .11B AT 14.5 (REF.17,18,AND 19)
     4.614(4+),4.975(0+),AND 6.272(3+) LEVELS SI-28
       EN 6.0 TO 7.5 MEV REF.16
       EN 14 MEV         REF.17 AND 18
       SHAPE OF CROSS SECTION FROM ELIESE CODE (REF.20)
     6.878 TO 6.887 LEVELS SI-28
       EN THRESHOLD TO 20 MEV FROM ELIESE
     6.887 TO 8.260 LEVELS SI-28
       EN THRESHOLD TO 9 MEV FROM ELIESE
     FIRST FIVE LEVELS OF SI-29 AND FIRST FOUR LEVELS OF SI-30
       EN THRESHOLD TO 4 MEV FROM ELIESE AND DATA OF REF.21
    SECTION 91 - CONTINUUM OF THE INELASTIC
     EN 4 TO 9 MEV       A CONSTANT REPRESENTING THE TOTAL CONTRI-
                         BUTIONS OF THE MINOR ISOTOPES
     EN 9 TO 20 MEV      SUBTRACTED FROM THE TOTAL INELASTIC THE SUM
                         OF THE SI-28 LEVELS UP TO 6.887 MEV
    SECTION 102 - RADIATIVE CAPTURE
     EN 1.E-5EV TO 20KEV 0.16B ASSUMED AT .0253EV AND A
                         1/V DEPENDENCE ON ENERGY
     EN 20 KEV TO 200KEV BASED ON REF.22
     EN 200KEV TO 20 MEV ASSUMED CONSTANT
    SECTION 103 - (N,P)
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     SI-NAT      BNL        EVAL-AUG71 DRAKE,YOUNG,WRIGHT,KINSEY
MATERIAL= 4151   ZA= 14000.   AWR =  27.8440      FILE=  1   SECTION= 451

      THE (N,P) CROSS SECTION IS A SUM OF THE ISOTOPIC (N,P) CROSS
      SECTIONS WEIGHTED BY THEIR RELATIVE ABUNDANCE.
      SI-28
      EN THRESHOLD -6 MEV REF.23
      EN 6 TO 9 MEV       REF.24
      EN 9 TO 12.6 MEV    SMOOTH CURVE CONNECTING DATA AT 9 TO 12.6
      EN 12.6 TO 20 MEV   REF.25 RENORMALIZED TO 220MB AT 14.5 MEV AND
                          REF.26
      SI-29 AND SI-30
      ESTIMATED USING VALUES OF 101 AND 180MB AT 14.5 MEV AND THE SAME
      GENERAL SHAPE AS SEEN IN THE SI-28 (N,P) CROSS SECTION.
     SECTION 104 - (N,D)
      SPECULATIVE - ZERO AT 10.5,19MB AT 14, AND .7MB AT 20 MEV
     SECTION 107 - (N,ALPHA)
      THIS CROSS SECTION OBTAINED BY COMBINING ISOTOPIC BY ABUNDANCE
      SI-28
      EN LESS THAN 6.2MEV REF.26
      EN 6.2 TO 8.4 MEV   REF.27 REDUCED BY 30PERCENT
      EN 8.4 TO 14 MEV    INCREASES TO 318.6MB AT 11 THEN DOWN TO 275
      EN 14 TO 20 MEV     E.TRAPOLATED USING OBSERVED SHAPE OF PARTIAL
      SI-29
      EN 2.4 TO 3.5 MEV   REF.28
      EN 3.5 TO 5.5 MEV   REF.29,30, AND 27
      EN 5.5 TO 8.0 MEV   REF.26
      EN 8 TO 20 MEV      CURVE DRAWN REACHING MA. AT 11MEV AS REF.31
      SI-30
      EN THRESHOLD-20 MEV SHAPE OF SI-28 AND VALUE AT 14MEV BASED OF
                          CROSS SECTION RATIO OF REF.32
     SECTIONS 251-253
      CALCULATED USING ANGULAR DISTRIBUTIONS OF FILE 4 SECTION 2
               FILE 4 - ANGULAR DISTRIBUTIONS OF SECONDARY NEUTRONS
     SECTION 2 - ELASTIC
      EN BELOW 158KEV     ISOTROPIC AS OBSERVED BY REF.33 AND 34
      EN .15 TO .70 MEV   REF.34
      EN .70 TO 1.17 MEV  REF.35
      EN 1.2 TO 3.0 MEV   REF.33,36,37, AND 38
      EN 3.0 TO 7.0 MEV   REF.16,39, AND 40
      EN 7.0 TO 20 MEV    ELIESE CODE (REF.20) USED. RESULTS AGREE
                          WELL WITH AVAILABLE E.PERIMENTS
     SECTION 16 - (N,2N)
      ANGULAR DISTRIBUTION ASSUMED TO BE ISOTROPIC.
     SECTION 28 - (N,NP)
      ANGULAR DISTRIBUTION ASSUMED TO BE ISOTROPIC.
     SECTIONS 51-91
      1.78(2+) LEVEL IN SI-28
      EN THRESHOLD-3.5MEV CALCULATED (REF.20)
      EN 3.5 TO 7.5 MEV   REF.16,40, AND 41
      EN 14 MEV           REF.18
      4.61(4+) AND 4.98(0+) LEVELS OF SI-28
      EN THRESHOLD-6.0MEV CALCULATED (REF.20)
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EN 6.0 TO 7.5 MEV REF.16
EN ABOVE 7.5 MEV CALCULATED (REF.20)
6.27,6.88,6.89, AND 7.38 LEVELS OF SI-28 CALCULATED (REF.20)
ALL OTHER LEVELS ASSUMED ISOTROPIC IN CM SYSTEM

FILE 5 - ENERGY DISTRIBUTIONS OF SECONDARY NEUTRONS

SECTIONS 16,28, AND 91 - (N,2N),(N,NP), AND (N,N GAM)-CONTINUUM
THE SECONDARY NEUTRON ENERGY DISTRIBUTIONS HAVE BEEN CONSIDERED TO HAVE A MA.WELLIAN SHAPE. ALL THREE REACTIONS USE THE NUCLEAR TEMPERATURE FOUND FOR THE (N,N GAM) REACTION AT 14.1 MEV (REF42) THE NUCLEAR TEMPERATURE WAS ASSUMED PROPORTIONAL TO THE SQUARE ROOT OF THE ENERGY.

FILE 12 - MULTIPLICITIES FOR PHOTONS

SECTION 102 - (N,GAM)
EN 1.E-5EV TO 50KEV REF.43,44, AND 45
EN 50KEV TO 20 MEV REF.46 MEASURED AT 68KEV E.TENDED TO 20 MEV BY INCREASING PRIMARY GAMMA RAYS ENERGY BY THE KINETIC ENERGY. UP TO 1 MEV THE PRIMARY GAMMA RAYS ARE INCREASED IN 1KEV STEPS AND TREATED AS DISCRETE GAMMA RAYS FOR 1 KEV INTERVALS. ABOVE 1 MEV,THE GAMMA RAYS ARE TREATED AS A CONTINUUM.

FILE 13 - PHOTON PRODUCTION CROSS SECTIONS

SECTION 3
EN 9 TO 20 MEV SUM OF THE PRODUCTION CROSS SECTION FOR DISCRETE GAMMA RAYS SUBTRACTED FROM THE TOTAL PHOTON PRODUCTION CROSS SECTION.

SECTION 4 - (N,N GAMMA)
EN THRESHOLD-9 MEV GENERATED USING THE E.CITATION CROSS SECTION OF FILE 3, SECTIONS 51-71, AND TRANSITION PROBABILITIES OF SECTION 2.4 IN GA-
EN 9 TO 20 MEV FOR THE 1.78,6.88,5.11, AND 2.84 GAMMA RAYS ONLY,THE PRODUCTION CROSS SECTIONS AT 14.5 MEV WERE DETERMINED FROM REFS.47,48,49, AND 50. THE CROSS SECTION WAS THEN E.TRAPOLATED FROM THE 9 MEV VALUE THROUGH THE VALUE AT 14.5 MEV.

SECTION 103 - (N,P-GAMMA)
EN THRESHOLD-9 MEV OBTAINED BY ANALYZING THE PARTIAL CROSS SECTIONS FOUND IN REFS.51,52, AND 53 AND USING THE TRANSITION PROBABILITIES

SECTION 107 - (N,ALPHA-GAMMA)
EN THRESHOLD-9 MEV AS IN SECTION 103. GROUND STATE FROM REFS.26 AND 54. FIRST,SECOND, AND THIRD PARTIAL FROM REF.27 REDUCED BY 30 PERCENT. FOURTH PARTIAL FROM REF.55.
EN 9 TO 20 MEV FOR THE .9747,.5852, AND .3894 GAMMA RAYS, VALUES AT 14.7 MEV FROM REF.47 WERE USED TO E.TRAPOLATE FROM 9 TO 20 MEV.

FILE 14 - ANGULAR DISTRIBUTIONS OF PHOTONS

SECTIONS 3,102,103, AND 107 - CONTINUUM PHOTONS,(N,GAMMA),

(N,P-GAMMA), AND (N,ALPHA-GAMMA) WERE ALL ASSUMED TO BE ISOTROPIC.

SECTION 4 - (N,N -GAMMA) DISTRIBUTIONS CALCULATED USING MANDY CODE (REF.56)

FILE 15 - ENERGY DISTRIBUTIONS OF PHOTONS

SECTION 3

EN 9 TO 20 MEV CALCULATED MA.WELLIAN TYPE SPECTRA USING THE EMPIRICALLY DETERMINED TEMPERATURE OF REF.57

SECTION 102 - RADIATIVE CAPTURE

EN 1 TO 20 MEV REF.46 E.TRAPOLATED

NO. REFERENCE

1 FIELDS AND WALT, PHYS. REV. 83, 479 (1951)
2 WHALEN AND MEADOWS, WASH-1068, PG. 9 - ALSO PRIVATE COMM FEB68
3 CIERJACKS ET AL., KFK-1000,SUPP.1 (1968)
4 CO., WASH-1068, PG.7 - UNPUBLISHED DATA FROM SCISRS OCT 67
5 FREIER ET AL., PHYS. REV. 78, 508 (1950)
6 FOSTER, UNPUBLISHED DATA FROM BNL SCISRS DATA TAPE OCT 67
7 CARLSON AND BARSCHALL, PHYS. REV. 158, 1142 (1967)
8 DAVIS AND NODA, SECOND CONF. ON NEUTRON CROSS SECTION AND TECHNOLOGY, ABSTRACT, WASHINGTON, D.C., 1968, PAPER B.8
9 PETERSON, BRATENAHL, AND STOERING, PHYS. REV. 120, 521 (1960)
10 DAY AND HENKEL, PHYS. REV. 92, 358 (1953)
11 NIKLAUS ET AL., Z. PHYSIK 190, 295 (1966)
12 WEISS, PHYS. REV. 83, 379 (1951)
13 ARNOLD, DISSERTATION ABSTRACTS 26, 3425 (1965)
14 ALLAN, NUCL. PHYS. 24, 274 (1961)
15 PEREY, ORNL PRIV. COMM. FEB 71
16 SATTLER ET AL., BULL. AM. PHYS. SOC. 11, 909 (1966) ALSO SEE CONDE ET AL., PROC. OF CONF. FOR NUC. DATA FOR REACTORS, IAEA, PARIS, OCT 66, VOL. I, PG.419
17 STELSON ET AL., NUCL. PHYS. 68, 97 (1965)
18 CLARKE AND CROSS, NUCL. PHYS. 53, 177 (1964)
19 MARTIN, STEWART, AND MARTIN, NUCL. PHYS. 61, 524 (1965)
20 NAKASHIMA, JAERI 1096 (SEP 1965)
21 LIND AND DAY, ANN. PHYS. (N.Y.) 12, 485 (1961)
22 MACKLIN AND GIBBONS, REV. MOD. PHYS. 37, 166 (1965)
23 MARION, BRUGGER, AND CHAPMAN, PHYS. REV. 101, 247 (1956)
24 BASS ET AL., EANDC(E) 66 U, PG.64
25 KERN, THOMPSON, AND FERGUSON, NUCL. PHYS. 10,226 (1959)
26 BETZ AND ROSSLE, EANDC(E) 57 U, (FEB 65), PG.3
27 MAINSBRIDGE, BONNER, AND RABSON, NUCL. PHYS. 48, 83 (1963)
28 KONIJN AND LAUBER, NUCL. PHYS. 48, 191 (1963)
29 POTENZA, RICAMO, AND RUBBINO, NUCL. PHYS. 41, 298 (1963)
30 BIRK, GOLDRING, AND HILLMAN, NUCL. INSTR. METHODS 21, 197(63)
31 KHURANA AND GOVIL, NUCL. PHYS. 69, 153 (1965)
32 GARDNER AND YU, NUCL. PHYS. 60, 49 (1964)
33 LANE ET AL., ANN. PHYS. (N.Y.) 12, 135 (1961)
34 LANE, ELWYN, AND LANGSDORF, PHYS. REV. 126, 1105 (1962)
35 SEE REF.4
36 BREDIN, PHYS. REV. 135, B412 (1964)

37 COPPOLA AND KNITTER, EUR 2798.E, GEEL ESTABL., BELGIUM, (66)
38 OKLHOVSKII AND TSEKHMISTRENKO, IZV. AKAD. NAUK SSSR, SER. FIZ 29, 319 (1965)
39 POPOV, SOVIET PROGRESS IN NEUTRON PHYSICS, ED. KRUPSCHITSKII, 1966, PG. 224
40 TSUKADA, PROC. OF IAEA CONF. ON PHYS. OF FAST AND INTERMEDIAT REACTORS, VIENNA, AUG 61, VOL. I, PG.75
41 PETITT ET AL., NUCL. PHYS. 79, 231 (1966)
42 ANUFRIENKO ET AL., YADERN. FIZ. 2, 589 (1966)
43 SPITS ET AL., NUCL. PHYS. A145, 449 (1970)
44 LYCKLAMA ET AL., CAN. JOUR. PHYS. 45, 1871 (1967)
45 BLICHERT-TOFT AND TRIPATHI, 69STUDSVIK, STI/PUB/235 (1969)
46 LUNDBERG AND BERGQVIST, PHYS. SCRIPTA 2, 265 (1970)
47 ENGESSER AND THOMPSON, J. NUCL. ENERGY 21, 487 (1967)
48 CALDWELL, MILLS, AND HICKMAN, NUCL. SCI. ENG. 8, 173 (1960)
49 NELLIS ET AL., USAEC REPORT TID-20657 (1962)
50 MARTIN AND STEWART, J. NUCL. ENERGY 19, 447 (1965)
51 ANDERSSON-LINDSTROM AND ROSSLE, PHYS. LETT. 5, 71 (1963)
52 MAUSBERG, IKF-14 (DEC 65)
53 DEBERTIN, GUNTHER, AND ROSSLE, NUCL. PHYS. A101, 473 (1967)
54 MILLER AND KAVANAGH, NUCL. INSTR. METHODS 48, 13 (1967)
55 SHANNON AND TRICE, NUCL. INSTR. METHODS 41, 255 (1966)
56 SHELDON AND VAN PATTER, REV. MOD. PHYS. 38, 143 (1966)
57 HOWERTON AND PLECHATY, UCRL-50185 (1967)

SI-NAT BNL EVAL-AUG71 DRAKE,YOUNG,WRIGHT,KINSEY
MATERIAL= 4151 ZA= 14000. AWR = 27.8440 FILE= 1 SECTION= 451

FILE	SECTION	DESCRIPTION	NO OF CARDS
1	451	DESCRIPTIVE	358
2	151	RESONANCE	4
3	1	TOTAL	393
3	2	ELASTIC	393
3	3	NON-ELASTIC	393
3	4	(N,N*) TOTAL	155
3	16	(N,2N)	84
3	28	(N,N*) P	25
3	51	(N,N*) LEVEL	52
3	52	(N,N*) LEVEL	121
3	53	(N,N*) LEVEL	38
3	54	(N,N*) LEVEL	35
3	55	(N,N*) LEVEL	31
3	56	(N,N*) LEVEL	20
3	57	(N,N*) LEVEL	12
3	58	(N,N*) LEVEL	9
3	59	(N,N*) LEVEL	7
3	60	(N,N*) LEVEL	6
3	61	(N,N*) LEVEL	23
3	62	(N,N*) LEVEL	19
3	63	(N,N*) LEVEL	16
3	64	(N,N*) LEVEL	15
3	65	(N,N*) LEVEL	15
3	66	(N,N*) LEVEL	14
3	67	(N,N*) LEVEL	8
3	68	(N,N*) LEVEL	8
3	69	(N,N*) LEVEL	7
3	70	(N,N*) LEVEL	6
3	71	(N,N*) LEVEL	5
3	91	(N,N*) CONT	37
3	102	(N,GAMMA)	335
3	103	(N,P)	197
3	104	(N,D)	49
3	107	(N,ALPHA)	211
3	251	MU BAR	25
3	252	XI	25
3	253	GAMMA	25
4	2	ELASTIC	223
4	16	(N,2N)	10
4	28	(N,N*) P	10
4	51	(N,N*) LEVEL	31
4	52	(N,N*) LEVEL	112
4	53	(N,N*) LEVEL	31
4	54	(N,N*) LEVEL	10
4	55	(N,N*) LEVEL	10
4	56	(N,N*) LEVEL	10
4	57	(N,N*) LEVEL	10
4	58	(N,N*) LEVEL	10
4	59	(N,N*) LEVEL	10
4	60	(N,N*) LEVEL	10

SI-NAT BNL EVAL-AUG71 DRAKE,YOUNG,WRIGHT,KINSEY
MATERIAL= 4151 ZA= 14000. AWR = 27.8440 FILE= 1 SECTION= 451

FILE	SECTION	DESCRIPTION	NO OF CARDS
4	61	(N,N*) LEVEL	40
4	62	(N,N*) LEVEL	40
4	63	(N,N*) LEVEL	31
4	64	(N,N*) LEVEL	31
4	65	(N,N*) LEVEL	22
4	66	(N,N*) LEVEL	22
4	67	(N,N*) LEVEL	10
4	68	(N,N*) LEVEL	10
4	69	(N,N*) LEVEL	10
4	70	(N,N*) LEVEL	10
4	71	(N,N*) LEVEL	10
4	91	(N,N*) CONT	10
5	16	(N,2N)	7
5	28	(N,N*)P	7
5	91	(N,N*) CONT	7
12	102	(N,GAMMA)	446
13	3	NON-ELASTIC	10
13	4	(N,N*) TOTAL	625
13	103	(N,P)	83
13	107	(N,ALPHA)	77
14	3	NON-ELASTIC	1
14	4	(N,N*) TOTAL	482
14	102	(N,GAMMA)	1
14	103	(N,P)	1
14	107	(N,ALPHA)	1
15	3	NON-ELASTIC	125
15	102	(N,GAMMA)	295
23	501	TOTAL PHOTON	18
23	502	COHERENT	18
23	504	INCOHERENT	18
23	516	PAIR PRD TOT	9
23	602	PHOTOELECTRC	18

TAPE NUMBER = 1

CALCIUM MOD 2 MAY 1972 FU,PEREY,DRAKE,DUDZIAK,YOUNG

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     CA          ORNL      EVAL-AUG71 FU,PEREY,DRAKE,DUDZIAK,YOUNG
MATERIAL= 4152   ZA= 20000.   AWR =  39.7360      FILE=  1   SECTION= 451

                          DIST-SEP71 MOD 2-MAY72

*****************   DNA 4152 MOD 2   ***************************

                             MAJOR REVISIONS

            1.  EXTENSION OF THE LOWER ENERGY LIMIT FROM
                0.001 EV TO 0.00001 EV.

            2.  REEVALUATION OF MF=3 CROSS SECTIONS FOR
                (N,N*), (N,P), (N,ALPHA), (N,N*P), AND
                (N,N*ALPHA) ABOVE 9 MEV.

            3.  REEVALUATION OF MF=5 ENERGY DISTRIBUTIONS
                OF SECONDARY NEUTRONS.

            4.  MF=12 GAMMA-RAY-PRODUCTION MULTIPLICITIES
                FOR (N,GAMMA), (N,N*), (N,P), AND (N,ALPHA)
                REACTIONS, PREVIOUSLY COMBINED FOR NONELASTIC
                REACTIONS, ARE NOW SEPARATELY GIVEN.
            5.  ADDITION OF MF=12 GAMMA-RAY-PRODUCTION
                MULTIPLICITIES FOR (N,N*P) AND (N,N*ALPHA)
                REACTIONS.

*****************   DNA 4152 MOD 1   ***************************

            THIS DATA IS FROM ENDF/B-III, MAT=1152    (BNL)

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CALCIUM EVALUATION - ORNL AUGUST 1971, MODIFIED JAN 1972
THIS EFFORT WAS UNDERTAKEN TO IMPROVE THE ORIGINAL EVALUATION BY
M.K.DRAKE,GULF GENERAL ATOMIC REPORT GA-7829,VOL.4,1967. THE DRAKE
EVALUATION WAS ORIGINALY TRANSLATED INTO ENDF FORMAT BY
D.J.DUDZIAK, LASL, JULY 1969. REVISED BY P.G.YOUNG, LASL, MAY 1970
AND BEARS MATERIAL NUMBER 540.
QUESTIONS AND COMMENTS CONCERNING THIS EVALUATION, MAT 1152,
ARE WELCOME AND SHOULD BE ADDRESSED TO F. G. PEREY, ORNL.
FILE 1 GENERAL INFORMATION
  SECTION 451 DISCRIPTIVE DATA AND DICTIONARY
FILE 2 RESONANCE PARAMETERS
  SECTION 151 GENERAL DESIGNATION FOR RESONANCE INFORMATION
    ONLY EFFECTIVE SCATTERING LENGTH GIVEN.  TAKEN FROM BNL-325.
FILE 3 NEUTRON CROSS SECTIONS
  SECTION 1 TOTAL INTERACTION
    0.00001 EV TO 10.0 EV -- ASSUMED TO BE THE SUM OF A CONSTANT
    SCATTERING CROSS SECTION AND 1/V CAPTURE CROSS SECTIONS.
    10.0 EV TO 0.466 MEV -- TAKEN FROM THE DRAKE EVALUATION
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(CURVE DRAWN THROUGH EXPERIMENTAL DATA).
0.466 MEV TO 20.0 MEV -- TAKEN FROM S. CIERJACKS OF KARLSRUHE.
COMPARISON OF CIERJACKS' DATA WITH THOSE OF R.B. SCHWARTZ OF
NBS REVEALS SUBSTANTIAL DISCREPANCY(UP TO 20%). EVALUATION IS
CONTINUING WITH ADDITIONAL MEASUREMENT AT ORNL.

SECTION 2 ELASTIC SCATTERING
DERIVED BY SUBTRACTING THE NON-ELASTIC CROSS SECTION FROM THE
TOTAL CROSS SECTION

SECTION 3 NON-ELASTIC INTERACTION
DERIVED BY SUMMING THE PARTIAL CROSS SECTIONS.

SECTION 4 TOTAL INELASTIC SCATTERING
DERIVED BY SUMMING THE PARTIAL CROSS SECTIONS.

SECTION 16 (N,2N) REACTION
TAKEN FROM THE DRAKE EVALUATION(CURVE DRAWN THROUGH
EXPERIMENTAL DATA).

SECTION 22 (N,NA) REATION
CALCULATED. DISCREPANCY AMONG EXPERIMENTAL DATA TOO LARGE TO
PROVIDE SUFFICIENT BASIS FOR EVALUATION.

SECTION 28 (N,NP) REACTION
CALCULATED. AVAILABLE DATA NEAR 14 MEV ARE SMALLER BY A
FACTOR OF 2. HOWEVER, OEVERALL CONSIDERATIONS SUGGESTED THE
ADOPTION OF THE CALCULATION.

SECTION 51 THROUGH 75 INELASTIC SCATTERING EXCITING LEVELS
SECTION 51 FIRST EXCITED STATE IN CA-44. DATA TAKEN
FROM EXPERIMENTS.
SECTION 52 TO 64 FIRST 13 EXCITED STATES IN CALCIUM-40.
CALCULATED DATA WITH GOOD AGREEMENT WITH EXPERIMENT.
SECTION 65 TO 74 FROM MERGING 48 LEVEL IN CA-40. CALCULATED.
THE CONTINUUM COVERS A SMALL ENERGY RANGE FROM 9.0 TO 9.35 MEV
AND IS TREATED AS A DISCRETE LEVEL IN SECTION 75.

SECTION 102 RADIATIVE CAPTURE
TAKEN FROM THE DRAKE EVALUATION WITH REDUCED DATA POINTS.
1/V UP TO 1.0 KEV. RESONANCE STRUCTURE CALCULATED WITH
A CONSTANT RADIATION WIDTH OF 2.5 EV.

SECTION 103 (N,P) REACTION
TAKEN FROM A COMBINATION OF CALCULATION AND EXPERIMENTAL DATA.

SECTION 107 (N,A) REACTION
CALCULATED, COMPARED FAVORABLY WITH EXPERIMENTS.

SECTION 251 MU BAR
TAKEN FROM THE DRAKE EVALUATION(DERIVED FROM ELASTIC ANGULAR
DISTRIBUTION).

FILE 4 ANGULAR DISTRIBUTION OF SECONDARY NEUTRONS
ALL DISTRIBUTIONS ARE GIVEN IN THE LEGENDRE POLYNOMIAL
REPRESENTATIONS.

SECTION 2 ELASTIC SCATTERING
TAKEN FROM THE DRAKE EVALUATION(AGREES WELL WITH RECENT DATA).
0.00001 EV TO 0.1 MEV-- ASSUMED ISOTROPIC.
0.1 MEV TO 6.0 MEV -- FROM EXPERIMENT.
6.0 MEV TO 20.0 MEV-- CALCULATED, GOOD AGREEMENT WITH
AVAILABLE DATA.

REPRESENTATION IS IN CENTER OF MASS SYSTEM.
TRANSFORMATION MATRIX IS GIVEN.
SECTION 16,22 AND 28
ASSUMED ISOTROPIC (CM).
SECTION 52 THROUGH 64
CALCULATED. REPRESENTATION IS IN CENTER OF MASS SYSTEM.
SECTION 65 THROUGH 75
ASSUMED ISOTROPIC(EACH SECTION REPRESENTS A GROUP OF LEVELS).
FILE 5 ENERGY DISTRIBUTION OF SECONDARY NEUTRONS
SECTION 16 (N,2N) REACTION
MAXWELLIAN DISTRIBUTIONS WITH TEMPERATURES DERIVED FROM
LEVEL DENSITIES AND LE COUTEUR THEFY.
SECTION 22 (N,NA) REATION
(N,NA) AND (N,AN) REACTIONS ARE CONSIDERED SEPARATELY, EACH
REPRESENTED BY AN EVAPORATION SPECTRUM.
SECTION 28 (N,NP) REACTION
(N,NP) AND (N,PN) REACTIONS ARE CONSIDERED SEPARATELY, EACH
REPRESENTED BY AN EVAPORATION SPECTRUM.
FILE 12 MULTIPLICITIES OF GAMMA RAYS PRODUCED BY NEUTRON REACTION
SECTION 4 TOTAL INELASTIC SCATTERING
BASED ON CALCULATED GAMMA-RAY SPECTRA. REASONABLE AGREEMENT
WITH EXPERIMENT. THE 1.158 MEV GAMMA-RAY FROM CA-44 IS
BASED ON EXPERIMENTAL DATA AND IS TREATED AS A DISCRETE
PHOTON.
SECTION 22 (N,NA) REATION
BASED ON CALCULATED GAMMA-RAY SPECTRA. ONLY ONE GAMMA-RAY
OF 1.97 MEV IS SIGNIFICANT AND IS TREATED AS A DISCRETE PHOTON
SECTION 28 (N,NP) REACTION
BASED ON CALCULATED GAMMA-RAY SPECTRA.
SECTION 102 RADIATIVE CAPTURE
ONLY GAMMA-RAYS FROM THERMAL-NEUTRON CAPTURE ARE INCLUDED.
SPECTRUM IS CONSTRUCTED FROM THE DECAY SCHEME PROPOSED BY
H. GRUPPELAAR AND P. SPILLING--NP A102(1967)226.
SECTION 103 (N,P) REACTION
CALCULATED, REASONABLE AGREEMENT WITH EXPERIMENTS.
SECTION 107 (N,A) REACTION
CALCULATED, REASONABLE AGREEMENT WITH EXPERIMENTS.
FILE 14 ANGULAR DISTRIBUTIONS OF SECONDARY GAMMA RAYS
ASSUMED ISOTROPIC.
FILE 15 ENERGY DISTRIBUTION OF SECCNDARY GAMMA RAYS
SEE FILE 12.
FILE 23 PHOTON INTERACTION CROSS SECTION
FROM W. H. MCMASTER ET AL.,UCRL-50400(1968)
SECTION 501 TOTAL INTERACTION
SECTION 502 COHEFENT SCATTERING
SECTION 504 INCOHERENT SCATTERING
SECTION 516 PAIR PRODUCTION PLUS TRIPLET PRODUCTION
SECTION 602 PHOTOELECTRIC INTERACTION

CA ORNL EVAL-AUG71 FU,PEREY,DRAKE,DUDZIAK,YOUNG
MATERIAL= 4152 ZA= 20000. AWR = 39.7360 FILE= 1 SECTION= 451

FILE	SECTION	DESCRIPTION	NO OF CARDS
1	451	DESCRIPTIVE	242
2	151	RESONANCE	4
3	1	TOTAL	622
3	2	ELASTIC	622
3	3	NON-ELASTIC	181
3	4	(N,N*) TOTAL	42
3	16	(N,2N)	10
3	22	(N,N*)ALPHA	9
3	28	(N,N*)P	9
3	51	(N,N*) LEVEL	9
3	52	(N,N*) LEVEL	9
3	53	(N,N*) LEVEL	10
3	54	(N,N*) LEVEL	8
3	55	(N,N*) LEVEL	8
3	56	(N,N*) LEVEL	7
3	57	(N,N*) LEVEL	9
3	58	(N,N*) LEVEL	9
3	59	(N,N*) LEVEL	9
3	60	(N,N*) LEVEL	9
3	61	(N,N*) LEVEL	8
3	62	(N,N*) LEVEL	9
3	63	(N,N*) LEVEL	7
3	64	(N,N*) LEVEL	6
3	65	(N,N*) LEVEL	7
3	66	(N,N*) LEVEL	6
3	67	(N,N*) LEVEL	7
3	68	(N,N*) LEVEL	8
3	69	(N,N*) LEVEL	8
3	70	(N,N*) LEVEL	7
3	71	(N,N*) LEVEL	8
3	72	(N,N*) LEVEL	8
3	73	(N,N*) LEVEL	8
3	74	(N,N*) LEVEL	8
3	75	(N,N*) LEVEL	9
3	102	(N,GAMMA)	139
3	103	(N,P)	10
3	107	(N,ALPHA)	12
3	251	MU BAR	25
4	2	ELASTIC	233
4	16	(N,2N)	8
4	22	(N,N*)ALPHA	8
4	28	(N,N*)P	8
4	51	(N,N*) LEVEL	8
4	52	(N,N*) LEVEL	45
4	53	(N,N*) LEVEL	38
4	54	(N,N*) LEVEL	36
4	55	(N,N*) LEVEL	34
4	56	(N,N*) LEVEL	34
4	57	(N,N*) LEVEL	29
4	58	(N,N*) LEVEL	32

CA ORNL EVAL-AUG71 FU,PEREY,DRAKE,DUDZIAK,YOUNG
MATERIAL= 4152 ZA= 20000. AWR = 39.7360 FILE= 1 SECTION= 451

FILE	SECTION	DESCRIPTION	NO OF CARDS
4	59	(N,N*) LEVEL	28
4	60	(N,N*) LEVEL	29
4	61	(N,N*) LEVEL	27
4	62	(N,N*) LEVEL	27
4	63	(N,N*) LEVEL	27
4	64	(N,N*) LEVEL	27
4	65	(N,N*) LEVEL	8
4	66	(N,N*) LEVEL	8
4	67	(N,N*) LEVEL	8
4	68	(N,N*) LEVEL	8
4	69	(N,N*) LEVEL	8
4	70	(N,N*) LEVEL	8
4	71	(N,N*) LEVEL	8
4	72	(N,N*) LEVEL	8
4	73	(N,N*) LEVEL	8
4	74	(N,N*) LEVEL	8
4	75	(N,N*) LEVEL	8
5	16	(N,2N)	7
5	22	(N,N*)ALPHA	15
5	28	(N,N*)P	17
12	4	(N,N*) TOTAL	25
12	22	(N,N*)ALPHA	6
12	28	(N,N*)P	7
12	102	(N,GAMMA)	4
12	103	(N,P)	8
12	107	(N,ALPHA)	8
14	4	(N,N*) TOTAL	1
14	22	(N,N*)ALPHA	1
14	28	(N,N*)P	1
14	102	(N,GAMMA)	1
14	103	(N,P)	1
14	107	(N,ALPHA)	1
15	4	(N,N*) TOTAL	587
15	28	(N,N*)P	207
15	102	(N,GAMMA)	32
15	103	(N,P)	601
15	107	(N,ALPHA)	595
23	501	TOTAL PHOTON	18
23	502	COHERENT	18
23	504	INCOHERENT	18
23	516	PAIR PRD TOT	9
23	602	PHOTOELECTRC	18

TAPE NUMBER = 1

BERYLLIUM-9 MOD 0 FEB. 1972 HOWERTON, PERKINS

BE-9 LLL EVAL-DEC71 R.J.HOWERTON AND S.T.PERKINS
MATERIAL= 4154 ZA= 4009. AWR = 8.9348 FILE= 1 SECTION= 451

DIST-JAN72 MOD 0-FEB72

********** DNA 4154 MOD 0 **********

THIS MODIFICATION WAS MADE TO ENABLE THE CURRENT DNA LIBRARY TO CONFORM TO THE ENDF/B-III LIBRARY AND TO ADD PHOTON INTERACTION DATA

THE DATA CORRESPONDS TO THE ENDF/B-III EVALUATION WITH THE MAT NUMBER HAVING THE SAME LAST 3 DIGITS.

FILE 23 DATA - PHOTON INTERACTION - TAKEN FROM RSIC DATA LIBRARY (DLC-7 D) IS BASED ON DATA FROM UCRL-50174 SEC. II, REV. 1969 BY MCMASTER ET AL. AND UCRL-50400, VOL. VI BY PLECHATY AND TERRALL.

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BE-9 EVALUATED NEUTRON CROSS SECTIONS
EVALUATED BY R.J.HOWERTON AND S.T.PERKINS
LAWRENCE LIVERMORE LABORATORY, LIVERMORE, CA.
DECEMBER, 1971

GENERAL COMMENTS

THE NEUTRON ENERGY RANGE COVERED E.TENDS FROM 1-0-5 EV TO 20 MEV. IN ADDITION TO ELASTIC SCATTERING WHICH OF COURCE IS EVERYWHERE ENERGETICALLY POSSIBLE, THE FOLLOWING REACTIONS HAVE THRESHOLDS (UCRL 50400, VOL.9) AT ENERGIES LESS THAN 20 MEV

REACTION	THRESHOLD (MEV)
N,2N	1.85
N,P	14.26
N,NP	18.76
N,D	16.29
N,ND	18.55
N,T	11.60
N,NT	19.65
N,ALPHA	0.67
N,N ALPHA	2.74
N,GAMMA	E.OERGIC

FOR THE (N,NP), (N,ND), AND (N,NT) REACTIONS, THERE ARE NO MEASUREMENTS AND SINCE THE THRESHOLDS ARE SUFFICIENTLY HIGH, THESE CROSS SECTIONS WILL BE CONSIDERED NEGLIGIBLE. THE (N,N ALPHA) REACTION IS IN REALITY A DECAY MODE FOR THE (N,2N) REACTION SINCE HE-5 IS UNSTABLE, DECAYING IMMEDIATELY TO A NEUTRON AND AN ALPHA PARTICLE. ADDITIONALLY, THE INELASTIC SCATTERING REACTION IS ALSO A DECAY MADE FOR THE (N,2N) REACTION SINCE THE BE-9* RECOIL NUCLEI ALWAYS DECAYS TO THE FINAL END

PRODUCTS OF A NEUTRON AND TWO ALPHA PARTICLES. THE WAY IN WHICH THE CROSS SECTIONS ARE SELECTED FOR ELASTIC SCATTERING, (N,2N), (N,P), (N,D), (N,T), (N, ALPHA), (N, GAMMA), AS WELL AS THE (N,. GAMMA) REACTION IS DISCUSSED BELOW.

ELASTIC SCATTERING CROSS SECTION

IN KEEPING WITH THE PRINCIPLE ESTABLISHED FOR THE ENTIRE LLL EVALUATED CROSS SECTION LIBRARY, THE FREE ATOM CROSS SECTION IS USED FOR ALL ENERGIES BELOW THE USUAL UPPER LIMIT OF THE MOLECULAR BINDING ENERGY (ABOUT 10 EV). THIS IS EFFECTIVELY ONLY THE NUCLEAR PART OF THE CROSS SECTION OF A STATIONARY TARGET AT ZERO DEGREES KELVIN. IT IS STRONGLY EMPHASIZED THAT THE NUMBERS ARE MEANINGLESS IN THE ABSENCE OF A PROPER THERMAL TREATMENT BY EITHER THE PROCESSING CODE OR THE NEUTRONICS CODE WHICH USES THESE NUMBERS. THEY ARE LIKEWISE MEANINGLESS IF THE MATERIALS FOR WHICH THEY ARE TO BE USED ARE BOUND IN MOLECULES UNLESS MOLECULAR BINDING IS TAKEN INTO ACCOUNT.

THE SCATTERING CROSS SECTION WAS TAKEN EQUAL TO 6 BARNS FROM 0.0001 EV UP TO 0.01 MEV. FROM THIS ENERGY UP TO THE (N,ALPHA) THRESHOLD OF 0.67 MEV, THE SCATTERING CROSS SECTION IS EQUAL TO THE TOTAL CROSS SECTION BECAUSE THE (N,GAMMA) CROSS SECTION IS ESSENTIALLY NEGLIGIBLE. THE CROSS SECTION HERE WAS BASED ON DATA OF REFS. 63, 92, 720, 772 AND 1002.

ABOVE THE (N,ALPHA) THRESHOLD, THE SCATTERING CROSS SECTION WAS TAKEN AS THE DIFFERENCE BETWEEN THE TOTAL AND THE NONELASTIC, WITH THE NONELASTIC BEING EQUAL TO THE SUM OF ITS PARTS. UP TO 2 MEV, THE TOTAL CROSS SECTION WAS BASED ON THE PREVIOUSLY MENTIONED DATA, AS WELL AS THAT FROM REFS. 72, 336 AND 1642. ABOVE THIS ENERGY, WE RELIED HEAVILY ON THE RESULTS OF REF. 3088 OVER THE 2.7 MEV RESONANCE, AND REF. 750 UP TO 15 MEV. THE E.TENSION TO 20 MEV UTILIZED DATA FROM REFS. 107, 673 AND 682.

ELASTIC SCATTERING ANGULAR DISTRIBUTIONS,NORMALIZED PROBABILITIES

UP TO 7 MEV, THERE ARE E.PERIMENTAL DIFFERENTIAL SCATTERING DATA IN REFS. 121, 151, 231, 296, 500, 571, 945, 1643, 1645, 1646 AND 1647. THESE RESULTS WERE USED TO DETERMINE THE NORMALIZED PROBABILITIES. IN BE BELOW THE (N,2N) THRESHOLD, THE TOTAL SCATTERING DATA IS EQUIVALENT TO THAT FOR ELASTIC SCATTERING, SINCE THERE IS NO INELASTIC SCATTERING AS SUCH. THE CHANGE IN SHAPE OF THE ANGULAR DISTRIBUTION GOING THROUGH THE SCATTERING RESONANCES WAS TAKEN INTO ACCOUNT. AT 14 MEV, THE PROBABILITIES WERE BASED ON THE RESULTS OF REF. 402, 2585 AND 3106. A SMOOTH E.TRAPOLATION WAS MADE TO 20 MEV.

(N,2N) CROSS SECTION

THE (N,2N) CROSS SECTION IS BASED ON THE (N,2N) CROSS SECTIONS, AND NONELASTIC MINUS ABSORPTION CROSS SECTIONS REFERENCED IN PERKINS (AN-1443, 1965), AS WELL AS THE NEW N,2N DATA UP TO 6.4 MEV GIVEN IN REF. 763. THE NONELASTIC RESULTS OF REF. 2595 APPEAR TOO LARGE AND WERE NOT USED. THE 20 MEV POINT

WAS BASED ON INTERPOLATING NONELASTIC CROSS SECTIONS BETWEEN THE 14 MEV VALUE AND THE VALUE AT 25.5 MEV QUOTED IN REF. 356.

(N,2N) ENERGY DISTRIBUTIONS

THE L=0 LEGENDRE MOMENT OF THE TRANSFERENCE FUNCTION HAS BEEN TAKEN FROM THE WORK OF PERKINS (AN-1443, 1965), SEE ALSO, UCRL-50520 (1968). BRIEFLY, THIS TREATED THE (N,2N) REACTION AS A SERIES OF TIME-SEQUENTIAL DECAYS, BE-9(N,N1)BE-9*(N2)BE-8*. LEVELS EXCITED WERE AT 2.43, 6.76 AND 9.1 MEV IN BE-9*, AND C., 2.90 AND 11.4 MEV IN BE-8*. THE EXPERIMENTAL CENTER OF MASS ANGULAR DISTRIBUTION OF THE INELASTICALLY SCATTERED NEUTRON FROM BE-9* (2.43 MEV) WAS DESCRIBED BY A P6 LEGENDRE EXPANSION. ALL OTHER REACTIONS WERE CONSIDERED ISOTROPIC IN THEIR RESPECTIVE CENTER OF MASS SYSTEMS.

THE CALCULATION WAS PERFORMED WITH THE AGN-SIGMA (AN-1447, 1965) MULTIGROUP CODE WITH 66 GROUPS. LETHARGY WIDTHS WERE 0.2 FOR ENERGIES ABOVE 10 MEV, AND 0.25 FOR ENERGIES BELOW 10 MEV. THIS INTRODUCES A SPREAD IN THE EMERGENT SPECTRA DUE TO THE FINITE GROUP WIDTHS. THE THRESHOLD SPECTRA WAS TAKEN EQUAL TO THAT OF 2 MEV, ALTHOUGH MODIFIED SO AS NOT TO VIOLATE ENERGY CONSERVATION. SIMILARLY, THE 20 MEV SPECTRUM WAS TAKEN EQUAL TO THAT AT 14.6 MEV.

(N,2N) ANGULAR DISTRIBUTIONS

THE LAB SYSTEM ANGULAR DISTRIBUTIONS WERE OBTAINED BY APPROPRIATELY SUMMING THE PARTIAL DISTRIBUTIONS OF PERKINS (UCRL-50520, 1968). THE THRESHOLD DISTRIBUTION IS ESSENTIALLY IN THE FORWARD DIRECTION.

THE DISTRIBUTIONS AT 2. AND 2.5 MEV WERE TAKEN EQUAL TO THAT AT 3. MEV, THOSE AT 5.5 AND 7. MEV WERE TAKEN EQUAL TO THAT AT 4. MEV, THOSE AT 9. AND 11. MEV WERE TAKEN EQUAL TO THAT AT 12. MEV, AND THAT AT 20. MEV WAS TAKEN EQUAL TO THAT AT 14.6 MEV.

THE ANGULAR DISTRIBUTIONS, USED IN CONJUNCTION WITH THE (N,2N) ENERGY DISTRIBUTIONS, NEGLECT THE ENERGY-ANGLE CORRELATION. THIS IS A VALID APPROXIMATION FOR THIS REACTION, AS HAS BEEN DISCUSSED PREVIOUSLY (NUCL. SCI. ENG. 31, 156 (1968)).

(N,P) CROSS SECTION

THIS CROSS SECTION WAS ESTIMATED FROM THE KNOWN THRESHOLD VALUE AND THE SINGLE MEASUREMENT AT 15.5 MEV GIVEN IN REF. 913.

(N,D) CROSS SECTION

THIS CROSS SECTION IS BASED IN ITS ENTIRETY ON THE DATA BETWEEN 16.5 AND 18.8 MEV REPORTED IN REF. 3101.

(N,T) CROSS SECTION

THE CROSS SECTION FOR THE (N,T) REACTION IS BASED ON THE ASSUMPTION THAT ALL TRANSITIONS PROCEED THROUGH LI-7*(0.477 MEV). THIS IS IN RELATIVE AGREEMENT WITH THE RESULTS OF REF. 496 AND 650 BUT IN TOTAL DISAGREEMENT WITH THE DATA FROM REF. 494. THE

UNCERTAINTIES IN THIS LATTER REFERENCE, HOWEVER, ARE LARGE ENOUGH SO AS TO NEGLECT THE WORK.

THE CROSS SECTION WAS BASED ON THE WORK IN REF. 605 FROM 13.6 - 14.7 MEV. ABOVE THIS ENERGY, THERE IS A RESONANCE STRUCTURE SEEN IN THE TOTAL CROSS SECTION REPORTED IN REF. 107 AND 682. THIS WAS ASSUMED TO BE DUE TO THE (N,T) REACTION AND IS NOT IN CONFLICT WITH THE RAPID INCREASE IN THE CROSS SECTION ABOVE 14.5 MEV SEEN BY REF. 605.

(N,ALPHA) CROSS SECTION

THE CROSS SECTION WAS BASED ON THE MEASUREMENTS REPORTED IN REF. 160, 494 AND 733 UP TO NEUTRON ENERGIES OF 8.6 MEV. IT WAS THEN TIED INTO THE THREE VALUES GIVEN AT 14 MEV, REFS. 86, 650 AND 2367, AND THEN SMOOTHLY E.TRAPOLATED TO 20. MEV. NOTE THAT THE MEASURED CROSS SECTION IS TO HE-6(0. MEV) WHICH BETA DECAYS TO LI-6, HIGHER STATES IN HE-6 DECAY TO ALPHA + 2N.

(N,GAMMA) CROSS SECTION

THE CROSS SECTION WAS ASSUMED TO BE 1/V BELOW 100 EV WITH A 2200 M/SEC CROSS SECTION OF 9.5 MB. IT WAS THEN E.TRAPOLATED LINEARLY ON A LOG-LOG BASIS TO 0.1 MB AT 1 KEV, AND THEN HELD CONSTANT AT THIS VALUE UP TO 20 MEV.

(N,. GAMMA) CROSS SECTION

GAMMA RAYS IN BE-9 ARE PRODUCED BY THE (N,GAMMA) AND THE (N,T) REACTIONS. AT THERMAL ENERGIES, REF. 2415 QUOTES GAMMA RAY ENERGIES OF 0.8535, 2.59, 3.368, 3.444, 5.958 AND 6.81 MEV AND THE CORRESPONDING (N,. GAMMA) CROSS SECTIONS. WE HAVE ASSUMED THAT THESE ENERGIES AND THEIR MULTIPLICITIES ARE INDEPENDENT OF ENERGY, AND HAVE USED THEM IN CONJUNCTION WITH OUR (N,GAMMA) CROSS SECTION TO DEVELOP THIS COMPONENT OF THE (N,. GAMMA) CROSS SECTION. THIS VIOLATES ENERGY CONSERVATION AS THE INCIDENT NEUTRON ENERGY IS INCREASED. WE INTENTIONALLY USED THIS APPROACH BECAUSE WE DONT KNOW HOW TO HANDLE THIS PROBLEM. THE COMPONENT RELEVANT TO THE (N,T) CROSS SECTION IS IN FACT EQUAL TO THE (N,T) CROSS SECTION SINCE ITS MULTIPLICITY IS UNITY.

REFERENCES

(REFERENCE NUMBERS QUOTED HERE REFER TO DATA IN THE LLL E.PERIMENTAL NEUTRON CROSS SECTION LIBRARY. SEE UCRL-50400, VOL. 2 AND 3 FOR COMMENTS AND INDE.ES TO THE DATA).

63. PHYS. REV. 80, 1011 (1950) C.K. BOCKELMAN.
72. PHYS. REV. 84, 69 (1951) C.K. BOCKELMAN, D.W. MILLER, R.K. ADAIR, H.H. BARSCHALL.
86. PHYS. REV. 89, 80 (1953) M.E. BATTAT, F.L. RIBE.
92. PRIVATE COMMUNICATION (1954) P.H. STELSON.
107. PHYS. REV. 94, 651 (1954) C.F. COOK, T.W. BONNER.
121. PHYS. REV. 98, 669 (1955) J.D. SEAGRAVE, R.L. HENKEL.
151. PHYS. REV. 104, 1319 (1956) J.R. BEYSTER, M. WALT, E.W. SALMI.

160. PHYS. REV. 106, 1252 (1957) P.H. STELSON, E.C. CAMPBELL.
231. ANL-5567 (1956) A. LANGSDORF, JR., R.O. LANE, J.E. MONAHAN, SEE ALSO, ANL-5554 P. 22 (1956), PHYS. REV. 107, 1077 (1957), ANL-5567 (REV.) (1961).
296. PHYS. REV. 98, 677 (1955) M. WALT, J.R. BEYSTER.
336. PROC. PHYS. SOC. (LONDON) 64, 388 (1951) G.H. STAFFORD.
356. PHYS. REV. 111, 1155 (1958) M.H. MACGREGOR, W.P. BALL, R. BOOTH.
402. PHYS. REV. 110, 1439 (1959) M.P. NAKADA, J.D. ANDERSON, C.C. GARDNER, C. WONG.
494. DOKLADY AKAD. NAUK S.S.S.R. 119, 914 (1958) S.S. VASILEV, V.V. KUMAROV, A.M. POPOVA, SEE ALSO, J. E.PTL. THEORET. PHYS. (USSR) 33, 527 (1957).
496. PHYS. REV. 112, 1264 (1958) M.E. WYMAN, E.M. FRYER, M.M. THORPE.
500. PHYS. REV. 114, 1584 (1959) J.B. MARION, J.S. LEVIN, L. CRANBERG.
571. ANL-6172 (1960) R.O. LANE, A.S. LANGSDORF, JR., J.E. MONAHAN, A.J. ELWYN, SEE ALSO, ANN. PHYS. (N.Y.) 12, 135 (1961).
605. UCRL-5596 (1959) J. BENVENISTE, A.C. MITCHELL, C.D. SCHRADER, J.H. ZENGER, SEE ALSO, NUCLEAR PHYS. 19, 52 (1960).
650. J. E.PTL. THEORET. PHYS. (USSR) 40, 1244 (1961) S.A. MYACHKOVA, V.P. PERELYGIN.
673. PHYS. REV. 120, 521 (1960) J.M. PETERSON, A. BRATENAHL, J.P. STOERING.
682. PHYS. REV. 123, 209 (1961) D.B. FOSSAN, R.L. WALTER, W.E. WILSON, H.H. BARSCHALL.
720. PRIVATE COMMUNICATION (1962) E.G. BILPUCH, J.A. FARRELL, G.C. KYKER, JR., P.B. PARKS, H. NEWSON.
733. NUCLEAR PHYS. 23, 122 (1961) R. BASS, T.W. BONNER, H.P.HAENNI.
750. PRIVATE COMMUNICATION (1967) D.G. FOSTER, JR., D.W. GLASGOW, SEE ALSO, HW-73116 (1962), HW-77311 (1963), PHYS. REV. C, 3, 576 (1971), PHYS. REV. C, 3, 604 (1971).
763. NUCLEAR PHYS. 129, 305 (1969) M. HOLMBERG, J. HANSEN, SEE ALSO, IAEA CONFERENCE ON NUCLEAR DATA, PARIS, PAPER CN-23/18 (1966).
772. COMPT. REND. 255, 277 (1962) A. PERRIN, G. SURGET, C. THIBAULT, F. VERRIERE.
913. PHYS. REV. 132, 328 (1963) D.E. ALBUGER.
945. ORNL-2610 P. 14 (1958) H.O. COHN, J.L. FOWLER, SEE ALSO, BULL. AM. PHYS. SOC. 3, 305 (1958).
1002. PRIVATE COMMUNICATION (1954) C.T. HIBDON, A. LANGSDORF.
1642. BULL. AM. PHYS. SOC. 4, 385 (1959) J.L. FOWLER, H.O. COHN.
1643. DOKLADY AKAD, NAUK S.S.S.R. 158, 574 (1964) G.V. GORLOV, N.S. LEBEDEVA, V.M. MOROZOV, SEE ALSO, YAD. FIZ. 5, 910 (1967).
1645. PRIVATE COMMUNICATION (1960) J.S. LEVIN, L. CRANBERG, SEE

ALSO, WASH-1028 P. 26 (1960), WASH-1029 P. 44 (1960).
1646. PRIVATE COMMUNICATION (1961) D.D. PHILLIPS.
1647. PHYS. REV. 133, 409 (1964) R.O. LANE, A.J. ELWYN, A. LANGSDORF, JR.
2367. NUCLEAR PHYS. 96, 476 (1967) G. PAIC, D. RENDIC, P. TOMAS.
2415. GA-10248 (DASA-2570) (1970) N.C. RASMUSSEN, V.J. ORPHAN, T.L. HARPER, J. CUNNINGHAM, S.A. ALI.
2585. PRIVATE COMMUNICATION (1966) R. BOUCHEZ, SEE ALSO, IAEA CONFERENCE ON NUCLEAR DATA, PARIS, PAPER CN-23/75 (1966).
2595. CONFERENCE ON NEUTRON CROSS SECTION TECHNOLOGY, WASHINGTON D. C., VOL. 1, P. 169 (1968) J.R.P. EATON, J. WALKER.
3088. CONFERENCE ON NEUTRON CROSS SECTION TECHNOLOGY, WASHINGTON D. C., P. 851 (1968) C.H. JOHNSON, F... HAAS, J.L. FOWLER, F.D. MARTIN, R.L. KERNELL, H.O. COHN
3101. Z. NATURFORSCH. 24, 289 (1969) W. SCOBEL.
3106. NP-17794 (1968) J. ROTURIER, SEE ALSO, COMPT. REND. 260, 4491 (1965), BNL-400, 3RD ED. (1970).

BE-9 LLL EVAL-DEC71 R.J.HOWERTON AND S.T.PERKINS
MATERIAL= 4154 ZA= 4009. AWR = 8.9348 FILE= 1 SECTION= 451

FILE	SECTION	DESCRIPTION	NO OF CARDS
1	451	DESCRIPTIVE	293
2	151	RESONANCE	4
3	1	TOTAL	34
3	2	ELASTIC	21
3	16	(N,2N)	7
3	102	(N,GAMMA)	12
3	103	(N,P)	5
3	104	(N,D)	6
3	105	(N,T)	6
3	107	(N,ALPHA)	8
3	251	MU BAR	11
3	252	XI	11
3	253	GAMMA	11
4	2	ELASTIC	156
4	16	(N,2N)	57
5	16	(N,2N)	60
13	3	NON-ELASTIC	73
14	3	NON-ELASTIC	1
23	501	TOTAL PHOTON	17
23	502	COHERENT	17
23	504	INCOHERENT	17
23	516	PAIR PRD TOT	9
23	602	PHOTOELECTRC	17

TAPE NUMBER = 1

SODIUM-23 MOD 0 FEB. 1972 PAIK, PITTERLE, PEREY

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     NA-23       WARD-ORNL EVAL-1971  PAIK, PITTERLE, PEREY
MATERIAL= 4156   ZA= 11023.   AWR =  22.7923       FILE=  1   SECTION= 451

                          DIST-FEB72 MOD 0 FEB72

     ****************   DNA 4156 MOD 0   ***************************

              THIS DATA IS FROM ENDF/B-III, MAT=1156    (BNL)

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     NEUTRON CROSS SECTIONS EVALUATED BY PAIK AND PITTERLE (WARD)
     PHOTON PRODUCTION CROSS SECTIONS EVALUATED BY PEREY (ORNL)
     *         *         *         *         *         *         *
    SODIUM-23 ENDF/B V3 EVALUATION BY PAIK AND PITTERLE, WARD(1971)
    MF=1                    GENERAL INFORMATION
        ATOMIC MASS GIVEN AS 22.991 FOR NEUTRON MASS OF 1.008986 AMU
      MT=453 RADIOACTIVE DECAY DATA-REF. 1
    MF=2                    RESONANCE PARAMETERS
      MT=151  PARAMETERS GIVEN FOR RESONANCES AT 2.85,7.53,35.4, 53.0
          114.7,129.5 AND 139.1 KEV, 2.85 KEV PARAMETERS FROM REFS.
          3 AND 28.  53.0 KEV PARAMETERS FROM REFS.2 AND 3.
          PARAMETERS FOR OTHER RESONANCES FROM REFS. 2 AND 5 WITH
          EMPHASIS ON CAPTURE AREAS OF REF.2.
          SCATTERING RADIUS CHOSEN TO PROVIDE GOOD ARGEEMENT BETWEEN
          CALCULATION OF THE 2.85 KEV RESONANCE AT ENERGIES ABOVE THE1
          RESONANCE WITH MEASURED DATA OF REF.20.  BACKGROUND CROSS
          SECTIONS ARE GIVEN IN FILE 3 TO IMPROVE AGREEMENT  BETWEEN
          CALCULATED AND MEASURED DATA BELOW 1.5 KEV. THE RESOLVED
          RESONANCE RANGE IS 600 EV TO 150 KEV.
    MF=3                    SMOOTH CROSS SECTIONS
      MT=1 TOTAL CROSS SECTIONS 0.001 TO 600 EV - REF.6, 600 EV TO
          150 KEV CALCULATED SAME AS MT=2, 0.15 MEV TO 0.52 MEV-REF.7
          AND 8, ABOVE 0.5 MEV-REF. 8 AND 9.
      MT=2  ELASTIC SCATTERING OBTAINED BY SUBTRACTING NONELASTIC
         CROSS SECTION FROM TOTAL CROSS SECTION E.CEPT FROM  600 EV TO
         .15MEV.  IN THIS ENERGY RANGE,IT IS CALCULATED FROM RESONANCE
         PARAMETERS OF FILE 2.  IN THIS ENERGY RANGE FILE 3 INCLUDES
         ONLY BACKGROUND CORRECTION TO THE RESONANCE CALCULATION.
      MT=3 NONELASTIC CROSS SECTION IS SUM OF SEPARATELY EVALUATED
         COMPONENTS
      MT=4 THE INELASTIC CROSS SECTION FOR THE 0.44 MEV LEVEL IS BASED
        ON REF.10 BELOW 2 MEV, REF.11,12,17 AND 18 FROM 2 TO 4 MEV,
        AND ON REF. 12 AND 13 ABOVE 4 MEV.   DATA FOR OTHER SEVENTEEN
        RESOLVED LEVELS ARE FROM REF.15,16,17 AND 11 BELOW 4.5MEV.
        ABOVE 4.5 MEV, DATA WERE OBTAINED FROM REF. 12.
        CONTINUUM DATA REPRESENT THE UNRESOLVED LEVEL ABOVE 7.79 MEV.
     THE DOUBLET AT 2.671 MEV HAS BEEN SPLIT INTO TWO LEVELS,ONE AT
     2.640(1/2-) AND 2.705(9/2+),ACCORDING TO CALCULATED RESULTS BY
     F.G. PEREY AT ORNL.
     MT=16  (N,2N) CROSS SECTION-REF. 19.
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NA-23 WARD-ORNL EVAL-1971 PAIK, PITTERLE, PEREY
MATERIAL= 4156 ZA= 11023. AWR = 22.7923 FILE= 1 SECTION= 451

MT=102 THERMAL CAPTURE GROSS SECTION FROM REF.27 = 0.534 BARN, 1/V BEHAVIOR ABOVE THERMAL ENERGY IS JOINED WITH RESONANCE CALCULATION NEAR 600 EV. FROM 600 EV TO 150 KEV,FILE 3 1 INCLUDES ONLY A BACKGROUND TO RESONANCE PARAMETER CALCU LATION ABOVE 150 KEV, EVALUATION IS BASED ON REFS.21 AND 22.
MT=103 (N,P) - REF. 23
MT=107 (N,ALPHA) -REF. 23
MT=251 UBAR CALCULATED FROM LEGENDRE POLYNOMIALS OF FILE 4.
MT=252 .I CALCULATED FROM LEGENDRE POLYNOMIALS OF FILE 4.
MT=253 GAMMA - REF. 24-BASED ON ISOTROPIC SCATTERING IN CM SYS.
MF=4 LEGENDRE POLYNOMIALS
MT=2 0.03 TO 0.3 MEV.-REF.25, 0.3 TO 1.5 MEV-REF.14.
1.5 TO 4.0 MEV - E.TRAPOLATION BASED ON DATA OF REF.26.
4.0 TO 8.52 MEV-REFS.11,12,15. ABOVE 10.0MEV-REFS.29, 30.
MF=5 SECONDARY ENERGY DISTRIBUTIONS
MT=4 NUCLEAR TEMP. FOR MA.WELLIAN DIS. ESTIMATED TO GIVE SAME AVERAGE ENERGY LOSS AS RESOLVED LEVELS AT 4 MEV. AND E.TRAPO-LATED TO HIGHER ENERGIES
MT=16 NUCLEAR TEMP. IS GIVEN FOR MA.WELLIAN DISTRIBUTION
MF=7 THERMAL SCATTERING LAW
MT=4 FREE GAS LAW USING FREE ATOM CROSS SECTION = 3.128.-REF. 2
Q VALUES FOR THRESHOLD REACTIONS ARE FROM REF. 24.

REFERENCES

1. CHART OF NUCLIDES - D. GOLDMAN, KAPL (1964).
2. HOCKENBURY,P.W.,BARTOLOME, Z.M., TATARCZUK, J.R., MOYER,W.R., AND BLOCK,R.C., PHYS. REV. 178, 1746 -1769 (1969).
3. MO.ON, M. C., PATTENDON, N. J., CN-23/27(1966 PARIS CONF.)
4. LE RIGOLEUR, C., ET AL., J. NUC. ENERGY A/B 20, 67 (1966).
5. RIBON, P., ET. AL., CN-23/72 (1966 PARIS CONF.)
6. JOKI, MILLER, EVANS, PHY. REV. 109,610 (1955)
7. WHALEN,J., AND SMITH, A.B., PRIVATE COMMUNICATION, ANL,(1970)
8. CIERJACKS,S.,FORTI,P.,KOPSCH,D., KROPP,L.,NEBE,J., AND UNSELD ,H., REVISED KFK DATA- KFK-1000,SUPPLEMENT 2 (1968)
9. STOLER,P.,YERGIN,P.F., CLEMENT,J.C., GOULDING,C.G., AND FAIRCHILD, R., THIRD CONFERENCE ON NEUTRON CROSS SECTIONS AND TECHNOLOGY, KNO.VILLE, MARCH 15-17 (1971)
10. PEREY, F.G., KINNEY,W.E. AND MACKLIN,R.L. THIRD CONFERENCE ON NEUTRON CROSS SECTIONS AND TECHNOLOGY, KNO.VILLE, MARCH 15-17, (TO BE PUBLISHED) (1971)
11. FASOLI,U., TONIOLO,D., ZAGO,G. AND BENZI,V., NUC. PHY. A125, 227-240 (1969)
12. PEREY,F.G., AND KINNEY,W.E., ORNL-4518, AUGUST (1970)
13. TOWLE,J.H., AND OWENS, NUCL.PHY. A100, 257 (1967)
14. CHIEN, J.P.,SMITH, A.B., NUC.SC.+ENG., 26,500 (1966)
15. TOWLE,J.H.,GILBOY,W.B., NUC. PHY. 32, 610 (1962)
16. FREEMAN,J., MONTAGUE, J., NUC. PHY. 9, 181 (1958)
17. LIND, D. A., ANN. OF PHYSICS 12, 485 (1961)
18. SHIPLEY, ET. AL., PHY. REV. 115, 122 (1959)
19. MENLOVE,H.O., COOP,K.L., GRENCH,H.A., AND SHER,R., PHYS.REV. 163, 1308-1314 (1967)

20. RAHN, F., CARMARDA,H., HACKEN,G., HAVENS ,W.JR., LIOU, H., RAINWATER, J., SLAGOWITZ, M., WYNCHANK,S., COLUMBIA UNIV. NEVIS LABORATORY (1968)
21. BAME, S. J., CUBITT, R. L., PHY. REV. 113, 256 (1959).
22. MENLOVE H. O., CONF-660303, VOL. 2 (1966).
23. BASS, R., ET AL., EANDC(E) 66U, P.64 (1966).
24. GARRISON, J.D. AND DRAKE, M.K. NDL-TR-89,PART2,GA-7829(1967)
25. LANE, R., MONAHAN, J., PHY.REV. 118, 533, (1960).
26. ELWYN, A.J., ET.AL., NUC. PHY. 59,113 (1964).
27. BNL-325 SECOND EDITION (1960) AND SUPP.*2 (1964).
28. YAMAMURO,N. ET.AL., NUC.SCI. ENG. 41,3,PP.445(1970).
29. CAMPBELL, R. ET.AL. NAA-SR-12533 (1968)
30. AGEE,F.P. AND ROSEN,L., LA-3538-MS, VOL.I AND II (1966)

SODIUM PHOTON PRODUCTION EVALUATION - ORNL AUGUST 1971

THE PREVIOUS PHOTON PRODUCTION EVALUATION FOR SODIUM BY M.K.DRAKE ET AL,MAT 5001, REF 1, WAS PERFORMED IN 1967. SINCE THEN, MUCH NEW E.PERIMENTAL INFORMATIONS HAVE BECOME AVAILABLE TO WARRANT A REVISION OF THIS EVALUATION IN THE LOWER ENERGY REGION. THIS REEVALUATION, MAT 1156, WAS ENDERTAKEN TO BE COMPATIBLE IN FORMAT WITH A REEVALUATION OF THE NEUTRON CROSS SECTIONS CONCURENTLY PERFORMED AT WARD. BECAUSE MUCH DATA WERE AVAILABLE AND DUE TO THE FORMATS CHOSEN, THESE PHOTON PRODUCTION FILES SHOULD BE QUITE RELIABLE UP TO 8 MEV INCIDENT NEUTRON ENERGY. ABOVE THAT ENERGY, WE HAVE BORROWED FROM MAT 5001 TO E.TEND THE FILES UP TO 15 MEV.

UP TO 8 MEV NEUTRON CAPTURE AND INELASTIC SCATTERING DOMINATE PHOTON PRODUCTION IN SODIUM. ALTHOUGH (N,P) AND (N,ALPHA) REACTIONS HAVE LOW THRESHOLDS, THE CROSS SECTIONS ARE SMALL BELOW 8 MEV AND CALCULATIONS INDICATE THAT MOSTLY THE GROUND STATES ARE POPULATED. THEREFORE WE HAVE NEGLECTED PHOTON PRODUCTION ARRISING FROM (N,P) AND (N,ALPHA) REACTIONS.

ABOVE 8 MEV THE ENERGY DISTRIBUTION FOR PHOTONS FOR MT=91 WAS FROM MAT 5001.

FILE 12

MT=51 TO 63

TRANSITION PROBABILITIES ARE RATHER WELL ESTABLISHED FOR THESE LEVELS AND THE VALUES ADOPTED FOLLOW THE REVIEW OF REF. 2. MT=58 REPRESENTS A DOUBLET OF LEVELS HAVING THE SAME SPIN BUT OPPOSITE PARITY. CALCULATIONS INDICATE THAT THE CROSS SECTIONS TO EACH MEMBER ARE EQUAL TO WITHIN A FEW PER CENT. THE TRANSITION PROBABILITIES FOR MT=58 ARE THE AVERAGE OF THOSES FOR THE TWO LEVELS.

MT=64 TO 68

EACH ONE OF THESE MT NUMBERS REPRESENT GROUPS OF LEVELS. NO E.PERIMENTAL DATA ARE AVAILABLE TO CORRECTLY DESCRIBE THE TRANSITION PROBABILITIES FOR MT=64 TO 68. FOR MT=64 AND 65 EQUAL PROBABILITY FOR DECAY TO THE GROUND STATE AND FIRST E.CITED STATE HAVE BEEN ASSIGNED. FOR MT=66 TO 68 WE HAVE GIVEN THE AVERAGE BRANCHING RATIO FOR 6 LEVELS SEEN FROM 6.9 TO 7.1 MEV IN REF. 3. THESE ASSIGNMENTS FOR MT=64 TO 68 SHOULD NOT

UNDERESTIMATE THE AMOUNT OF PENETRATING PHOTONS FOR THESE LEVELS

MT=91

THIS IS ADAPTED FROM MAT 5001, REF. 1.

MT=102

THE LOW ENERGY NEUTRON CAPTURE IN SODIUM IS DOMINATED BY THE 2.85 KEV RESONNANCE. THERE ARE NO DATA WHICH INDICATE THAT THE GAMMA RAY SPECTRUM OBSERVED AT THERMAL SHOULD NOT APPLY TO THE 2.85 KEV RESONNANCE. WE HAVE THEREFORE USED A SINGLE GAMMA RAY SPECTRUM TO DESCRIBE CAPTURE OVER THE COMPLETE ENERGY RANGE. THE MULTIPLICITIES WERE ARRIVED AT FROM A DECAY SCHEME BASED ON THE VERY CONSISTENT THERMAL CAPTURE DATA OF REF. 4 AND 5.

FILE 14

ALL GAMMA RAYS HAVE BEEN ASSUMED TO BE ISOTROPIC. THERE IS SUFFICIENT INFORMATION ON MANY TRANSITIONS TO GENERATE FAIRLY ACCURATE ANGULAR DISTRIBUTIONS SHOULD THE NEED ARRISE.

FILE 15

THE CONTINUOUS PHOTON ENERGY SPECTRA FOR MT=91 IN THIS FILE WERE TAKEN FROM MAT 5001.

FILE 23

THE SEMI-EMPIRICAL PHOTON CROSS SECTION INFORMATION IN THIS FILE IS FROM UCRL 50400

REFERENCES

1- M.K.DRAKE ET AL GA-7829
2- A.R.POLETTI ET AL PHYS. REV. C2-964 (1970)
3. C.P.SWANN NUC. PHYS. A167-201 (1971)
4. R.C.GREENWOOD PHYS. LETTERS 23-482 (1966) AND GIVEN IN BARTHOLOMEW ET AL NUC. DATA 3-367 (1967)
5. NICHOL ET AL CAN. JOUR. PHYS. 47-953 (1969)

NA-23 WARD-ORNL EVAL-1971 PAIK, PITTERLE, PEREY
MATERIAL= 4156 ZA= 11023. AWR = 22.7923 FILE= 1 SECTION= 451

FILE	SECTION	DESCRIPTION	NO OF CARDS
1	451	DESCRIPTIVE	283
1	453	DECAY CHAIN	11
2	151	RESONANCE	13
3	1	TOTAL	608
3	2	ELASTIC	592
3	3	NON-ELASTIC	152
3	4	(N,N*) TOTAL	94
3	16	(N,2N)	6
3	51	(N,N*) LEVEL	95
3	52	(N,N*) LEVEL	32
3	53	(N,N*) LEVEL	27
3	54	(N,N*) LEVEL	24
3	55	(N,N*) LEVEL	24
3	56	(N,N*) LEVEL	20
3	57	(N,N*) LEVEL	16
3	58	(N,N*) LEVEL	15
3	59	(N,N*) LEVEL	13
3	60	(N,N*) LEVEL	12
3	61	(N,N*) LEVEL	12
3	62	(N,N*) LEVEL	12
3	63	(N,N*) LEVEL	11
3	64	(N,N*) LEVEL	11
3	65	(N,N*) LEVEL	11
3	66	(N,N*) LEVEL	10
3	67	(N,N*) LEVEL	8
3	68	(N,N*) LEVEL	9
3	91	(N,N*) CONT	7
3	102	(N,GAMMA)	20
3	103	(N,P)	37
3	107	(N,ALPHA)	37
3	251	MU BAR	21
3	252	XI	21
3	253	GAMMA	21
4	2	ELASTIC	225
4	16	(N,2N)	10
4	51	(N,N*) LEVEL	10
4	52	(N,N*) LEVEL	10
4	53	(N,N*) LEVEL	10
4	54	(N,N*) LEVEL	10
4	55	(N,N*) LEVEL	10
4	56	(N,N*) LEVEL	10
4	57	(N,N*) LEVEL	10
4	58	(N,N*) LEVEL	10
4	59	(N,N*) LEVEL	10
4	60	(N,N*) LEVEL	10
4	61	(N,N*) LEVEL	10
4	62	(N,N*) LEVEL	10
4	63	(N,N*) LEVEL	10
4	64	(N,N*) LEVEL	10
4	65	(N,N*) LEVEL	10

NA-23 WARD-ORNL EVAL-1971 PAIK, PITTERLE, PEREY
MATERIAL= 4156 ZA= 11023. AWR = 22.7923 FILE= 1 SECTION= 451

FILE	SECTION	DESCRIPTION	NO OF CARDS
4	66	(N,N*) LEVEL	10
4	67	(N,N*) LEVEL	10
4	68	(N,N*) LEVEL	10
4	91	(N,N*) CONT	10
5	16	(N,2N)	7
5	91	(N,N*) CONT	8
7	4	(N,N*) TOTAL	4
12	51	(N,N*) LEVEL	3
12	52	(N,N*) LEVEL	3
12	53	(N,N*) LEVEL	3
12	54	(N,N*) LEVEL	3
12	55	(N,N*) LEVEL	3
12	56	(N,N*) LEVEL	3
12	57	(N,N*) LEVEL	4
12	58	(N,N*) LEVEL	4
12	59	(N,N*) LEVEL	3
12	60	(N,N*) LEVEL	3
12	61	(N,N*) LEVEL	3
12	62	(N,N*) LEVEL	3
12	63	(N,N*) LEVEL	3
12	64	(N,N*) LEVEL	3
12	65	(N,N*) LEVEL	3
12	66	(N,N*) LEVEL	5
12	67	(N,N*) LEVEL	5
12	68	(N,N*) LEVEL	5
12	91	(N,N*) CONT	8
12	102	(N,GAMMA)	187
14	51	(N,N*) LEVEL	1
14	52	(N,N*) LEVEL	1
14	53	(N,N*) LEVEL	1
14	54	(N,N*) LEVEL	1
14	55	(N,N*) LEVEL	1
14	56	(N,N*) LEVEL	1
14	57	(N,N*) LEVEL	1
14	58	(N,N*) LEVEL	1
14	59	(N,N*) LEVEL	1
14	60	(N,N*) LEVEL	1
14	61	(N,N*) LEVEL	1
14	62	(N,N*) LEVEL	1
14	63	(N,N*) LEVEL	1
14	64	(N,N*) LEVEL	1
14	65	(N,N*) LEVEL	1
14	66	(N,N*) LEVEL	1
14	67	(N,N*) LEVEL	1
14	68	(N,N*) LEVEL	1
14	91	(N,N*) CONT	1
14	102	(N,GAMMA)	1
15	91	(N,N*) CONT	48
23	501	TOTAL PHOTON	18
23	502	COHERENT	18

NA-23 WARD-ORNL EVAL-1971 PAIK, PITTERLE, PEREY
MATERIAL= 4156 ZA= 11023. AWR = 22.7923 FILE= 1 SECTION= 451

FILE	SECTION	DESCRIPTION	NO OF CARDS
23	504	INCOHERENT	18
23	516	PAIR PRD TOT	9
23	602	PHOTOELECTRC	18

TAPE NUMBER = 1

TANTALUM-181 MOD 0 FEB. 1972 HOWERTON, PERKINS, MACGREGOR

TA-181 LLL EVAL-JAN72 HOWERTON, PERKINS, MACGREGOR
MATERIAL= 4179 ZA= 73181. AWR = 179.3900 FILE= 1 SECTION= 451

DIST-JAN72 MOD 0-FEB72

********** DNA 4179 MOD 0 **********

FILE 23 DATA - PHOTON INTERACTION - TAKEN FROM RSIC DATA LIBRARY (DLC-7 D) IS BASED ON DATA FROM UCRL-50174 SEC. II, REV. 1969 BY MCMASTER ET AL. AND UCRL-50400, VOL. VI BY PLECHATY AND TERRALL.

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TA-181 EVALUATED NEUTRON CROSS SECTIONS
EVALUATED BY R.J.HOWERTON, S.T.PERKINS, AND M.MACGREGOR
LAWRENCE LIVERMORE LABORATORY, LIVERMORE, CALIFORNIA
JANUARY 1971

GENERAL COMMENTS

THE NEUTRON ENERGY RANGE EXTENDS FROM .0001 EV TO 20 MEV. IN ADDITION TO ELASTIC SCATTERING, WHICH OCCURS AT ALL ENERGIES, THE FOLLOWING REACTIONS HAVE THRESHOLD (UCRL-50400, VOL. 9) ENERGIES LESS THAN 20 MEV.

REACTION	THRESHOLD (MEV)
N,2N	7.69
N,3N	14.3
N,P	0.24
N,NP	5.97
N,D	3.73
N,ND	11.16
N,T	4.87
N,NT	11.00
N,HE3	6.20
N,NHE3	13.24
N,ALPHA	EXOERGIC
N,N ALPHA	EXOERGIC
N,GAMMA	EXOERGIC

ALL CHARGED PARTICLE PRODUCING REACTIONS, EXCEPT THE (N,P) PROCESS WILL BE NEGLECTED AS THERE ARE ESSENTIALLY NO MEASUREMENTS. THE CROSS SECTIONS FOR ELASTIC SCATTERING, (N,2N), (N,3N), (N,P), (N,GAMMA), AND (N,X GAMMA) REACTIONS ARE DISCUSSED BELOW.

THE DATA BASE FOR THE EVALUATION IS GIVEN IN UCRL-50400, VOL. 2 AND 3. REFERENCES NOT SPECIFICALLY CITED HERE ARE GIVEN IN THESE TWO VOLUMES.

NEUTRON CROSS SECTIONS

ELASTIC SCATTERING CROSS SECTION

THE ELASTIC SCATTERING CROSS SECTIONS IS EQUAL TO 6.25 BARNS AT 0.0253 EV, THE DIFFERENCE BETWEEN THE TOTAL AND N,GAMMA CROSS SECTIONS, AND IS ESSENTIALLY CONSTANT OVER THE THERMAL ENERGY REGION. IN THE RESOLVED RESONANCE REGION, UP TO ABOUT 300 EV, THE CROSS SECTION WAS DETERMINED FROM A SINGLE LEVEL ANALYSIS FOR ZERO DEGREES KELVIN MATERIAL TEMPERATURE. THE PARAMETERS USED WERE THE RECOMMENDED SET IN BNL-325, SUPPL. 2, VOL. IIC (1966).

AT HIGHER ENERGIES, THE ELASTIC SCATTERING CROSS SECTION WAS TAKEN AS THE DIFFERENCE BETWEEN THE TOTAL AND THE NONELASTIC CROSS SECTION. THE NONELASTIC WAS DERIVED FROM THE SUM OF ITS PARTS WHERE DATA WERE AVAILABLE, FROM MEASUREMENTS OF THE NONELASTIC C/S WHERE AVAILABLE AND OTHERWISE FROM SYSTEMATICS.

ELASTIC SCATTERING ANGULAR DISTRIBUTIONS,
NORMALIZED PROBABILITIES

THE ELASTIC SCATTERING WAS ASSUMED TO BE ISOTROPIC IN THE CENTER OF MASS SYSTEM FOR ENERGIES LESS THAN 50 KEV. FROM 50 KEV TO 14.6 MEV, EXPERIMENTAL DATA WERE USED. OPTICAL MODEL CALCULATIONS WERE PERFORMED FOR HIGHER ENERGIES.

INELASTIC SCATTERING CROSS SECTION

THE EXCITATION FUNCTIONS FOR THE FIRST 6 LEVELS WERE OBTAINED FROM REF. 885. THE RESULTS WERE SMOOTHLY EXTRAPOLATED TO 10 MB AT 2-4 MEV AND KEPT CONSTANT TO 20 MEV.

THE TOTAL INELASTIC CROSS SECTION WAS BASED ON INDIVIDUAL LEVEL DATA AT ENERGIES OF THE ORDER OF ONE MEV. FROM 1 TO 20 MEV THERE ARE FEW MEASUREMENTS AND THE EXCITATION FUNCTION WAS ESTIMATED FROM NUCLEAR SYSTEMATICS. THE DIFFERENCE BETWEEN THE TOTAL INELASTIC AND THE LEVEL DATA WAS ASSIGNED TO THE INELASTIC CONTINUUM CROSS SECTION.

INELASTIC SCATTERING ANGULAR DISTRIBUTIONS,
NORMALIZED PROBABILITIES

THE LEVEL DATA WERE ASSUMED ISOTROPIC IN THE CENTER OF MASS SYSTEM AND THE CONTINUUM COMPONENT WAS ASSUMED ISOTROPIC IN THE LABORATORY SYSTEM.

INELASTIC SCATTERING ENERGY DISTRIBUTIONS

THE CONTINUUM INELASTIC SCATTERING ENERGY DISTRIBUTION IS COMPOSED OF AN EVAPORATION COMPONENT PLUS A HIGH ENERGY PRE-EQUILIBRIUM COMPONENT. THIS LATTER PORTION IS TAKEN CONSTANT OVER FINAL NEUTRON ENERGY AND ITS CONTRIBUTION INCREASES WITH THE INCIDENT NEUTRON ENERGY. THE EVAPORATION TEMPERATURE WAS ASSUMED TO VARY AS THE SQUARE ROOT OF THE INCIDENT NEUTRON ENERGY.

(N,2N) CROSS SECTION

THE (N,2N) EXCITATION FUNCTION WAS BASED MAINLY ON THE WORK OF REF. 2402, WITH A SMOOTH EXTRAPOLATION TO 20 MEV.

(N,2N) ENERGY DISTRIBUTIONS

THE FORMALISM OF THE TEMPERATURE MODEL WAS USED FOR CONVENI-

ENCE IN THE ABSENCE OF MEASUREMENT. THE EVAPORATION TEMPERATURE WAS SELECTED SUCH THAT ENERGY IS CONSERVED ON THE AVERAGE, INCLUDING GAMMA EMISSION.

(N,3N) CROSS SECTION

THE (N,3N) EXCITATION FUNCTION WAS BASED ON THE DIFFERENCE BETWEEN A CONSTANT NONELASTIC CROSS SECTION OF 2.45 BARNS AND THE SUM OF THE INELASTIC AND (N,2N) CROSS SECTIONS.

(N,3N) ENERGY DISTRIBUTIONS

THIS IS IDENTICAL IN CONTEXT TO THE SECTION ON (N,2N) ENERGY DISTRIBUTIONS.

(N,P) CROSS SECTION

THE (N,P) CROSS SECTION WAS BASED ON THE DATA OF REF. 2887, WITH SMOOTH EXTRAPOLATIONS TO THRESHOLD AND TO 20 MEV.

(N,GAMMA) CROSS SECTION

THE (N,GAMMA) CROSS SECTION IS EQUAL TO 21.9 BARNS AT 0.0253 EV AND IS 1/V OVER THE THERMAL REGION. IN THE RESOLVED RESONANCE REGION, THE CROSS SECTION (AT ZERO DEGREES KELVIN) WAS OBTAINED FROM A SINGLE LEVEL ANALYSIS - SEE SECTION UNDER ELASTIC SCATTERING CROSS SECTION.

FROM ABOUT 300 EV TO 10 KEV, THE LEAD SLOWING-DOWN-TIME SPECTROMETER DATA OF REF. 1960 WAS USED. THIS WAS MERGED SMOOTHLY INTO THE RELATIVELY LARGE AMOUNT OF DATA AVAILABLE FOR ENERGIES BELOW 5 MEV, AND SMOOTHLY EXTRAPOLATED TO 20 MEV.

GAMMA RAY PRODUCTION CROSS SECTIONS

(N,X GAMMA) CROSS SECTION FROM THE (N,GAMMA) REACTION

THE MULTIPLICITY FOR GAMMA RAYS, M(E), FROM THE (N,X GAMMA) REACTION, AS A FUNCTION OF INCIDENT NEUTRON ENERGY, E, WAS TAKEN AS M(E)=MO(BE+E)/BE, WHERE BE IS THE BINDING ENERGY. MO IS THE MULTIPLICITY AT ZERO NEUTRON ENERGY AND WAS TAKEN EQUAL TO 2.61 FROM THE THERMAL CAPTURE DATA OF REF. 2415. THE (N,X GAMMA) CROSS SECTION AT A NEUTRON ENERGY E IS EQUAL TO THE CORRESPONDING (N,GAMMA) CROSS SECTION TIMES THE MULTIPLICITY. NOTE THAT THE ASSUMED ENERGY VARIATION OF THE MULTIPLICITY CONSERVES ENERGY FOR THE REACTION WITH THE ENERGY DISTRIBUTION DESCRIBED BELOW.

(N,X GAMMA) ENERGY DISTRIBUTION FROM THE (N,GAMMA) REACTION

THE ENERGY DISTRIBUTION WAS TAKEN FROM THE THERMAL CAPTURE RESULTS OF REF. 2415. IT IS EXPRESSED IN A NORMALIZED HISTOGRAMMIC FORM WITH 250 KEV BINS, IN THE LLL LIBRARY BUT WAS CONVERTED TO A NORMALIZED PROBABILITY DISTRIBUTION FOR THE ENDF/B MAT 4540 BECAUSE THE ENDF/B FORMAT WILL ACCEPT ONLY THE LATTER TYPE DISTRIBUTION, AND IS ASSUMED INDEPENDENT OF INCIDENT NEUTRON ENERGY.

(N,X GAMMA) CROSS SECTION

THIS COMPONENT INCLUDES ALL GAMMA RAYS EXCEPT THAT FROM THE (N,GAMMA) REACTION.

FROM THE INELASTIC SCATTERING THRESHOLD TO 1 MEV, INDIVIDUAL GAMMA RAYS (0.137 AND 0.485 MEV) FROM INELASTIC SCATTERING WERE TAKEN FROM REF. 137, 140, AND 11. THE REMAINING PORTION OF THE (N,X GAMMA) CROSS SECTION WAS CALCULATED BY USING ENERGY CONSERVATION WITH THE EXISTING INELASTIC SCATTERING CROSS SECTION AND ASSUMING THAT THE EMERGENT NEUTRON TAKES HALF THE AVAILABLE ENERGY.

FROM 1 MEV TO 20 MEV, THE RECIPE OF HOWERTON AND PLECHATY (NUCL. SCI. ENG. 32, 178 (1968)) WAS USED TO OBTAIN THE CROSS SECTION.

(N,X GAMMA) ENERGY DISTRIBUTIONS

THIS COMPONENT, EXTENDING FROM AN INCIDENT NEUTRON ENERGY OF THRESHOLD FOR INELASTIC SCATTERING TO 1 MEV, INCLUDES ONLY GAMMA RAYS FROM INELASTIC SCATTERING. IT IS EXPRESSED IN A NORMALIZED HISTOGRAMMIC FORM WITH 250 KEV BIN WIDTH (SEE COMMENT ABOVE ABOUT CONVERSION TO NORMALIZED PROBABILITIES FOR ENDF/B MAT 4540). INCLUDED ARE THE 0.137 AND 0.485 MEV PHOTONS AS WELL AS THOSE FROM THE REMAINING PORTION OF THE (N,X GAMMA) CROSS SECTION. THE PHOTON ENERGY FROM THIS LATTER COMPONENT WAS DISTRIBUTED UNIFORMLY OVER THE AVAILABLE BINS.

FROM 1 TO 20 MEV, IT WAS ASSUMED THAT ONLY CONTINUUM GAMMA RAYS WERE PRESENT, AND THE RECIPE OF HOWERTON AND PLECHATY (NUCL. SCI. ENG. 32, 178 (1968)) WAS USED. THIS DISTRIBUTES THE PHOTONS IN AN EVAPORATION SPECTRA. THE INVERSE TEMPERATURE, R, FOR THIS DISTRIBUTION WAS TAKEN FROM WORK ON GAMMAS FROM INELASTIC NEUTRON SCATTERING ONTO TUNGSTEN (REF. 1019 AND 1497). THE ADDED ASSUMPTION WAS MADE, BASED ON EXPERIMENTAL RESULTS, THAT THE INVERSE TEMPERATURE IS PROPORTIONAL TO 1/U, WHERE U IS THE AVAILABLE EXCITATION ENERGY IN THE RESIDUAL NUCLEUS. THIS PRODUCES SHARP CHANGES IN THE SPECTRA WHEN GAMMAS FROM OTHER REACTIONS, E.G., (N,2N) AND (N,3N), BECOME PREDOMINANT.

REFERENCES

REFERENCE NUMBERS QUOTED HERE REFER TO DATA IN THE LLL EXPERIMENTAL NEUTRON CROSS SECTION LIBRARY. SEE UCRL-50400, VOL. 2 AND 3 FOR COMMENTS AND INDEXES TO THE DATA, AS WELL AS FOR OTHER EXPERIMENTAL RESULTS THAT WERE USED IN THE EVALUATION.

11. ANN. PHYS. 12, 485 (1961) D.A.LIND, R.B.DAY (U.COLORADO)
137. PHYS. REV. 101, 1516 (1956) J.B.GURNSEY, A.WATTENBERG (MIT)
140. PHYS. REV. 102, 767 (1956) R.B.DAY (LASL)
885. PRIVATE COMMUNICATION (1966) A.B.SMITH (ANL)
1019. PRIVATE COMMUNICATION (1968) W.E.TUCKER (TEXAS NUCLEAR)
1497. NUCLEAR SCI. ENG. 40, 294 (1970) D.M.DRAKE ET AL. (LASL)
1960. J.EXPTL.THEORET.PHYS. (USSR) 46, 80 (1964) V.A.KONKS ET AL.

TA-181 LLL EVAL-JAN72 HOWERTON, PERKINS, MACGREGOR
MATERIAL= 4179 ZA= 73181. AWR = 179.3900 FILE= 1 SECTION= 451

2402. INR-795/I/PL (1967) J.BRZOSKO ET AL. (POLAND)
2415. GA-10248 (DASA-2570) (1970) N.C.RASMUSSEN ET AL. (GGA)
2887. NUCLEAR PHYS. 123, 603 (1969) J.S.BRZOSKO ET AL. (POLAND)

TA-181 LLL EVAL-JAN72 HOWERTON, PERKINS, MACGREGOR
MATERIAL= 4179 ZA= 73181. AWR = 179.3900 FILE= 1 SECTION= 451

FILE	SECTION	DESCRIPTION	NO OF CARDS
1	451	DESCRIPTIVE	245
2	151	RESONANCE	4
3	1	TOTAL	887
3	2	ELASTIC	351
3	4	(N,N*) TOTAL	18
3	16	(N,2N)	7
3	17	(N,3N)	5
3	51	(N,N*) LEVEL	8
3	52	(N,N*) LEVEL	6
3	53	(N,N*) LEVEL	7
3	54	(N,N*) LEVEL	7
3	55	(N,N*) LEVEL	6
3	56	(N,N*) LEVEL	6
3	91	(N,N*) CONT	8
3	102	(N,GAMMA)	616
3	103	(N,P)	5
4	2	ELASTIC	115
4	16	(N,2N)	8
4	17	(N,3N)	8
4	51	(N,N*) LEVEL	10
4	52	(N,N*) LEVEL	10
4	53	(N,N*) LEVEL	10
4	54	(N,N*) LEVEL	10
4	55	(N,N*) LEVEL	10
4	56	(N,N*) LEVEL	10
4	91	(N,N*) CONT	8
5	16	(N,2N)	64
5	17	(N,3N)	60
5	91	(N,N*) CONT	109
12	102	(N,GAMMA)	4
13	3	NON-ELASTIC	11
14	3	NON-ELASTIC	1
14	102	(N,GAMMA)	1
15	3	NON-ELASTIC	224
15	102	(N,GAMMA)	18
23	501	TOTAL PHOTON	23
23	502	COHERENT	23
23	504	INCOHERENT	23
23	516	PAIR PRD TOT	9
23	602	PHOTOELECTRC	23

TAPE NUMBER = 1

NATURAL IRON MOD 0 MAR. 1972 PENNY,KINNEY,WRIGHT,PEREY,FU

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     IRON       ORNL        EVAL-1970  PENNY,KINNEY,WRIGHT,PEREY,FU
MATERIAL= 4180   ZA= 26000.   AWR =  55.3650      FILE=  1   SECTION= 451

     ORNL-4617(1970)       DIST-MAR72 MOD 0-MAR72

     ****************************    DNA 4180 MOD 0   ***************

              THIS DATA IS FROM ENDF/B-III, MAT=1180     (BNL)

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     *         *          *          *         *          *          *
     DATA MODIFIED JAN.1972
     THE 2200 M/SEC CROSS SECTION WAS CHANGED TO 2.56 BARNS TO
     CONFORM TO THE CSEWG NORMALIZATION AND STANDARDS SUBCOMMITTEE
     RECOMMENDED VALUE. ALL LOW ENERGY RADIATIVE CAPTURE CROSS
     SECTIONS WERE MODIFIED BELOW 500 EV TO BE CONSISTENT
     *         *          *          *         *          *          *
     NATURAL IRON                    DEC. 1971
     *         *          *          *         *          *          *
     NATURAL IRON       DEC. 1971-ORNL-PENNY,KINNEY,WRIGHT,PEREY,FU


              DETAILS OF THE EVALUATION ARE REPORTED IN
        S.K. PENNY AND W.E. KINNEY, A RE-EVALUATION OF NATURAL IRON
        NEUTRON AND GAMMA-RAY-PRODUCTION CROSS SECTIONS, ENDF/B MATER-
        IAL 1124, ORNL-4617  ENDF-139   1970

              THE GAMMA-RAY PRODUCTION FILES HAVE BEEN MODIFIED
         TAKING INTO ACCOUNT THE DATA OF ORPHAN AND HOOT, REF. 50.


    FILE 2 RESONANCE PARAMETERS
         MULTILEVEL BREIT-WIGNER PARAMETERS ARE GIVEN FOR FE-54, FE-56
         , AND FE-57 FOR THE ENERGY RANGE 1-60 KEV.
         REFS. 1 AND 2.
    FILE 3 NEUTRON CROSS SECTIONS
       SECTION 1 TOTAL INTERACTION
           .00001 EV TO 330 KEV --- REFS. 1, 2, AND 3.
           BACKGROUND CORRECTIONS FOR THE 24-KEV WINDOW HAVE BEEN EN-
           TERED TO RAISE THE MINIMUM TO 425 MBNS.----PRELIMINARY RE-
           SULTS FROM ORELA MEASUREMENTS OF JACK HARVEY ET AL.
           330 KEV TO 15 MEV --- REFS. 4, 5, 6, AND 7.
       SECTION 2 ELASTIC SCATTERING
           DERIVED BY SUBTRACTING THE NON-ELASTIC CROSS SECTION FROM
           THE TOTAL CROSS SECTION.
       SECTION 3 NON-ELASTIC INTERACTION
           DERIVED BY ADDING THE TOTAL INELASTIC SCATTERING,  N,2N ,
           CAPTURE,  N,A , AND  N,P  CROSS SECTIONS.
       SECTION 4 TOTAL INELASTIC SCATTERING
           DERIVED BY ADDING INELASTIC SCATTERING CROSS SECTIONS FOR
           EXCITING DISCRETE LEVELS AND THE CONTINUUM OF LEVELS.
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SECTION 16  N,2N  REACTION
    REF. 8
SECTION 51 INELASTIC SCATTERING EXCITING FIRST LEVEL IN FE-56
    0.8611 MEV TO 1.5 MEV --- REFS. 8 AND 9.
    1.5 MEV TO 2.122 MEV --- REFS. 9 AND 10.
    2.122 MEV TO 15 MEV --- REFS. 11 - 19, 47, AND 48.
SECTION 52 INELASTIC SCATTERING EXCITING FIRST LEVEL IN FE-54
    REF. 4
SECTION 53 INELASTIC SCATTERING EXCITING SECOND THROUGH
 /THROUGH/      NINETEENTH LEVELS IN FE-56.
SECTION 70
    REFS. 11 - 19, 47, AND 48.
SECTION 91 INELASTIC SCATTERING EXCITING THE CONTINUUM
    REFS. 11 AND 20.
SECTION 102 RADIATIVE CAPTURE
    Q-VALUE IS AVERAGED WITH THERMAL CROSS SECTIONS.
    REFS. 1 AND 2.
SECTION 103  N,P  REACTION
    Q-VALUE IS AVERAGED WITH ABUNDANCES.
    REFS. 3 AND 4.
SECTION 107  N,A  REACTION
    Q-VALUE IS AVERAGED WITH ABUNDANCES.
    REFS. 3 AND 4.
SECTION 251 MU BAR
    DERIVED FROM ELASTIC SCATTERING ANGULAR DISTRIBUTIONS AND
    KINEMATICS USING THE COMPUTER PROGRAM SAD.
SECTION 252 XI
    SEE SECTION 251.
SECTION 253 GAMMA
    SEE SECTION 251.
FILE 4 ANGULAR DISTRIBUTIONS OF SECONDARY NEUTRONS
     ALL DISTRIBUTIONS ARE GIVEN IN THE CENTER OF MASS SYSTEM IN
     THE LEGENDRE POLYNOMIAL REPRESENTATION.
SECTION 2 ELASTIC SCATTERING
    .00001 EV TO 1.23 MEV --- REFS. 21, 22, AND 23.
    1.23 MEV TO 4 MEV --- REFS. 11, 12, AND 24 THROUGH 34.
    4 MEV TO 15 MEV --- REFS.   11, 12, AND 24.
    TRANSFORMATION MATRIX GIVEN WAS CALCULATED USING THE COMP-
    UTER PROGRAM SAD.
SECTION 16  N,2N  REACTION
    BOTH NEUTRONS ARE ASSUMED TO BE ISOTROPIC.
SECTION 51 INELASTIC SCATTERING EXCITING FIRST LEVEL IN FE-56
    REFS. 11 THROUGH 19.
SECTION 52 INELASTIC SCATTERING EXCITING FIRST LEVEL IN FE-54
    ASSUMMED ISOTROPIC.
SECTION 53 INELASTIC SCATTERING EXCITING SECOND THROUGH
 /THROUGH/      NINETEENTH LEVELS IN FE-56.
SECTION 70
    REFS. 11 THROUGH 19.
SECTION 91 INELASTIC SCATTERING EXCITING THE CONTINUUM
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ASSUMMED ISOTROPIC --- REF. 11.
FILE 5 ENERGY DISTRIBUTIONS OF SECONDARY NEUTRONS
SECTION 16 N,2N REACTION
REF. 49.
SECTION 91 INELASTIC SCATTERING EXCITING THE CONTINUUM
THERE ARE TWO LAWS FOR THIS SECTION NAMELY, A MAXWELLIAN DISTRIBUTION, WHICH HAS A NON-ZERO PROBABILITY ONLY AFTER 7.2 MEV INCIDENT NEUTRON ENERGY, AND AN ARBITRARY TABULATED DISTRIBUTION. --- REFS. 11, 47, AND 48.
FILE 12 MULTIPLICITIES OF GAMMA RAYS PRODUCED BY NEUTRON REACTIONS
THERE IS NO REPETITION OF GAMMA RAYS IN THIS FILE. TO ACCOUNT FOR ALL GAMMA RAYS ONE MUST TAKE THE JOIN OF ALL SECTIONS.
SECTION 3 NON-ELASTIC INTERACTION
THESE GAMMA RAYS ARE FROM N,N* , N,A , AND N,P REACTIONS IN FE-56. THE REPRESENTATION IS A CONTINUUM DISTRIBUTION AND THE NEUTRON ENERGY RANGE IS 2.122 MEV TO 15 MEV. REFS. 11 THROUGH 19, 35, 36, 37, AND 50.
SECTION 16 N,2N REACTION
THESE GAMMA RAYS ARE TREATED AS A CONTINUUM DISTRIBUTION.
SECTION 51 INELASTIC SCATTERING EXCITING FIRST LEVEL IN FE-56
NEUTRON ENERGY RANGE IS 0.8611 TO 2.122 MEV. ONE DISCRETE GAMMA RAY IS GIVEN.
SECTION 52 INELASTIC SCATTERING EXCITING FIRST LEVEL IN FE-54
ONE DISCRETE GAMMA RAY IS GIVEN.
SECTION 102 RADIATIVE CAPTURE
THESE GAMMA RAYS ARE REPRESENTATIVE OF NEUTRON ENERGY RANGES. THE LAST RANGE STRICTLY EXTENDS ONLY TO 1 MEV BUT IS ASSUMMED TO EXTEND TO 15 MEV. THE GAMMA RAYS ARE TREATED AS A CONTINUUM DISTRIBUTION.
REFS. 1, 2, 15, 18, AND 38 THROUGH 44.
FILE 14 ANGULAR DISTRIBUTIONS OF SECONDARY GAMMA RAYS
THE SECTIONS CORRESPOND TO THE SECTIONS IN FILE 12 AND IT IS ASSUMED THAT ALL THE DISTRIBUTIONS ARE ISOTROPIC.
FILE 15 ENERGY DISTRIBUTIONS OF SECONDARY GAMMA RAYS.
THE DISTRIBUTIONS ARE HISTOGRAMS WITH UNIFORM GAMMA RAY ENERGY WIDTHS OF 50 KEV. --- REFS. SEE FILE 12
FILE 23 PHOTON INTERACTION CROSS SECTIONS
REFS. 45 AND 46.
SECTION 501 TOTAL INTERACTION
SECTION 502 COHERENT SCATTERING
SECTION 504 INCOHERENT SCATTERING
SECTION 516 PAIR PRODUCTION PLUS TRIPLET PRODUCTION
SECTION 602 PHOTOELECTRIC INTERACTION

REFERENCES

1. J.S. STORY, U.K.A.E.A. WINFRITH, PRIVATE COMMUNICATION 1970
2. R.W. HOCKENBURY ET AL., PHYS. REV. 178, P.1746 1969
3. J.J. SCHMIDT, NEUTRON CROSS SECTIONS FOR FAST REACTOR MATERIALS, PART I - EVALUATION, KFK-120 EANDC-E 35 U 1966
4. D.C. IRVING AND E.A. STRAKER, EVALUATION OF THE CROSS SECTIONS

OF IRON- ENDF/B MAT-1101, ORNL-TM-2891 ENDF-138 1970
5. S. CIERJACKS ET AL., HIGH RESOLUTION TOTAL NEUTRON CROSS SECTIONS BETWEEN 0.5 AND 30 MEV, KFK-1000 1968
6. A.D. CARLSON AND R.J. CERBONE, HIGH RESOLUTION MEASUREMENTS OF THE TOTAL NEUTRON CROSS SECTIONS OF NITROGEN AND IRON, GA-9149 1969
7. E. BARNARD ET AL., NUCL. PHYS. A118, 321 1968
8. NESTOR AZZIZ ET AL., IRON, NICKEL, AND CHROMIUM NEUTRON CROSS SECTIONS FROM 0 TO 15 MEV, WCAP 7281 ENDF-129 1969
9. R.L. MACKLIN, ORNL, PRIVATE COMMUNICATION
10. W.B. GILBOY AND J.H. TOWLE, NUCL. PHYS. 64, 130 1965
11. W.E. KINNEY AND F.G. PEREY, NEUTRON ELASTIC- AND INELASTIC-SCATTERING CROSS SECTIONS FOR FE-56 IN THE ENERGY RANGE 4.19 TO 8.56 MEV, ORNL-4515 1970
12. S.K. PENNY, HELENE-A COMPUTER PROGRAM TO CALCULATE NUCLEAR CROSS SECTIONS EMPLOYING THE HAUSER-FESHBACH MODEL, PORTER-THOMAS WIDTH FLUCTUATIONS, AND CONTINUUM STATES, ORNL-TM-2590 1969
13. A. ASPINALL ET AL., NUCL. PHYS. 46, 33 1963 - A. SPERDUTO AND N.W. BUECHNER, PHYS. REV. 134, B142 1964 - A.D. KATSANOS ET AL., PHYS. REV. 141, 1053 1966 - G. BROWN ET AL., NUCL. PHYS. 77, 365 1966 - B.L. COHEN AND R. MIDDLETON, PHYS. REV. 146, 748 1966 - J.R. MACDONALD AND M.A. GRACE, NUCL. PHYS. A92, 593 1967 - P.F. HENRICHSEN ET AL., NUCL. PHYS. A101, 81 1967 - K. VAUGHAN ET AL., NUCL. PHYS. A130, 62 1969
14. M.N. RAO ET AL., NUCL. PHYS. A121, 1 1968
15. NUCLEAR DATA GROUP, NUCLEAR DATA SHEETS B3, NOS. 3-4, ACADEMIC PRESS, 1970
16. R.H. BASSEL, PRIVATE COMMUNICATION
17. C.M. PEREY ET AL., DISTORTED-WAVE BORN ANALYSIS OF 11-MEV PROTON SCATTERING, NEUT. PHYS. DIV. ANN. PROGR. REPT. FOR PERIOD ENDING MAY 31, 1967, ORNL-4134 1967
18. A. GILBERT AND A.G.W. CAMERON, CAN. J. PHYS. 43, 1446 1965
19. R. H. BASSEL ET AL., THE DISTORTED WAVE THEORY OF DIRECT NUCLEAR REACTIONS, ORNL-3240 1962
20. M.D. GOLDBERG ET AL., NEUTRON CROSS SECTIONS, VOL. IIA, Z 21 TO 40, BNL-325, 2ND ED., SUPPL. 2 1966
21. S.A. COX, BULL. AM. PHYS. SOC. 8, 478 1963
22. I.O. KORZH AND M.T. SKYLAR, UKR. FIZ. ZH. 8, 1389 1963
23. M.V. PASECHNIK ET AL., AT. EN. USSR 16, 207 1964
24. F.G. PEREY, ORNL, PRIVATE COMMUNICATION
25. W.D. WHITEHEAD AND S.C. SNOWDON, PHYS. REV. 92, 114 1953
26. NORMAN A. BOSTROM ET AL., WADC-TR-59-31 1959
27. B. HOLMQVIST, ARKIV FYSIK 38, 403 1968
28. K. TSUKADA ET AL., EAN J 3, 18 1966
29. C. O. MUEHLHAUSE ET AL., PHYS. REV. 103, 720 1956
30. H.H. LANDON ET AL., PHYS. REV. 112, 1192 1958
31. LAWRENCE CRANBERG AND JULES S. LEVIN, PHYS. REV. 103, 343 1969
32. J.R. BEYSTER ET AL., PHYS. REV. 104, 1319 1956

33. R.L. BECKER ET AL., NUCL. PHYS. 89, 154 1966
34. M.K. MACHWE ET AL., PHYS. REV. 114, 1563 1959
35. J.B. MCGRORY, PHYS. REV. 160, 915 1967
36. J.K. DICKENS, ORNL, PRIVATE COMMUNICATION
37. R.E. MAERKER AND F.J. MUCKENTHALER, GAMMA-RAY SPECTRA ARISING FROM FAST-NEUTRON INTERACTIONS IN ELEMENTS FOUND IN SOILS, CONCRETES, AND STRUCTURAL MATERIALS, ORNL-4475 1970
38. J.E. WHITE, ORNL, PRIVATE COMMUNICATION
39. K.J. YOST, NUCL. SCI. ENG. 32, 62 1968
40. R.E. CHRIEN ET AL., GAMMA RAYS FOLLOWING RESONANT NEUTRON CAPTURE IN FE-56, BNL-14104 1970
41. B.B.V. RAJU ET AL., THE MEASUREMENT OF THERMAL NEUTRON CAPTURE GAMMA RAYS IN IRON, COBALT, AND SCANDIUM, AAEC/TM 512 1969
42. NORMAN C. RASMUSSEN ET AL., THERMAL NEUTRON CAPTURE GAMMA-RAY SPECTRA OF THE ELEMENTS, AECRL-69-0071 MTNE-85 1969
43. C.Y. FU, ORNL, PRIVATE COMMUNICATION
44. S.K. PENNY, AVA, TO BE PUBLISHED
45. W.H. MCMASTER ET AL., COMPILATION OF X-RAY CROSS SECTIONS, UCRL 50174 SEC. II, REV. 1 1969
46. ERNEST F. PLECHATY AND JOHN R. TERRALL, AN INTEGRATED SYSTEM FOR PRODUCTION OF NEUTRON IC AND PHOTONIC CALCULATIONAL CONSTANTS-VOL. VI PHOTON CROSS SECTIONS 1 KEV TO 100 MEV, UCRL 50400 1968
47. G.S. MANI, SPIN ASSIGNMENTS TO EXCITED STATES OF FE-56 USING INELASTIC PROTON SCATTERING, SCHUSTER LABORATORY, MANCHESTER UNIVERSITY, MANCHESTER, ENGLAND 1970
48. R.J. PETERSON, ANNALS OF PHYSICS 53, 40 1969
49. SURESH C. MATHUR ET AL., PHYS. REV. 186, 1038 1969
50. V.J. ORPHAN AND C.G. HOOT, GAMMA-RAY PRODUCTION CROSS SECTIONS FOR IRON AND ALUMINUM, GULF-RT-A10743, 1971

IRON ORNL EVAL-1970 PENNY,KINNEY,WRIGHT,PEREY,FU
MATERIAL= 4180 ZA= 26000. AWR = 55.3650 FILE= 1 SECTION= 451

FILE	SECTION	DESCRIPTION	NO OF CARDS
1	451	DESCRIPTIVE	309
2	151	RESONANCE	45
3	1	TOTAL	1268
3	2	ELASTIC	764
3	3	NON-ELASTIC	326
3	4	(N,N*) TOTAL	461
3	16	(N,2N)	6
3	51	(N,N*) LEVEL	431
3	52	(N,N*) LEVEL	34
3	53	(N,N*) LEVEL	13
3	54	(N,N*) LEVEL	13
3	55	(N,N*) LEVEL	12
3	56	(N,N*) LEVEL	13
3	57	(N,N*) LEVEL	12
3	58	(N,N*) LEVEL	14
3	59	(N,N*) LEVEL	14
3	60	(N,N*) LEVEL	16
3	61	(N,N*) LEVEL	13
3	62	(N,N*) LEVEL	13
3	63	(N,N*) LEVEL	13
3	64	(N,N*) LEVEL	14
3	65	(N,N*) LEVEL	14
3	66	(N,N*) LEVEL	13
3	67	(N,N*) LEVEL	12
3	68	(N,N*) LEVEL	14
3	69	(N,N*) LEVEL	14
3	70	(N,N*) LEVEL	15
3	91	(N,N*) CONT	11
3	102	(N,GAMMA)	97
3	103	(N,P)	44
3	107	(N,ALPHA)	24
3	251	MU BAR	37
3	252	XI	37
3	253	GAMMA	37
4	2	ELASTIC	282
4	16	(N,2N)	8
4	51	(N,N*) LEVEL	260
4	52	(N,N*) LEVEL	8
4	53	(N,N*) LEVEL	45
4	54	(N,N*) LEVEL	40
4	55	(N,N*) LEVEL	39
4	56	(N,N*) LEVEL	35
4	57	(N,N*) LEVEL	35
4	58	(N,N*) LEVEL	35
4	59	(N,N*) LEVEL	31
4	60	(N,N*) LEVEL	30
4	61	(N,N*) LEVEL	31
4	62	(N,N*) LEVEL	31
4	63	(N,N*) LEVEL	32
4	64	(N,N*) LEVEL	29

IRON ORNL EVAL-1970 PENNY,KINNEY,WRIGHT,PEREY,FU
MATERIAL= 4180 ZA= 26000. AWR = 55.3650 FILE= 1 SECTION= 451

FILE	SECTION	DESCRIPTION	NO OF CARDS
4	65	(N,N*) LEVEL	26
4	66	(N,N*) LEVEL	27
4	67	(N,N*) LEVEL	27
4	68	(N,N*) LEVEL	25
4	69	(N,N*) LEVEL	25
4	70	(N,N*) LEVEL	25
4	91	(N,N*) CONT	8
5	16	(N,2N)	549
5	91	(N,N*) CONT	2132
12	3	NON-ELASTIC	12
12	16	(N,2N)	5
12	51	(N,N*) LEVEL	4
12	52	(N,N*) LEVEL	9
12	102	(N,GAMMA)	8
14	3	NON-ELASTIC	1
14	16	(N,2N)	1
14	51	(N,N*) LEVEL	1
14	52	(N,N*) LEVEL	1
14	102	(N,GAMMA)	1
15	3	NON-ELASTIC	1030
15	16	(N,2N)	74
15	102	(N,GAMMA)	837
23	501	TOTAL PHOTON	18
23	502	COHERENT	18
23	504	INCOHERENT	18
23	516	PAIR PRD TOT	9
23	602	PHOTOELECTRC	18

TAPE NUMBER = 1

URANIUM-238 MOD 0 JULY 1972 HOWERTON, MACGREGOR

U-238 LLL EVAL-MAR72 HOWERTON, MACGREGOR
MATERIAL= 4187 ZA= 92238. AWR = 236.0100 FILE= 1 SECTION= 451

DIST-JUL72 MOD 0-JUL72

********** DNA 4187 MOD 0 **********

U-238 EVALUATED NEUTRON CROSS SECTIONS
EVALUATED BY R.J.HOWERTON AND M.H.MACGREGOR
LAWRENCE LIVERMORE LABORATORY, LIVERMORE, CALIFORNIA
MARCH 1972

GENERAL COMMENTS

THE NEUTRON ENERGY RANGE EXTENDS FROM .0001 EV TO 20 MEV. IN ADDITION TO ELASTIC SCATTERING, WHICH OCCURS AT ALL ENERGIES, THE FOLLOWING REACTIONS HAVE THRESHOLD (UCRL-50400, VOL. 9) ENERGIES LESS THAN 20 MEV.

REACTION	THRESHOLD (MEV)
N,2N	6.17
N,3N	11.32
N,4N	17.89
N,P	3.19
N,NP	7.69
N,D	5.46
N,ND	11.41
N,T	5.13
N,NT	9.99
N,FISSION	0.4
N,NALPHA	EXOERGIC
N,GAMMA	EXOERGIC

ALL CHARGED-PARTICLE-PRODUCING REACTIONS ARE NEGLECTED, BOTH BECAUSE THERE ARE ESSENTIALLY NO MEASUREMENTS AND BECAUSE THESE REACTIONS ARE SUPPRESSED BY THE COULOMB BARRIER. CROSS SECTIONS FOR ELASTIC AND INELASTIC SCATTERING, (N,2N), (N,3N), (N,4N), (N,GAMMA), (N,FISSION), AND (N,X,GAMMA) REACTIONS ARE DISCUSSED BELOW. THE DATA BASE FOR THE EVALUATION IS GIVEN IN UCRL-50400, VOL. 2 AND 3. REFERENCES NOT SPECIFICALLY CITED HERE ARE GIVEN IN THESE TWO VOLUMES. BELOW 1 KEV, POOR-RESOLUTION CROSS SECTIONS ARE USED, CONSTITUTING AVERAGES OVER RESONANCES. NO RESONANCE-PARAMETER DATA ARE INCLUDED EXPLICITLY IN THIS EVALUATION.

NEUTRON CROSS SECTIONS

ELASTIC SCATTERING CROSS SECTION

THE ELASTIC SCATTERING CROSS SECTION HAS A THERMAL VALUE OF 8 BARNS (TOTAL CROSS SECTION MINUS CAPTURE CROSS SECTION). EXPERIMENTAL MEASUREMENTS OF THE ELASTIC CROSS SECTION EXIST BETWEEN 0.3 AND 4 MEV AND AT 7 AND 14.1 MEV. THESE MEASUREMENTS WERE COMBINED WITH THE SYSTEMATICS OBTAINED FROM THE DIFFERENCE BETWEEN TOTAL AND NONELASTIC CROSS SECTIONS WHERE THESE HAVE BEEN MEASURED.

ELASTIC SCATTERING ANGULAR DISTRIBUTIONS,
NORMALIZED PROBABILITIES

EXPERIMENTAL MEASUREMENTS OF ELASTIC SCATTERING ANGULAR DISTRIBUTIONS EXIST FROM 0.075 TO 4 MEV AND AT 7 AND 14.1 MEV. AT HIGHER ENERGIES OPTICAL MODEL CALCULATIONS FORMED THE BASIS FOR THE EVALUATION.

INELASTIC SCATTERING CROSS SECTION

A BROAD-RESOLUTION EXCITATION FUNCTION IS USED TO DESCRIBE THIS CROSS SECTION. FOR NEUTRON ENERGIES UP TO 4 MEV, THE EXCITATION OF INDIVIDUAL LINES IS COMBINED WITH A CONTRIBUTION FROM THE CONTINUUM, WITH THE RESULTS BASED ON EXPERIMENTAL DATA. ABOVE 4 MEV, ONLY THE CONTINUUM EXCITATION IS CONSIDERED, AND THE INELASTIC SCATTERING EVALUATION IS BASED ON NUCLEAR SYSTEMATICS.

INELASTIC SCATTERING ANGULAR DISTRIBUTIONS,
NORMALIZED PROBABILITIES

SOME DATA DO EXIST ON THE ANGULAR DISTRIBUTIONS OF INELASTICALLY-SCATTERED NEUTRONS. HOWEVER, THESE DATA INDICATE ALMOST ISOTROPIC ANGULAR DISTRIBUTIONS. HENCE, ALTHOUGH ANGULAR DISTRIBUTION DATA ARE ENTERED INTO THE EVALUATION, ALL OF THESE EXCEPT FOR THE LOWEST LEVEL (0.05 MEV) SHOW ISOTROPIC DISTRIBUTIONS.

INELASTIC SCATTERING ENERGY DISTRIBUTIONS

AT NEUTRON ENERGIES BELOW 4 MEV, THE ENERGY SPECTRUM OF THE INELASTICALLY-SCATTERED NEUTRONS IS OBTAINED FROM EXPERIMENT (SEE REFERENCES 397, 1264, 1267, 1272, AND 1274) ABOVE 4 MEV, THE ENERGY SPECTRUM OF THE INELASTICALLY-SCATTERED NEUTRONS IS TAKEN FROM A MODEL THAT INCLUDES BOTH A LOW ENERGY TEMPERATURE COMPONENT AND A HIGH ENERGY TAIL. THE HIGH ENERGY TAIL, WHICH COMPRISES ABOUT 15 PERCENT OF THE INELASTICALLY-SCATTERED NEUTRONS AT 4 MEV AND ESSENTIALLY 100 PERCENT AT 15 MEV AND ABOVE, CONSISTS OF DIRECT-INTERACTION AND PRE-EQUILIBRIUM NEUTRONS, CHOSEN IN APPROPRIATE FRACTIONS.

(N,2N) CROSS SECTION

THE (N,2N) EXCITATION FUNCTION IS BASED ON EXPERIMENTAL DATA FROM 6.4 TO 16 MEV (SEE REFERENCES 359, 2092, AND 2519) AND ON NUCLEAR SYSTEMATICS.

(N,2N) ENERGY DISTRIBUTIONS

THE FORMALISM OF THE TEMPERATURE MODEL IS USED FOR CONVENIENCE IN THE ABSENCE OF MEASUREMENT. THE EVAPORATION TEMPERATURE IS ASSUMED TO BE THE SAME FOR BOTH NEUTRONS AND IS SELECTED SO THAT ENERGY IS CONSERVED ON THE AVERAGE, TAKING INTO ACCOUNT THE ENERGY THAT APPEARS AS GAMMA RADIATION.

(N,3N) CROSS SECTION

THE (N,3N) EXCITATION FUNCTION IS BASED ON EXPERIMENTAL DATA

FROM 12.6 TO 18.8 MEV (SEE REFERENCES 1270, 1347, AND 2519) AND ON NUCLEAR SYSTEMATICS.

(N,3N) ENERGY DISTRIBUTIONS

THE FORMALISM FOR (N,2N) SPECTRA WAS ALSO USED FOR (N,3N) SPECTRA.

(N,4N) CROSS SECTION

THE (N,4N) EXCITATION FUNCTION IS BASED ON EXPERIMENTAL DATA AT 17.8 AND 18.8 MEV (SEE REFERENCE 1347) AND ON NUCLEAR SYSTEMATICS.

(N,4N) ENERGY DISTRIBUTIONS

THE FORMALISM FOR (N,2N) SPECTRA WAS ALSO USED FOR (N,4N) SPECTRA.

(N,GAMMA) CROSS SECTION

THE (N,GAMMA) CROSS SECTION WAS OBTAINED FROM EXPERIMENTAL DATA UP TO 7.6 MEV AND AT 14.5 MEV, AND FROM NUCLEAR SYSTEMATICS.

(N,FISSION) CROSS SECTION

THE (N,FISSION) CROSS SECTION WAS TAKEN FROM EXPERIMENT.

(N,FISSION) ANGULAR DISTRIBUTION,
NORMALIZED PROBABILITIES

THE ANGULAR DISTRIBUTION OF FISSION NEUTRONS IS ASSUMED TO BE ISOTROPIC. HENCE NO DATA ENTRY IS MADE FOR THESE DATA.

(N,FISSION) ENERGY DISTRIBUTIONS

THE ENERGY SPECTRUM OF FISSION NEUTRONS WAS OBTAINED FROM THE PAPERS OF HOWERTON (REF.1) AND OF HOWERTON AND DOYAS (REF.2). THE FIRST OF THESE PAPERS GIVES A METHOD FOR PREDICTING THE VALUE OF NUBAR IN THE ABSENCE OF MEASUREMENTS, WHERE NUBAR IS THE AVERAGE NUMBER OF NEUTRONS EMITTED PER FISSION. THE SECOND PAPER GIVES THE FISSION TEMPERATURE AS A FUNCTION OF NUBAR. THUS A COMBINATION OF THESE RESULTS GIVES THE FISSION NEUTRON ENERGY SPECTRUM. THE SLOPE OF THE ENERGY DEPENDENCE OF NUBAR CHANGES AS THE THRESHOLDS CORRESPONDING TO (N,FISSION), (N,N* FISSION), (N,2N FISSION), ETC., ARE REACHED. HENCE IN THE EVALUATION, THE FISSION NEUTRON ENERGY SPECTRUM IS QUOTED AT ENERGIES THAT CORRESPOND TO THRESHOLDS AND MIDPOINTS BETWEEN THRESHOLDS.

(N,FISSION) PROMPT NUBAR

THE DATA AND THE SYSTEMATICS FOR CALCULATING PROMPT NUBAR FOR U-238 ARE GIVEN IN DETAIL IN THE PAPER OF HOWERTON (REFERENCE 1). PREDICTED VALUES FROM THE SYSTEMATICS (1963) ARE IN VERY GOOD AGREEMENT WITH EXPERIMENTS CARRIED OUT SUBSEQUENT TO THE DEVELOPMENT OF THE SYSTEMATICS (SEE ESPECIALLY REFERENCE 211, MEASUREMENTS BY SOLIELHAC ET AL.).

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GAMMA RAY PRODUCTION CROSS SECTIONS

GENERAL COMMENTS

AT NEUTRON ENERGIES OF 0.3 MEV AND ABOVE, EXPERIMENTAL (N,X GAMMA) MEASUREMENTS EXIST WHICH ENCOMPASS ALL OF THE GAMMA-PRODUCING REACTIONS. AT ENERGIES BELOW 0.3 MEV, WHERE (N,X GAMMA) MEASUREMENTS HAVE NOT YET BEEN CARRIED OUT, GAMMA RAYS ARE PRODUCED BY NEUTRON CAPTURE PROCESSES, AND ALSO BY INELASTIC SCATTERING TO SOME LOW-LYING LEVELS. THE CROSS SECTIONS FOR INELASTIC SCATTERING AT NEUTRON ENERGIES BELOW 0.3 MEV ARE SMALL AS COMPARED TO CAPTURE CROSS SECTIONS. ALSO, THE GAMMA RAYS FROM INELASTIC SCATTERING AT LOW NEUTRON ENERGIES ARE NECESSARILY LOW IN ENERGY AS COMPARED TO THE GAMMA RAYS FROM NEUTRON CAPTURE. THUS IT INTRODUCES NEGLIGIBLE ERROR INTO THE EVALUATION IF WE ASSUME THAT ONLY NEUTRON CAPTURE CONTRIBUTES TO GAMMA RAY PRODUCTION FOR NEUTRON ENERGIES BELOW 0.3 MEV.

(N,X GAMMA) CROSS SECTION FROM THE (N,GAMMA) REACTION

THE ENERGY SPECTRUM OF GAMMA RAYS FROM NEUTRON CAPTURE IN U-238 HAS BEEN MEASURED ONLY AT THERMAL ENERGIES. TO OBTAIN THE PROPER MULTIPLICITY FOR GAMMA RAY PRODUCTION AT HIGHER ENERGIES, THE MULTIPLICITY AT THERMAL WAS INCREASED BY THE RATIO (EN +Q238) /Q238, WHERE EN IS THE NEUTRON KINETIC ENERGY AND Q238 IS THE THERMAL NEUTRON CAPTURE ENERGY RELEASE.

(N,X GAMMA) ENERGY DISTRIBUTION FROM THE (N,GAMMA) REACTION

THE GAMMA RAY ENERGY SPECTRUM FROM THERMAL NEUTRON CAPTURE WAS TAKEN FROM REFERENCES 3 AND 1561. IN THE ABSENCE OF DATA, THIS ENERGY SPECTRUM WAS ASSUMED TO BE INDEPENDENT OF THE INCIDENT NEUTRON ENERGY.

(N,X GAMMA) CROSS SECTION

THIS CROSS SECTION WAS MEASURED AT NEUTRON ENERGIES EXTENDING FROM 1.09 MEV TO 14.8 MEV BY P. S. BUCHANAN ET AL. (REFERENCE 4). THESE MEASUREMENTS GIVE BOTH THE ABSOLUTE CROSS SECTIONS AND THE SPECTRAL SHAPES. THE 14.8 MEV MEASUREMENT WAS ASSUMED TO APPLY AT ENERGIES ABOVE 14.8 MEV. AT ENERGIES BELOW 0.3 MEV, GAMMA RAY PRODUCTION WAS ATTRIBUTED SOLELY TO CAPTURE PROCESSES, AS WAS DESCRIBED ABOVE.

TESTING OF THE EVALUATED DATA

IN THE MORE EXTENSIVE REPORT FORM OF THIS DISCUSSION, RESULTS OF CRITICAL ASSEMBLY CALCULATIONS WILL BE GIVEN IN SOME DETAIL. FOR THIS ABBREVIATED DESCRIPTION, IT SUFFICES TO POINT OUT THAT A LARGE NUMBER OF U-238-CONTAINING INTEGRAL NEUTRON EXPERIMENTS HAVE BEEN CALCULATED, WITH SATISFACTORY AGREEMENT BETWEEN EXPERIMENT AND CALCULATION.

U-238 LLL EVAL-MAR72 HOWERTON, MACGREGOR
MATERIAL= 4187 ZA= 92238. AWR = 236.0100 FILE= 1 SECTION= 451

REFERENCES

1. NUCL. SCI. AND ENG. 46, 42 (1971) R.J.HOWERTON (LLL)
2. NUCL. SCI. AND ENG. 46, 414 (1971) R.J.HOWERTON AND R.J.DOYAS
3. CAN. J. PHYS. 37, 377 (1959) P.J.CAMPION ET AL. (CHALK RIVER)
4. TEXAS NUCLEAR REPORT ORO-2791-32, FEB. 15 (1971) P.S.BUCHANAN

THE REFERENCE NUMBERS QUOTED BELOW REFER TO DATA IN THE LLL EXPERIMENTAL CROSS SECTION LIBRARY. SEE UCRL-50400, VOLS. 2 AND 3, FOR COMMENTS AND INDEXES TO THE DATA, AS WELL AS FOR OTHER EXPERIMENTAL RESULTS THAT WERE USED IN THE EVALUATION.

211. PRIVATE COMMUNICATION (1968) M.SOLEILHAC ET AL. (FRANCE)
359. PHYS.REV.112,259(1958) J.D.KNIGHT ET AL. (LASL)
397. PHYS.REV.109,2063(1958) L.CRANBERG,J.S.LEVIN (LASL)
1264. NUCL.PHYS.65,236(1965) R.BATCHELOR ET AL. (AWRE)
1267. NUCL.PHYS.80,46(1966) E.BARNARD ET AL. (AERE)
1270. J.NUCL.ENERGY, PARTS A/B,14,100(1961) K.W.ALLEN ET AL.(AWRE)
1272. NUCL.PHYS.47,633(1963) A.B.SMITH (ANL)
1274. PROC.PHYS.SOC.(LONDON)73,193(1959) R.BATCHELOR ET AL.(AWRE)
1347. J.NUCL.ENERGY, PARTS A/B,16,261(1962) P.H.WHITE (AWRE)
1561. PHYS.REV.151,1011(1966. R.K.SHELINE ET AL. (FLORIDA STATE)
2092. PRIVATE COMMUNICATION (1969) D.S.MATHUR (AWRE)
2519. AWRE-O-47/69 D.S.MATHUR,L.F.PAIN (AWRE)

U-238 LLL EVAL-MAR72 HOWERTON, MACGREGOR
MATERIAL= 4187 ZA= 92238. AWR = 236.0100 FILE= 1 SECTION= 451

FILE	SECTION	DESCRIPTION	NO OF CARDS
1	451	DESCRIPTIVE	273
1	452	NU BAR	6
2	151	RESONANCE	4
3	1	TOTAL	76
3	2	ELASTIC	43
3	4	(N,N*) TOTAL	18
3	16	(N,2N)	8
3	17	(N,3N)	6
3	18	SUM FISSION	10
3	37	NOT ASSIGNED	4
3	51	(N,N*) LEVEL	9
3	52	(N,N*) LEVEL	7
3	53	(N,N*) LEVEL	6
3	54	(N,N*) LEVEL	7
3	55	(N,N*) LEVEL	7
3	56	(N,N*) LEVEL	7
3	57	(N,N*) LEVEL	6
3	91	(N,N*) CONT	11
3	102	(N,GAMMA)	50
4	2	ELASTIC	210
4	16	(N,2N)	10
4	17	(N,3N)	10
4	18	SUM FISSION	10
4	37	NOT ASSIGNED	10
4	51	(N,N*) LEVEL	10
4	52	(N,N*) LEVEL	10
4	53	(N,N*) LEVEL	10
4	54	(N,N*) LEVEL	10
4	55	(N,N*) LEVEL	10
4	56	(N,N*) LEVEL	10
4	57	(N,N*) LEVEL	10
4	91	(N,N*) CONT	10
5	16	(N,2N)	80
5	17	(N,3N)	104
5	18	SUM FISSION	203
5	37	NOT ASSIGNED	37
5	91	(N,N*) CONT	143
12	102	(N,GAMMA)	4
13	3	NON-ELASTIC	6
14	3	NON-ELASTIC	1
14	102	(N,GAMMA)	1
15	3	NON-ELASTIC	87
15	102	(N,GAMMA)	24
23	501	TOTAL PHOTON	24
23	502	COHERENT	24
23	504	INCOHERENT	24
23	516	PAIR PRD TOT	9
23	602	PHOTOELECTRC	24

TAPE NUMBER = 1

URANIUM-235 MOD 0 JULY 1972 HOWERTON, MACGREGOR

U-235 LLL EVAL-APR72 HOWERTON, MACGREGOR
MATERIAL= 4188 ZA= 92235. AWR = 233.0200 FILE= 1 SECTION= 451

DIST-JUL72 MOD 0-JUL72

********** DNA 4188 MOD 0 **********

U-235 EVALUATED NEUTRON CROSS SECTIONS
EVALUATED BY R.J.HOWERTON AND M.H.MACGREGOR
LAWRENCE LIVERMORE LABORATORY, LIVERMORE,CALIFORNIA
JANUARY 1972

GENERAL COMMENTS

THE NEUTRON ENERGY RANGE EXTENDS FROM .0001 EV TO 20 MEV. IN ADDITION TO ELASTIC SCATTERING, WHICH OCCURS AT ALL ENERGIES, THE FOLLOWING REACTIONS HAVE THRESHOLD (UCRL-50400, VOL. 9) ENERGIES LESS THAN 20 MEV.

REACTION	THRESHOLD(MEV)
N,2N	5.33
N,3N	12.20
N,4N	17.97
N,P	0.62
N,NP	6.76
N,D	4.53
N,ND	9.75
N,T	3.47
N,NT	10.01
N,HE3	4.70
N,NHE3	9.50
N,ALPHA	EXOERGIC
N,NALPHA	EXOERGIC
N,GAMMA	EXOERGIC
N,FISSION	EXOERGIC

ALL CHARGED-PARTICLE-PRODUCING REACTIONS ARE NEGLECTED, BOTH BECAUSE THERE ARE ESSENTIALLY NO MEASUREMENTS AND BECAUSE THESE REACTIONS ARE SUPPRESSED BY THE COULOMB BARRIER. CROSS SECTIONS FOR ELASTIC AND INELASTIC SCATTERING, (N,2N), (N,3N), (N,4N), (N,GAMMA), (N,FISSION), AND (N,X,GAMMA) REACTIONS ARE DISCUSSED >ELOW. THE DATA BASE FOR THE EVALUATION IS GIVEN IN UCRL-50400, VOL. 2 AND 3. REFERENCES NOT SPECIFICALLY CITED HERE ARE GIVEN IN THESE TWO VOLUMES. BELOW 1 KEV, POOR-RESOLUTION CROSS SECTIONS ARE USED, CONSTITUTING AVERAGES OVER RESONANCES. NO RESONANCE-PARAMETER DATA ARE INCLUDED EXPLICITLY IN THIS EVALUATION.

NEUTRON CROSS SECTIONS

ELASTIC SCATTERING CROSS SECTION

THE ELASTIC SCATTERING CROSS SECTION HAS A THERMAL VALUE OF 14 BARNS (TOTAL CROSS SECTION MINUS CAPTURE MINUS FISSION). EXPERIMENTAL MEASUREMENTS OF THE ELASTIC CROSS SECTION EXIST BETWEEN 0.3 AND 1.5 MEV. ABOVE AND BELOW THIS ENERGY RANGE, THE

ELASTIC SCATTERING CROSS SECTION WAS DETERMINED FROM SYSTEMATICS AND FROM THE DIFFERENCE OF MEASURED TOTAL AND NONELASTIC CROSS SECTIONS WHERE THEY EXIST.

ELASTIC SCATTERING ANGULAR DISTRIBUTIONS,
NORMALIZED PROBABILITIES

TRIBUTIONS EXIST FROM 0.5 MEV TO 4 MEV. ABOVE THIS ENERGY, OPTI-
EXPERIMENTAL MEASUREMENTS OF ELASTIC SCATTERING ANGULAR DIS-
CAL MODEL CALCULATIONS PROVIDED THE BASIS FOR THE EVALUATION. IN THE ENERGY RANGE BELOW 0.5 MEV, THE EVALUATION IS BASED ON DATA MEASURED FOR U-238.

INELASTIC SCATTERING CROSS SECTION

A BROAD-RESOLUTION EXCITATION FUNCTION IS USED TO DESCRIBE THIS CROSS SECTION. FOR NEUTRON ENERGIES UP TO 4 MEV, THIS EXCITATION FUNCTION IS BASED ON EXPERIMENTAL DATA. ABOVE 4 MEV, IT IS BASED ON NUCLEAR SYSTEMATICS.

INELASTIC SCATTERING ANGULAR DISTRIBUTIONS,
NORMALIZED PROBABILITIES

THE INELASTICALLY-SCATTERED NEUTRONS ARE ASSUMED TO BE ISOTROPIC IN THE LABORATORY FRAME OF REFERENCE. SINCE THIS RESULT IS IMPLICIT IN THE EVALUATION, NO ENTRY IS MADE FOR THESE DATA.

INELASTIC SCATTERING ENERGY DISTRIBUTIONS

AT NEUTRON ENERGIES BELOW 4 MEV, THE ENERGY SPECTRUM OF THE INELASTICALLY-SCATTERED NEUTRONS IS OBTAINED FROM EXPERIMENT (SEE REFERENCES 77, 1377, AND 2598). ABOVE 4 MEV, THE ENERGY SPECTRUM OF THE INELASTICALLY-SCATTERED NEUTRONS IS TAKEN FROM A MODEL THAT INCLUDES BOTH A LOW ENERGY TEMPERATURE COMPONENT AND A HIGH ENERGY TAIL. THE HIGH ENERGY TAIL, WHICH COMPRISES ABOUT 15 PERCENT OF THE INELASTICALLY-SCATTERED NEUTRONS AT 4 MEV AND ESSENTIALLY 100 PERCENT AT 15 MEV AND ABOVE, CONSISTS OF DIRECT-INTERACTION AND PRE-EQUILIBRIUM NEUTRONS, CHOSEN IN APPROPRIATE FRACTIONS.

(N,2N) CROSS SECTION

THE (N,2N) EXCITATION FUNCTION IS BASED ON TWO MEASURED POINTS (AT 7 AND 8 MEV) AND ON NUCLEAR SYSTEMATICS.

(N,2N) ENERGY DISTRIBUTIONS

THE FORMALISM OF THE TEMPERATURE MODEL IS USED FOR CONVENIENCE IN THE ABSENCE OF MEASUREMENT. THE EVAPORATION TEMPERATURE IS ASSUMED TO BE THE SAME FOR BOTH NEUTRONS AND IS SELECTED SO THAT ENERGY IS CONSERVED ON THE AVERAGE, TAKING INTO ACCOUNT THE ENERGY THAT APPEARS AS GAMMA RADIATION.

(N,3N) AND (N,4N) CROSS SECTIONS

THE (N,3N) AND (N,4N) EXCITATION FUNCTIONS ARE BASED ON NUCLEAR SYSTEMATICS.

(N,3N) AND (N,4N) ENERGY DISTRIBUTIONS

THE FORMALISM FOR (N,2N) SPECTRA WAS ALSO USED FOR (N,3N) AND (N,4N) SPECTRA.

(N,GAMMA) CROSS SECTION

THE (N,GAMMA) CROSS SECTION UP TO 1 MEV WAS OBTAINED FROM EXPERIMENT. ABOVE 1 MEV, THE CROSS SECTION WAS ASCERTAINED BY USE OF NUCLEAR SYSTEMATICS.

(N,FISSION) CROSS SECTION

THE (N,FISSION) CROSS SECTION WAS TAKEN FROM EXPERIMENT. FOR ENERGIES OF LESS THAN ONE KEV, BROAD-RESOLUTION MEASUREMENTS WERE USED. IN THE MODERATE KEV RANGE, THE STRUCTURE OBSERVED IN EXPERIMENTS PERFORMED AT LLL, LASL, AND IN FRANCE WAS USED. IN THE HIGH KEV AND MEV RANGES, THE NECESSARY SELECTION FROM AMONG THE MANY MEASUREMENTS WAS MADE BY READING THE EXPERIMENTAL REPORTS AND DISCUSSING THEM WITH VARIOUS EXPERIMENTALISTS.

(N,FISSION) ANGULAR DISTRIBUTION,
NORMALIZED PROBABILITIES

THE ANGULAR DISTRIBUTION OF FISSION NEUTRONS IS ASSUMED TO BE ISOTROPIC. HENCE NO DATA ENTRY IS MADE FOR THESE DATA.

(N,FISSION) ENERGY DISTRIBUTIONS

THE ENERGY SPECTRUM OF FISSION NEUTRONS WAS OBTAINED FROM THE PAPERS OF HOWERTON (REF.1) AND OF HOWERTON AND DOYAS (REF.2). THE FIRST OF THESE PAPERS GIVES A METHOD FOR PREDICTING THE VALUE OF NUBAR IN THE ABSENCE OF MEASUREMENTS, WHERE NUBAR IS THE AVERAGE NUMBER OF NEUTRONS EMITTED PER FISSION. THE SECOND PAPER GIVES THE FISSION TEMPERATURE AS A FUNCTION OF NUBAR. THUS A COMBINATION OF THESE RESULTS GIVES THE FISSION NEUTRON ENERGY SPECTRUM. THE SLOPE OF THE ENERGY DEPENDENCE OF NUBAR CHANGES AS THE THRESHOLDS CORRESPONDING TO (N,FISSION), (N,N* FISSION), (N,2N FISSION), ETC., ARE REACHED. HENCE IN THE EVALUATION, THE FISSION NEUTRON ENERGY SPECTRUM IS QUOTED AT ENERGIES THAT CORRESPOND TO THRESHOLDS AND MIDPOINTS BETWEEN THRESHOLDS.

(N,FISSION) PROMPT NUBAR

A PROMPT NUBAR VALUE OF 2.42 WAS SELECTED FOR A NEUTRON ENERGY OF 0.025 EV. THE VALUE FOR NUBAR WAS INCREASED SMOOTHLY AS A FUNCTION OF INCREASING NEUTRON ENERGY SO AS TO MATCH THE MEASUREMENTS OF SOLEILHAC ET AL. (REF.211). THESE MEASUREMENTS WERE USED FOR THE EVALUATION OVER THE ENTIRE RANGE OF ENERGIES COVERED BY THEIR EXPERIMENT. FROM ABOUT 15 MEV TO 20 MEV, THE TREND ESTABLISHED BELOW 15 MEV WAS CONTINUED. THE VARIOUS CONTRADICTORY MEASUREMENTS BELOW 1 MEV WERE NOT USED FOR THIS EVALUATION.

GAMMA RAY PRODUCTION CROSS SECTIONS

GENERAL COMMENTS

AT NEUTRON ENERGIES OF 1.09 MEV AND ABOVE, EXPERIMENTAL (N,X GAMMA) MEASUREMENTS EXIST WHICH ENCOMPASS ALL OF THE GAMMA-PRODUCING REACTIONS. AT ENERGIES BELOW 1.09 MEV, WHERE (N,X GAMMA) MEASUREMENTS HAVE NOT YET BEEN CARRIED OUT, GAMMA RAYS ARE PRODUCED BY CAPTURE AND FISSION PROCESSES, AND ALSO BY INELASTIC SCATTERING TO SOME LOW-LYING LEVELS. THE CROSS SECTIONS FOR INELASTIC SCATTERING AT NEUTRON ENERGIES BELOW 1 MEV ARE SMALL AS COMPARED TO THE CAPTURE AND FISSION CROSS SECTIONS. ALSO, THE GAMMA RAYS FROM INELASTIC SCATTERING AT LOW NEUTRON ENERGIES ARE NECESSARILY LOW IN ENERGY AS COMPARED TO THE GAMMA RAYS FROM CAPTURE AND FROM FISSION. THUS IT INTRODUCES NEGLIGIBLE ERROR INTO THE EVALUATION IF WE ASSUME THAT ONLY CAPTURE AND FISSION PROCESSES CONTRIBUTE TO GAMMA RAY PRODUCTION FOR NEUTRON ENERGIES BELOW 1.09 MEV.

(N,X GAMMA) CROSS SECTION FROM THE (N,GAMMA) REACTION

NO MEASUREMENTS EXIST ON THE SPECTRUM OF GAMMA RAYS FROM NEUTRON CAPTURE IN U-235. ACCORDINGLY, THE SPECTRUM OF GAMMA RAYS FROM NEUTRON CAPTURE IN U-238 WAS TAKEN OVER AND USED FOR THE U-235 EVALUATION. DENOTING THE MULTIPLICITY OF GAMMA RAYS FROM THERMAL NEUTRON CAPTURE IN U-238 AS MO, WE TOOK THE MULTIPLICITY FOR THERMAL NEUTRON CAPTURE IN U-235 TO BE MO X Q235/Q238, WHERE Q235 AND Q238 ARE (N,GAMMA) Q-VALUES FOR U235 , U238. ALSO, FOR NEUTRON CAPTURE AT HIGHER NEUTRON ENERGIES, THE THERMAL MULTIPLICITY WAS INCREASED BY THE RATIO (EN + Q235)/Q235, WHERE EN IS THE INCIDENT NEUTRON ENERGY. ALTHOUGH THE CAPTURE CROSS SECTION IS INCLUDED EXPLICITLY OVER THE ENTIRE ENERGY RANGE UP TO 20 MEV, THE MULTIPLICITY IS SET EQUAL TO ZERO AT 1.09 MEV AND ABOVE, SINCE CAPTURE GAMMA RAYS ARE IMPLICITLY INCLUDED IN THE MEASURED (N,X GAMMA) SPECTRA, WHICH START AT 1.09 MEV.

(N,X GAMMA) ENERGY DISTRIBUTION FROM THE (N,GAMMA) REACTION

AS STATED ABOVE, THE ENERGY DISTRIBUTION OF CAPTURE GAMMA RAYS WAS TAKEN FROM THERMAL CAPTURE MEASUREMENTS IN U-238. IN THE LLL LIBRARY IT IS EXPRESSED IN A NORMALIZED HISTOGRAMMIC FORM WITH 250 KEV BINS, BUT FOR THE ENDF/B FORMAT IT WAS CONVERTED TO A NORMALIZED PROBABILITY DISTRIBUTION, SINCE THE ENDF/B FORMAT WILL ACCEPT ONLY THE LATTER TYPE OF DISTRIBUTION. THE ENERGY DISTRIBUTION IS ASSUMED, IN THE ABSENCE OF DATA, TO BE INDEPENDENT OF INCIDENT NEUTRON ENERGY. THE U-238 CAPTURE GAMMA SPECTRUM WAS DETERMINED FROM THE MEASUREMENTS OF REFERENCES 3 AND 4.

(N,X GAMMA) CROSS SECTION FROM THE (N,FISSION) REACTION

THE FISSION GAMMA RAY SPECTRUM WAS TAKEN FROM THE MEASUREMENTS OF REF. 5. IN THE ABSENCE OF DATA, THIS SPECTRUM WAS

ASSUMED TO APPLY AT ALL ENERGIES UP TO 1.09 MEV. ABOVE 1.09 MEV, THE FISSION GAMMA RAYS ARE INCLUDED IN THE MEASURED (N,X GAMMA) SPECTRA. HENCE NO EXPLICIT FISSION GAMMA RAYS ARE INCLUDED ABOVE 1.09 MEV, EXCEPT THAT THE MEASURED FISSION SPECTRUM WAS USED AS THE BASIS FOR ATTACHING A SMALL (AND PROBABLY UNIMPORTANT) HIGH ENERGY GAMMA RAY TAIL ONTO THE MEASURED (N,X GAMMA) SPECTRA.

(N,X GAMMA) CROSS SECTION

THIS CROSS SECTION WAS MEASURED AT NEUTRON ENERGIES EXTENDING FROM 1.09 MEV TO 14.8 MEV BY P. S. BUCHANAN ET AL. (REF.6) AND AT 4, 6, AND 7.5 MEV BY DRAKE (REF.7). THESE MEASUREMENTS GIVE BOTH THE ABSOLUTE CROSS SECTIONS AND THE SPECTRAL SHAPES. THE TWO MEASUREMENTS AGREE WELL IN THEIR REGION OF OVERLAP. ALSO, THE MEASUREMENTS WERE COMPARED TO THE RECIPE OF HOWERTON AND PLECHATY (REF.8), AND THE AGREEMENT WAS GOOD. THE DATA OF REF. 7 ARE USEFUL IN EXTRAPOLATING THE DATA OF REF. 6 DOWN TO ZERO GAMMA RAY ENERGY. THE 14.8 MEV ENERGY MEASUREMENT WAS ASSUMED TO APPLY AT ENERGIES ABOVE 14.8 MEV. AS STATED ABOVE, A SMALL HIGH ENERGY TAIL OF FISSION GAMMA RAYS WAS ADDED TO THE MEASURED (N,X GAMMA) SPECTRA. AT ENERGIES BELOW 1.09 MEV, GAMMA RAY PRODUCTION IS ATTRIBUTED TO CAPTURE AND FISSION PROCESSES, AS DESCRIBED ABOVE.

TESTING OF THE EVALUATED DATA

IN THE MORE EXTENSIVE REPORT FORM OF THIS DISCUSSION, RESULTS OF CRITICAL ASSEMBLY CALCULATIONS WILL BE GIVEN IN SOME DETAIL. FOR THIS ABBREVIATED DESCRIPTION, IT SUFFICES TO POINT OUT THAT UPWARDS OF FORTY U-235-CONTAINING INTEGRAL NEUTRON EXPERIMENTS HAVE BEEN CALCULATED, WITH SATISFACTORY AGREEMENT BETWEEN EXPERIMENT AND CALCULATION.

REFERENCES

1. NUCL. SCI. AND ENG. 46, 42 (1971) R.J.HOWERTON (LLL)
2. NUCL. SCI. AND ENG. 46, 414 (1971) R.J.HOWERTON AND R.J.DOYAS
3. CAN. J. PHYS. 37, 377 (1959) R.J.CAMPION ET AL. (CHALK RIVER)
4. PHYS. REV. 151, 1011 (1966) R.K.SHELINE ET AL. (FLORIDA STATE)
5. NUCL. SCI. ENG. 40, 485 (1970) R.W.PEELEE,F.C.MAIENSCHEIN(ORNL)
6. TEXAS NUCLEAR REPORT ORO-2791-32, FEB. 15 (1971) P.S.BUCHANAN
7. NUCL. PHYS. A133, 108 (1969) D.M.DRAKE (LASL)
8. NUCL. SCI. ENG. 32, 178 (1968) R.J.HOWERTON AND E. PLECHATY

THE REFERENCE NUMBERS QUOTED BELOW REFER TO DATA IN THE LLL EXPERIMENTAL NEUTRON CROSS SECTION LIBRARY (WHICH ALSO INCLUDES SOME OF THE REFERENCES LISTED ABOVE). SEE UCRL-50400, VOL. 2 AND 3, FOR COMMENTS AND INDEXES TO THE DATA, AS WELL AS FOR OTHER EXPERIMENTAL RESULTS THAT WERE USED IN THE EVALUATION.

77. LOS ALAMOS REPORT LA-2177 (1959) L. CRANBERG
211. PRIVATE COMMUNICATION (1968) M.SOLEILHAC ET AL. (FRANCE)
1377. IAEA CONFERENCE ON NUCLEAR DATA, PARIS (1966) PAPER CN-23/22
2598. AWRE-O-55/69 (1969) R.BATCHELOR AND K.WYLD (AWRE)

U-235 LLL EVAL-APR72 HOWERTON, MACGREGOR
MATERIAL= 4188 ZA= 92235. AWR = 233.0200 FILE= 1 SECTION= 451

FILE	SECTION	DESCRIPTION	NO OF CARDS
1	451	DESCRIPTIVE	289
1	452	NU BAR	9
2	151	RESONANCE	4
3	1	TOTAL	130
3	2	ELASTIC	32
3	4	(N,N*) TOTAL	12
3	16	(N,2N)	8
3	17	(N,3N)	5
3	18	SUM FISSION	93
3	37	NOT ASSIGNED	4
3	91	(N,N*) CONT	12
3	102	(N,GAMMA)	65
4	2	ELASTIC	330
4	16	(N,2N)	10
4	17	(N,3N)	10
4	18	SUM FISSION	10
4	37	NOT ASSIGNED	10
4	91	(N,N*) CONT	10
5	16	(N,2N)	73
5	17	(N,3N)	61
5	18	SUM FISSION	150
5	37	NOT ASSIGNED	37
5	91	(N,N*) CONT	131
12	18	SUM FISSION	4
12	102	(N,GAMMA)	4
13	3	NON-ELASTIC	7
14	3	NON-ELASTIC	1
14	18	SUM FISSION	1
14	102	(N,GAMMA)	1
15	3	NON-ELASTIC	123
15	18	SUM FISSION	32
15	102	(N,GAMMA)	24
23	501	TOTAL PHOTON	24
23	502	COHERENT	24
23	504	INCOHERENT	24
23	516	PAIR PRD TOT	9
23	602	PHOTOELECTRC	24

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