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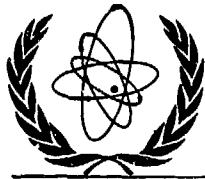
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INTERNATIONAL ATOMIC ENERGY AGENCY

NUCLEAR DATA SERVICES

DOCUMENTATION SERIES OF THE IAEA NUCLEAR DATA SECTION

287 pages

EXFOR MANUAL

Center-to-Center Exchange Format

Version 89-1

Edited by V. McLane
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Upton, NY 11973, USA

for the Nuclear Reaction Data Centers

September 1989

Abstract

EXFOR is the agreed exchange format for the transmission of nuclear reaction data between national and international nuclear data centers for the benefit of nuclear data users in all countries.

EXFOR is a database with several million data records containing the world's experimental nuclear reaction data induced by neutrons, photons or charged particles. Data retrievals can be obtained from the IAEA Nuclear Data Section (NDS) or from one of the co-operating data centers whose names and addresses can be found inside the manual. Their contributions and co-operative efforts are gratefully acknowledged.

NOTE

This official "EXFOR MANUAL" is edited by the US National Nuclear Data Center on behalf of the co-operating Nuclear Reaction Data Centers. In the documentation series of the IAEA Nuclear Data Section it was reproduced unchanged under the report code IAEA-NDS-103.

Another version of this manual is the "NDS EXFOR MANUAL" under the report code IAEA-NDS-3. This contains for many items more detailed explanations and additional procedures used by NDS.

Other reports documenting the IAEA EXFOR system are:

IAEA-NDS-1	Short Guide to EXFOR
IAEA-NDS-2	EXFOR Dictionaries
IAEA-NDS-66	EXFOR-Index

H.D. Lemmel
IAEA Nuclear Data Section
October 1988

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Chapter 1

INTRODUCTION

This manual describes EXFOR, the exchange format designed to allow center-to-center transmission of nuclear data between the data compilation centers. It was originally conceived for the exchange of neutron data through discussions held between programming personnel from a number of laboratories (i.e., Saclay, Vienna, Livermore and Brookhaven) and accepted as a result of a meeting of the neutron data centers at Saclay, Vienna, Brookhaven and Obninsk, which was held in Moscow in November 1969.

Subsequently, the format was further developed and finally adapted to cover all types of nuclear reaction data as a result of two meetings held in Vienna in 1975/1976 on Charged Particle Nuclear Data Compilation, attended by an increased number of data centers.

The format is designed to meet the diverse needs of the nuclear data compilation centers, and has been designed for flexibility rather than optimization of data processing. The center-to-center exchange format should not be confused with either a center input format or a center-to-user format. The input formats have evolved independently at each center in order to allow the hardware at each center to be used in an optimum manner (i.e., to minimize both input-format errors and the amount of work associated with input). Similarly, the center-to-user formats have been developed to meet the needs of the users within each center's own sphere of responsibility.

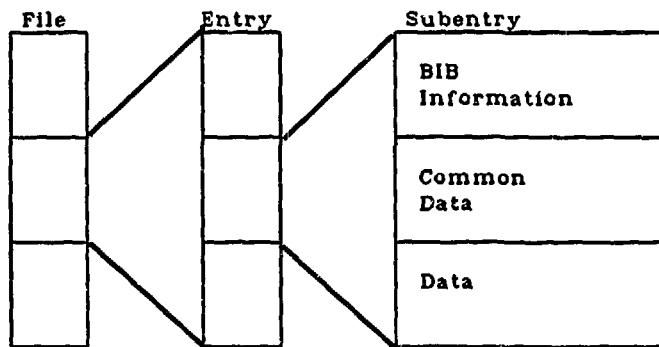
The exchange format as outlined is designed to allow a large variety of numerical data tables with explanatory and bibliographic information to be transmitted in an easily machine-readable format (for checking and indicating possible errors) and a format that can be read by personnel (for passing judgment on and correcting any errors indicated by the machine). In order to accomplish this end, the exchange format has not been optimized for subsequent processing and retrieval. Converting the information from the exchange format to a format or formats that best meet the needs of their users is the responsibility of the individual centers.

General structure of the exchange format

1. Each entry (work) falls naturally into two parts - bibliographic or descriptive information (alphanumeric) and data (numeric). In addition, the data for each entry is divided into subentries (sub-works). Further, common bibliographic or descriptive information and common data may be associated with the whole entry and/or each subentry. A set of system identifiers has been devised for separating these logical blocks of information within an entry.
2. Each item of bibliographic or descriptive information must be identified for retrieval purposes and a set of information identifiers (keywords) has been devised for this purpose.
3. Each piece of information requiring coding (e.g., reference, laboratory, etc.) has these codes, enclosed in parentheses, following the identifier. A set of dictionaries is provided for these codes.
4. Unlimited free text is permitted with each information-identifier.
5. Common data, meaning data values which are common throughout the entry or subentry, are treated in a similar way to the data (see 6, below) except that individual items in common are not directly interrelated.
6. The data for a subentry are presented in the form of a table of fixed field widths, but with no positional meaning. Each table is preceded by its data heading and data units.
7. Part of each record is reserved for identification. This includes accession number (entry), subaccession number (subentry) and record number within the subaccession number. This will guarantee that each record may be uniquely referenced within the system (i.e., no two records will have the same identification).
8. Flags are used to indicate records altered since the previous transmission of a particular entry.
9. The record size is 80 characters to allow card input to be used.

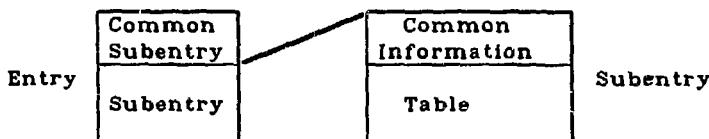
Summary of exchange file format

The exchange file will contain a number of entries. Each entry will be divided into a number of subentries. The subentries will be further subdivided into bibliographic or descriptive information (hereafter called BIB information), common data that applies to all lines of a data table in a subentry and finally a data table. The file may therefore be considered to be of the following form:



A number of system identifiers are used to define the beginning and end of each of the above units.

In order to avoid repetition of information that is common to all subentries within an entry or to all lines within a subentry, information may be associated with an entire entry or with an entire subentry. In order to accomplish this the first subentry of each work, which is given subaccession number 1, must only contain information that applies to all other subentries, and within each subentry, the information common to all lines of the table simply precedes the table. Two levels of hierarchy are thereby established to avoid repetition of information:



The common information (or common subentry) is further subdivided into common BIB information (alphanumeric) and common data (numeric) information.

Definition of a subentry

In order to avoid duplication of effort and to ensure that the identification scheme will be universally applicable, each center will divide entries into appropriate subentries prior to transmission. This will ensure that an entry has been divided into subentries in a unique manner (by the originating center) which may be referenced by all centers (this avoids the possibility of two centers decomposing an entry into different constituent subentries, thus voiding the applicability of the universal identification scheme).

A subentry will be defined as:

1. A table as a function of one or more independent variables: i.e., X, X' vs. Y with associated errors for X, X' and Y (e.g., X = energy; X' = angle; Y = differential cross section) and any associated variables (e.g., standard).
2. Independent variables will precede dependent variables and will be monotonic in the left-most independent variable. Values in following independent-variable fields must be monotonic until the value in the preceding independent-variable field changes.
3. When more than one representation of Y is present, the table may be X vs. Y and Y', with associated errors for X, Y and Y' and a possible flag (e.g., X = energy; Y = absolute cross section, Y' = relative cross section). The criteria for grouping a Y with a Y' is that they both be derived from the same experimental information by the author of the data.
4. Variables may appear either in the COMMON portion of a subentry (when uniformly applied to all points) or as an additional field of the data table (when applied pointwise).
5. For some data the data table does not have an independent variable X but only the function Y. (Examples: spontaneous $\bar{\nu}$; resonance energies without resonance parameters; etc.)
6. If the function Y is given for a single value of the variable X, and if this value of X is common for all subentries in a given entry, then X may be entered in the COMMON section of the first subentry. The following subentries may then contain only the value of Y under DATA.

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Permitted character set

The following characters are permitted for use in the exchange format:

All Roman capitals, A to Z

All numbers, 0 to 9

The special characters:

+	(plus)
-	(minus)
.	(decimal point/full stop)
)	(right parenthesis)
((left parenthesis)
*	(asterisk)
/	(slash)
=	(equals)
'	(apostrophe)
,	(comma)
%	(percent)
<	(less than)
>	(greater than)
:	(colon)
;	(semi-colon)
!	(exclamation point)
?	(question mark)
&	(ampersand)

Chapter 2
RECORD IDENTIFICATION

Columns 67-80 are used to identify uniquely each record and to flag altered records. These columns are divided into five fields as follows:

67	originating center identification		universal
68-71	center-assigned accession number		accession number
72-74	center-assigned subaccession number		
75-78	sequential numbering within a subaccession number		
80	alter flag		

Each of these fields is described in detail in this chapter.

ORIGINATING CENTER IDENTIFICATION

Column 87 of every record, the first position of accession numbers, and the first position of a transmission file identification contain a number or letter indicating the center at which the information originated. The following center identifications have been assigned:

0 Preliminary: may be assigned by data producers when transmitting information to the center in the exchange format, or by centers for their internal use.

1 NNDc (Brookhaven)
 2 NEA-DB (Saclay)
 3 NDS (Vienna)
 4 CJD (Obninsk)

NND EXFOR transmission

5 data from area 1
 6 data from area 2
 7 data from area 3
 8 data from area 4

data entered by NNDc; not part of the normal NND EXFOR transmission; may be gradually converted to 2, 3, 4 series.

9 special use for transmission of dictionaries (see page 7.1)

A CAJAD (Moscow)
 B KACHAPAG (Karlsruhe)
 C NNDc (Brookhaven)
 D NDS (Vienna)
 E "Study Group" (Sapporo)
 R RIKEN
 S CNDC

CPND EXFOR transmission

G NDS (Vienna)
 L NNDc (Brookhaven)
 M CDFE (Moscow)
 Q CJD (Obninsk)

Photonuclear data

N NEA-DB

Currently used only for memos

P NDS (Vienna)

MacGowen CPX file as corrected and coded by KACHAPAG

V NDS (Vienna)

selected evaluated neutron data 'VIEN' file not part of the normal EXFOR transmission

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CENTER-ASSIGNED ACCESSION NUMBER (COLUMNS 68-71)

Columns 68 - 71 contain a four-digit accession number assigned by the originating center. Columns 67-71 (originating center identification and center assigned accession number) may be considered a universal accession number, allowing 9,998 entries for each center identification.

An accession number is associated with one work throughout the life of the EXFOR system. If an entry is deleted from the system, the accession number is not reassigned to another work.

The methods of assigning accession numbers may be different at each center. That is to say, a center may assign them manually or automatically, by computer. The accession numbers need not be assigned sequentially, however, the entries will appear on the exchange file in ascending number order. A center may assign legal EXFOR accession numbers only to works within its agreed area of responsibility.

Note: Where the responsibility for compiling a given data set is not clear, the centers concerned should consult each other before compiling the data, in order to avoid duplicate entry of the same data, see LEXFOR Institute.

CENTER-ASSIGNED SUBACCESSION NUMBER (COLUMNS 72-74)

Columns 72 - 74 contain a three-digit subaccession number assigned by the originating center (leading zeros should be included). The subaccession number is used to divide an entry into a number of subentries while maintaining an interrelationship between the subentries (i.e., all subentries within a given entry contain the same universal accession number). Each subentry may be conceptually thought of as an individual data table and its associated BIB information.

Up to 998 subentries (tables) may be associated with each entry (work). The center-assigned subaccession numbers are sequentially assigned within each entry, starting at 1 and increasing toward 998.

A subaccession number is associated with a table throughout the life of the EXFOR system. If a subentry is deleted from the system, the subaccession number is not reassigned to another data table within the same entry.

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SEQUENTIAL NUMBERING WITHIN A SUBACCESSION NUMBER (Cols.75-79)

Columns 75 - 79 contain a five-digit sequential number (leading zeros are included).

The sequential number is used to uniquely define a record within a subentry (subaccession number) (all records within a subentry are labeled with the same subaccession number).

Up to 99,999 records may be associated with each subentry (subaccession number). The sequential numbering within each subentry begins at 1 and increases sequentially toward 99999.

The function of the sequential numbering within each subentry is to allow for reference at the record level during the ALTER procedure and to allow manual and machine checking of the record sequence (e.g., a check for records out of order or for missing records). Therefore, a given sequence number need not be associated with a given record over an extended period of time. The records within a subentry are renumbered sequentially following an ALTER procedure. Alterations on an entry are transmitted only by the originating center. THE RECORDS WITHIN A SUBENTRY ARE ALWAYS TRANSMITTED IN SEQUENTIAL ORDER.

ALTER FLAG (COLUMN 80)

Column 80 is used to indicate that a record or following records have been altered since the work was last transmitted. This column will normally be blank (not zero) to indicate an unaltered record. The following symbols are used to indicate an altered record:

C the record flagged has been corrected. When a subentry is updated, the flag C is also be added to the ENTRY and SUBENT records and the date of last updated is changed (N2 field, see pages 3.4 and 3.5).

D a record or records has been deleted following the record flagged.

I the record flagged has been inserted. In the case of the SUBENT record, the entire subentry has been inserted.

T two updates have occurred as follows:

- a) the record flagged has been inserted or corrected and
- b) a record or records has been deleted following the record flagged.

R the record flagged is a replacement. This is used when a large block of records is revised, e.g., the complete BIB section or a section of the data table. The flag, R, appears in each replacement record. An entry is made under HISTORY explaining the alteration, e.g.,

(710608A) Between 1.0 eV and 700 eV data replaced by a new set calculated from the old one averaging over five data points
or

(710709A) BIB section rewritten, full paper published.

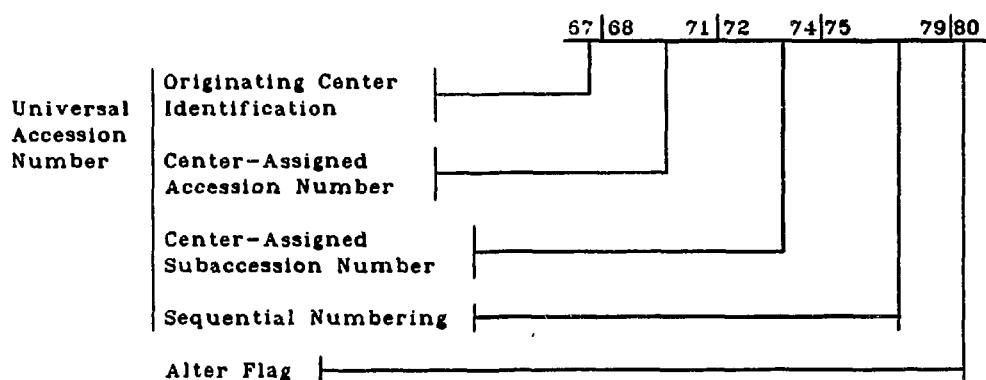
* on an ENTRY or SUBENT record means: this entry or subentry has been deleted. (See page 9.2 for details on deletion of entries or subentries.)

The alter flag is used to inform other centers when an alter procedure has been performed on an entry. Alter flags are not be accumulated over a number of transmissions (i.e., alter flags are set only to indicate those records which have been altered since the last time the work was transmitted). Therefore, all flags are, at least conceptually, considered reset to blank after the work has been transmitted. The procedure that is actually carried out at each center of course depends upon the use that the center intends to make of the information conveyed by the alter flag.

See also page 9.1, Alterations to EXFOR entries.

RECORD IDENTIFICATION SUMMARY

Columns 67-79 of each record are used to uniquely identify each record in the EXFOR system. This is accomplished by dividing the record identification into four fields as shown below. Column 80 is used as an alteration flag.



The first field (column 67) is alphanumeric, the next 3 fields (columns 68-79) are strictly numeric and may vary over the following ranges:

- (1) Originating Center Identification: see page 2.2
 - (2) Center Assigned Accession Number: 1 to 9998
 - (3) Center Assigned Subaccession Number: 1 to 998
 - (4) Sequential Numbering within a subentry: 1 to 99999

They may be used in combination to uniquely reference information within the library at any of a number of levels as follows:

- (1) Col. 67: Uniquely identifies all information from a given center.
(2) Cols.67-71: Uniquely identifies an entry within the EXFOR system.
(3) Cols.67-74: Uniquely identifies a subentry within the EXFOR system.
(4) Cols.67-79: Uniquely identifies a record within the EXFOR system.

The first three fields (columns 67-74) are associated with a subentry throughout the life of the system. That is, accession numbers and subaccession numbers are not changed, once they are assigned. If the subentry is deleted from the system, the same identification is not assigned to another subentry. The fourth field (columns 75-78) is maintained in sequential order, i.e., the sequence number on a record may change after an alteration to the subentry.

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Columns 67-79 are padded with zeros (0) rather than blanks. This allows the entire library to be handled by the standard sort/merge packages available on a wide variety of computers.

The alter flag (column 80) is used to identify records that have been altered. The fact that a record has been altered should be transmitted to all centers only once.

On a transmission file the records are in ascending order according to the record identification, that is, column 67 to 79.

Chapter 3

SYSTEM IDENTIFIERS

Each of these basic system-identifier keywords refers to one of the hierarchy of units contained on a transmission file. These units and their corresponding basic system identifiers are:

- TRANS - A transmission is the unit
- ENTRY - A work (entry) is the unit
- SUBENT - A sub-work (subentry) is the unit
- BIB - The BIB section of a complete work or sub-work is the unit
- COMMON - The common data section of a complete work or sub-work is the unit
- DATA - The data table section of a sub-work is the unit

These basic system identifier keywords are combined with the modifiers

NO
END

to indicate three conditions:

- 1. The beginning of a unit (basic system identifier only)
- 2. The end of a unit (modifier END preceding the basic system identifier)
- 3. A positive indication that a unit is intentionally omitted (modifier NO preceding the basic system identifier)

However, only those combinations of basic system identifier keywords and modifiers which are defined on the following pages, and are included in Dictionary 1, are used.

The general format of a system identifier record is:

1 [System Identifier]	11	22 N1	33 N2	Free text	68
--------------------------	----	----------	----------	-----------	----

[System Identifier] may be any of the permitted system identifier keywords (the brackets are not included), left adjusted to begin in column 1; N1 and N2 are integers right adjusted to columns 22 and 33, respectively. The significance of N1 and N2 depends on the system identifier used.

Columns 34-88 (with the exception of the special uses for columns 34-44 of the ENTRY and SUBENT records) may contain any free text that a center wishes to use or may be used internally by the centers for additional coded information. The following pages describe all permitted system identifier records in detail. The detailed description is followed by a brief summary of the characteristics of the system-identifier records.

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1. TRANS

This record is the first one on the transmission file. N1 and N2 are interpreted as:

N1 - The transmission file identification, consisting of:
 column 19: the originating center identification,
 column 20-22: a three-digit number, sequentially assigned to allow
 other centers a simple means of determining whether or
 not they have received all files transmitted.

N2 - A six-digit integer containing the date (year, month, and day) on which
the transmission file was generated. The format is: YYMMDD.

The record identification contains the originating center identification code in
column 67 and zeros (not blanks) in columns 68-79.

2. ENDTRANS

This record is the last one on the transmission file. N1 and N2 are
interpreted as:

N1 - The number of entries (accession numbers) on the file.
N2 - Presently unused (may be blank or zero).

The record identification contains the center identification code in column 67
and 9's in columns 68-79.

Note: Column 67 need contain the originating center code only in the case of
center-to-center transmission files. On files which contain EXFOR entries
with different center-identification codes, column 67 is assigned such
that the record sorts at the end of the file (e.g., equal to, or
greater than, the center identification of the last entry included on the
file).

- 3. DICTION (not part of an exchange file)***
- 4. ENDDICTION (not part of an exchange file)***
- 5. NODICTION (not part of an exchange file)***

* When dictionaries are transmitted, they must be in a separate file apart
from the EXFOR data entries. See Chapter 7.

6. ENTRY

This record is the first one of each work. N1 and N2 are interpreted as:

N1 - 5-digit universal accession number (originating center identification and center assigned accession number).

N2 - Date of last update (or date of entry if never updated) (yyymmdd).

The record identification contains the universal accession number (columns 67-71), the subaccession number zero (000) (columns 72-74), and the sequence number one (00001) (columns 75-79).

Note: The following special uses are made of the free text field in the ENTRY record:

NDS: for identifying entries containing evaluated or recommended data, a 'V' is inserted in column 44.

Columns 45-55 contain the initials of the physicist who compiled the entry or made the last revision.

NNDC: Columns 43, 44 contain a compiler-identification code.

7. ENDENTRY

This record is the last one of each work. N1 and N2 are interpreted as:

N1 - The number of subentries (subaccession numbers) in the work.

N2 - Presently unused (may be blank or zero).

The record identification contains the universal accession number (columns 67-71), the subaccession number 999 (columns 72-74), and the sequence number (99999) (columns 75-79).

Note: When NOSUBENT records are included in an entry, they are counted as subentries when computing N1.

8. NOENTRY (cancelled)

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9. SUBENT

This record is the first one of each subentry. N1 and N2 are interpreted as:

N1 - 8-digit universal subaccession number (originating center identification, center assigned accession and subaccession number).

N2 - Date of last update (or date of entry if never updated) (yyymmdd).

N3 - Special use: for identifying data types on a subentry level:

 column 42: R - recommended data

 column 43: E - evaluated data

 column 44: D - differential CPND

An entry in this field in subentry 1 means all subentries contain such data. (This field is considered a free text field for NND entries.)

The record identification contains the universal subaccession number (columns 67-74) and sequence number one (00001) (columns 75-79).

Note: The following special uses are made of the free text field:

KACHAPAG: Columns 52-66 contain center-internal information.

10. ENDSUBENT

This record is the last one of each subentry. N1 and N2 are interpreted as:

N1 - The number of records within the subentry.

N2 - Presently unused (may be blank or zero).

The record identification contains the universal subaccession number (columns 67-74) and sequence number 99999 (columns 75-79).

11. NOSUBENT

This record indicates that a subaccession number has been assigned by the center but that either the information associated with it was not ready at the time the file was transmitted by the center, or that the subentry has been deleted, or combined with another subentry (see page 9.2). N1 and N2 are interpreted as:

N1 - 8-digit universal subaccession number (originating center identification, center assigned accession and subaccession number).

N2 - Date of last alter or blank (if merely assigned and not yet used).

The record identification is the same as on a SUBENT record.

12. BIB

This record is the first one of each BIB section. N1 and N2 are interpreted as:

- N1 - Number of keywords in the BIB section (not counting pointers in column II, see page 6.1).
N2 - Number of records in the BIB section.

13. ENDBIB

This record is the last one of each BIB section. N1 and N2 are interpreted as:

- N1 - Number of records in BIB section.
N2 - Presently unused (may be blank or zero).

14. NOBIB

A positive indication that no BIB section is given in the subentry. N1 and N2 are interpreted as:

- N1 - Presently unused (may be blank or zero).
N2 - Presently unused (may be blank or zero).

Note: The record identification for these system identifiers contains the universal accession and subaccession numbers of the subentry in which they are located. The sequence number is assigned sequentially within the subentry.

15. COMMON

This record is the first one of each common data section. N1 and N2 are interpreted as:

N1 - Number of common data fields.

N2 - Number of records within common data section.

16. ENDCOMMON

This record is the last one of each common data section. N1 and N2 are interpreted as:

N1 - Number of records within the common data section.

N2 - Presently unused (may be zero or blank).

17. NOCOMMON

A positive indication that no common data section is given in the subentry. N1 and N2 are interpreted as:

N1 - Presently unused (may be blank or zero).

N2 - Presently unused (may be blank or zero).

Note: The record identification for these system identifiers contains the universal accession and subaccession numbers of the subentry in which they are located. The sequence number is assigned sequentially within the subentry.

18. DATA

This record is the first one of each data table section. N1 and N2 are interpreted as:

N1 - Number of fields (variables) associated with each line of a data table.
N2 - Number of data lines within the table (excluding headings and units).
Note that if N1 > 8, a line will consist of more than one record.

19. ENDDATA

This record is the last one of each data table section. N1 and N2 are interpreted as:

N1 - Number of records within the data section.
N2 - Presently unused (may be zero or blank).

20. NODATA

A positive indication that no data table section is given in the subentry.
N1 and N2 are interpreted as:

N1 - Presently unused (may be zero or blank).
N2 - Presently unused (may be zero or blank).

21. XDATA (cancelled)

Note: The record identification for these system identifiers contains the universal accession and subaccession numbers of the subentry in which they are located. The sequence number is assigned sequentially within the subentry.

The above 'DATA' system identifiers do not appear in the first (all common) section of an entry (i.e., subaccession number 1).

SUMMARY OF SYSTEM IDENTIFIER RECORDS

The following similarities may be noted between system identifier records:

1. The TRANS, ENTRY, and SUBENT records all use N1 to uniquely identify the unit (file, entry, subentry, respectively) and N2 to give a date (TRANS - date file was generated; ENTRY and SUBENT - date of last update).
2. The BIB, COMMON and DATA records (the units that actually contain information) use N1 and N2 to define the contents of the information records.
3. All END[System Identifier] records use N1 to indicate the number of sub-units within the unit:

ENDTRANS - the number of entries;

ENDENTRY - the number of subentries;

ENDSUBENT, ENDBIB, ENDCOMMON, and ENDDATA - the number of records.

To be consistent at all levels (e.g., entry, subentry, record), the system identifier records are not included in the N1 total for BIB, COMMON, and DATA (see examples on following pages). N2 is presently unused on all END[System Identifier] records.

Since the above rules describe all of the system-identifier records, a minimum number of rules need be remembered.

The following hierarchy has been established on the file:

1. A transmission is one logical file

- (a) Headed byTRANS CXXX YYMMDD
 - (b) Ended byENDTRANS N1

CXXX - file identification

YYMMDD - date file was generated

N1 - number of entries on the file

2. Entries are:

- (a) Headed byENTRY CXXXX YYMMDD
 - (b) Ended byENDENTRY N1

CXXXX - universal accession number

YYMMDD - date entry was last updated

N1 - number of subentries in the entry (including NOSUBENT's)

3. Entries are divided into subentries (subaccession numbers). The subentry is:

- | | | | | | |
|-----------------------------|----|--------|-------------|----|--------|
| (a) Headed bySUBENT | N1 | YYMMDD | or NOSUBENT | N1 | YYMMDD |
| (b) Ended byENDSUBENT | N2 | | | | |

N1 - subaccession number

YYMMDD - date subentry was last updated

N2 - number of records in the subentry (excluding the SUBENT and ENDSUBENT records)

4. Each subentry but the first contains three sections (there will always be a positive indication of no information in a section). The sections are:

BIB Section:

- | | | | |
|--------------------------|----|----|----------|
| (a) Headed byBIB | K | N2 | or NOBIB |
| (b) Ended byENDBIB | N1 | | |

K - Number of keywords in the BIB section

N2 - number of records in the BIB section

N1 - number of records in the BIB section (excluding the BIB and ENDBIB records)

COMMON Section:

- | | | | |
|-----------------------------|----|----|-------------|
| (a) Headed byCOMMON | M | N1 | or NOCOMMON |
| (b) Ended byENDCOMMON | N1 | | |

M - number of common data fields

N1 - number of records in the common data section (including data titles and units but excluding the COMMON and ENDCOMMON records)

DATA Section:

- | | | | |
|---------------------------|----|---|-----------|
| (a) Headed byDATA | C | L | or NODATA |
| (b) Ended byENDDATA | N1 | | |

C - number of fields in the data table

L - number of lines (rows) in the data table

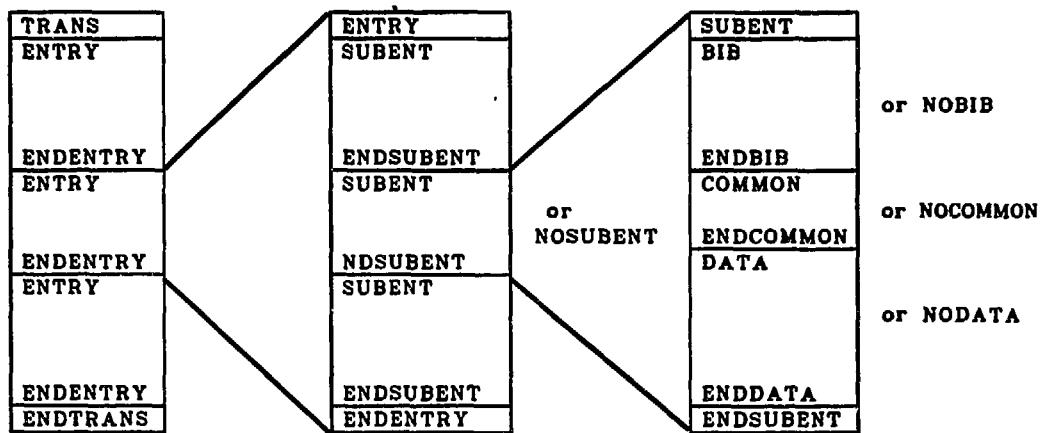
N1 - number of records in the data table section (including data titles and units, but excluding the DATA and ENDDATA records)

The DATA (or NODATA) section does not appear in the first (all common) subentry.

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The transmission file has the following form:



Note: DATA, ENDDATA, and NODATA do not appear in the first (all common) subaccession number.

LEGAL SYSTEM IDENTIFIER SEQUENCES

The following tables specify the permissible order in which system identifiers may appear. The first table lists all records that may follow a given system identifier. The second table lists all records that may precede a given system identifier. The two tables are provided for clarity rather than necessity (i.e., one table can easily be derived from the other).

SYSTEM IDENTIFIER	LEGAL <u>FOLLOWING</u> RECORD
(1) TRANS	ENTRY
(2) ENDTRANS	(no information follows ENDTRANS)
(3) ENTRY	SUBENT, NOSUBENT
(4) ENDENTRY	ENTRY, ENDTRANS
(5) SUBENT	BIB, NOBIB
(6) ENDSUBENT	SUBENT, ENDENTRY, NOSUBENT
(7) NOSUBENT	SUBENT, ENDENTRY, NOSUBENT
(8) BIB	(a bibliographic record)
(9) ENDBIB	COMMON, NOCOMMON
(10) NOBIB	COMMON, NOCOMMON
(11) COMMON	(a common data record)
(12) ENDCOMMON	DATA*, NODATA*, ENDSUBENT**
(13) NOCOMMON	DATA*, NODATA*, ENDSUBENT**
(14) DATA	(a data heading record)
(15) ENDDATA	ENDSUBENT
(16) NODATA	ENDSUBENT

* Not in the first subentry (i.e., subaccession # = 001), where no data section is permitted.

** In the first subentry only (i.e., subaccession number = 001), where no data section is permitted.

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SYSTEM IDENTIFIER LEGAL PRECEDING RECORDS

(1) TRANS	(no information precedes TRANS)
(2) ENDTRANS	ENDENTRY
(3) ENTRY	ENDENTRY, TRANS
(4) ENDENTRY	ENDSUBENT, NOSUBENT
(5) SUBENT	ENTRY, ENDSUBENT, NOSUBENT
(6) ENDSUBENT	ENDDATA*, NODATA*, ENDCOMMON**, NOCOMMON**
(7) NOSUBENT	ENTRY, ENDSUBENT, NOSUBENT
(8) BIB	SUBENT
(9) ENDBIB	(a bibliographic record)
(10) NOBIB	SUBENT
(11) COMMON	ENDBIB, NOBIB
(12) ENDCOMMON	(a common data record)
(13) NOCOMMON	ENDBIB, NOBIB
(14) DATA	ENDCOMMON, NOCOMMON
(15) ENDDATA	(a data heading record)
(16) NODATA	ENDCOMMON, NOCOMMON

* Not in the first subentry (i.e., subaccession number = 001), where no data section is permitted.

** In first subentry only (i.e., subaccession number = 001), where no data section is permitted.

Chapter 4

BIB SECTION

This section is identified on a transmission file as that information between the system identifiers BIB and ENDBIB. Although it is called 'BIB section' it contains information which is other than strictly bibliographic, that is, information required to describe an experiment (e.g., neutron source, method, facility, etc.). Administrative information (e.g., history) is also included in this section.

A BIB record consists of up to four parts:

columns 1-11: keyword field
columns 12-66: information field, which may contain coded information
 and/or free text
columns 67-80: identification field (see Chapter 2)

Keywords are used to identify specific information, which may be given in coded form, with or without free text explanation, or in free text without codes. The keywords may, in general, appear in any order within the BIB section.

BIB information for a given subentry consists of the information contained in the BIB section of that subentry together with the BIB information in subentry 001. Therefore, information coded in subentry 001 applies to all other subentries in the same entry. A specific BIB keyword may be included in either subentry or both.

Keyword (Information Identifier)

The information-identifier keyword is used to define the significance of the information given in columns 12-66. The keyword is left adjusted to begin in column 1, and does not exceed a length of 10 characters (column 11 is either blank, or contains a pointer, see below).

A keyword is not repeated within any one BIB section. The pointer is given in the first record of the information to which it is attached and is not repeated on continuation records. The pointer is assumed to refer to all BIB information until either another pointer or a new keyword is encountered. This implies that pointer-independent information for each keyword appears first.

See Dictionary 2 for a list of all keywords. For detailed coding rules, see Chapter 8.

See Chapter 6 for use of pointers.

Machine-Retrievalable Information

Machine-retrievable information may be used:

- to define the actual BIB information,
- as a link to the COMMON and DATA section,
- to code numerical data.

Machine-retrievable information is enclosed in parentheses and left adjusted so that the opening parenthesis appears in column 12. Several pieces machine-retrievable information may be associated with a given keyword.

For some keywords a restriction is placed upon the maximum length of the associated machine-retrievable information; it may be continued onto successive records. Information on continuation records does not begin before column 12 (columns 1-10 are blank and column 11 is blank or contains a pointer (see Keyword, above)). The machine-retrievable information is kept as concise as possible so that it may be used efficiently.

Note that some keywords have no machine retrievable-information associated with them and that, for many keywords which may have machine-retrievable information associated with them, it need not always be present.

See Chapter 8 for formats and coding rules, and Chapter 7 and the Dictionaries for codes. See page 7.10 for maximum length of codes.

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Free Text

Free text may be entered in columns 12 - 66 under each of the keywords in the BIB section and may be continued onto any number of records. It may include parentheses, if necessary, although, in order to avoid confusion, a left parenthesis in the text will not be used in column 12 (as this implies the opening parenthesis of machine-retrievable information).

The free text will use clear English phrasing; no codes are used within the free text.

See also LEXFOR Free Text.

Codes and free text

In general, coded information given with keywords is for retrieval purposes and the free text is self-explanatory. That is, coded information is expanded into clear English and amplified as necessary in the free text. However, for some keywords, such an expansion of the codes is, in general, expressly forbidden*, on the assumption that such expansion will be done by an editing program. For some other keywords an indication may be given as to whether or not the coded information is expanded in the free text.

An indication that the code is not expanded is given by:

either a decimal point/full stop immediately following the closing parenthesis,
or a completely blank field between the closing parenthesis and column 66.

See page 8.5 for details on specific keywords.

* Expansions of these codes may be used, at the compiler's discretion, embedded in a free text comment.

An example of several BIB information entries is given below:

	11	12	68
ENTRY		00001	
SUBENT		00001001	
BIB			
AUTHOR	(J.W.DOW,M.P.JONES) THIS SPACE MAY CONTAIN ANY FREE TEXT. THE BEGINNING OF A NEW BIB ENTRY IS INDICATED BY A NON-BLANK IN THE KEYWORD FIELD COLUMNS 1 - 10.		
INSTITUTE	(SAAAABBB) SINCE THE KEYWORD FIELD IS NON-BLANK, THIS IS CONSIDERED A NEW BIB ENTRY.		
N-SOURCE	(ABC,WXYZ) THIS IS AN EXAMPLE OF A BIB ENTRY WITH MORE THAN ONE PIECE OF MACHINE-RETRIEVABLE INFORMATION IN ONE SET OF PARENTHESES. THE ABSENCE OF A POINTER IN COLUMN 11 SHOWS THAT THIS INFORMATION REFERS TO ALL DATA.		
COMMENT	THIS IS AN EXAMPLE OF A BIB ENTRY WITHOUT MACHINE-RETRIEVABLE INFORMATION.		
	1 THE POINTER IN COLUMN 11 INDICATES THAT THIS RECORD, AND THE FOLLOWING RECORDS UNTIL A NEW POINTER IS ENCOUNTERED, REFER TO ALL DATA WITH THE SAME POINTER IN ALL FOLLOWING SUBENTRIES.		
ENDBIB			
NOCOMMON			
ENDSUBENT			
SUBENT	00001002		
BIB			
REACTION	1	(92-U-235(N,EL),,WID) THIS IS AN EXAMPLE OF MULTIPLE	
	2	(92-U-235(N,F),,WID) REACTIONS WITH POINTERS	
ANALYSIS	1	(CDEFG). THIS IS AN EXAMPLE OF A BIB ENTRY WITH MORE	
	2	THAN ONE PIECE OF MACHINE-RETRIEVABLE INFORMATION,	
	(HIJ).	EACH CODED IN ITS OWN SET OF PARENTHESES.	
		EACH PART OF THE BIB ENTRY IS LINKED BY A POINTER	
		IN COLUMN 11 TO OTHER INFORMATION IN THIS SUBENTRY	
		AND IN SUBENTRY 1 WITH THE SAME POINTER.	
		THE POINT AFTER THE CLOSING PARENTHESIS INDICATES THAT	
		THE CONTENTS OF THE PARENTHESES IS NOT REPEATED IN	
		FREE TEXT, AS WOULD BE REQUIRED IF THE POINT WERE ABSENT	
ENDBIB			
NOCOMMON			
DATA			
EN	DATA	1DATA-ERR	1DATA
EV	MILLI-EV	MILLI-EV	2
ENDDATA			
ENDSUBENT			
ENDENTRY			

Chapter 5

COMMON AND DATA SECTIONS

The format of the common and point data sections is identical; however, the significance of the content is different. Each section is a table of data with a heading and units associated with each field. The only differences between the common data table and the point data table is that the common data table contains constant parameters that apply to each line of a point data table. The point data table contains rows of information; each row, generally, contains values as a function of one or more independent variables (e.g., angle, angular error, cross section, cross section error).

Since each record contains six information fields, each 11 columns wide, up to six fields of information may be contained on a record. If more than six fields are used, the remaining information is contained on the following records (see example on page 5.6). The number of fields in each section is restricted to 18.

Records are not packed; rather, individual point information is kept on individual records (i.e., if only four fields are associated with a point value, the remaining two fields are left blank, and, in the case of the data point table, the information for the next point begins on the following record. Similarly, if eight fields are used, the remaining four fields on the second record remain blank. These rules apply not only to the data, but also to the headings and units associated with each field (see example on page 5.6).

The content of the COMMON and DATA sections are as follows:

1. Data headings for each field (if more than six fields are needed, the headings are continued onto successive records). The data headings are left adjusted to the beginning of each field (columns 1, 12, 23, 34, 45, 56). See Dictionary 24 for permissible data-heading keywords.
- A one-character pointer is placed in the last (eleventh) column of any data-heading field if the corresponding field is linked to the BIB or COMMON of the same subentry or subentry 001. See page 6.1 for more information on pointers.
2. Data units for each field (if more than six fields are needed, the units are continued onto successive records). The data units are left adjusted to the beginning of each field (Columns 1, 12, 23, 34, 45, 56). See Dictionary 25 for permissible data-unit keywords.
3. The numerical data which is Fortran-readable using an 'E' format (see following, Numerical Data Formats). If more than six fields are used, the data is continued onto successive records.

Numerical Data Formats

The prescribed format for numerical data entered in the COMMON or DATA section of an EXFOR entry is defined as "FORTRAN-readable according to an E format".

This means, in detail:

- A decimal-point is always present, even for integers.
- A decimal number without an exponent can have any position within the 11-character field.
- No blank is allowed following a sign (+ or -).
- A plus sign may be omitted, except that of an exponent when there is no E.
- In an exponential notation, the exponent is right-adjusted within the 11-character field. The mantissa may have any position.

All the following examples are valid entries:

Fixed Point Numbers with a Decimal Point	Floating Point Numbers with an Exponent
0.14	+0.0014E+01
0.14	0.0014E+2
0.14	0.0014E2
+0.14	.0014E+2
-0.140	-0.140E+00
-.14	-.14E0
	1.4E-1
	1.4-1
	1.40 E-01

The values are either zero or have absolute values between 1.0000E-38 and 9.999E+38.

Notes: Compilers should aim at a neat-looking and easily-readable arrangement of the numbers.

Centers using PL/I may have to apply special manipulation when numerical fields include embedded blanks.

The following two restrictions apply within the three sections:

COMMON section of subentry nnn ≠ 001,
DATA section of subentry nnn ≠ 001,
COMMON section of subentry 001 of same entry.

Multiple representations of independent variables

Only one representation of an independent variable may be given for each data line (e.g., either angle or cosine may be given, not both).

Repetition of data headings

No data heading (data-heading keyword plus perhaps a pointer) will be repeated except for the following cases. (Any additional case of repeated data headings which the centers may agree to accept, must be described here).

Fields with identical data headings will be adjacent and will appear within only one of the three sections mentioned above.

1. Two or more unresolved secondary energies are entered as follows:

E-LVL	E-LVL	E-LVL
MEV	MEV	MEV
0.077	0.107	0.177

Similarly, the data heading EN-RES may be repeated in the case of unresolved resonance energies.

2. An angle given in degrees and minutes is entered in two separate fields with the data heading ANG repeated, as follows:

ANG	ANG
ADEG	AMIN
90.	47.

Other keywords beginning with ANG- may be repeated in the same way.

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3. Half-life values in different units, such as SEC, D, YR, are entered as follows:

HL	HL	HL
SEC	D	YR
15.		
	28.3	
4.8		

COM
This
bet
exp

In
suc
The
sect

An
and

1
COM
EN
MEV
2.7
END

- Any other data-heading keyword starting with HL... may be repeated in the same way. This usage cannot occur in a COMMON section.

4. Two or more flags defined under the BIB keyword FLAG which apply to the same line of the data table are entered as follows:

FLAG	FLAG
NO-DIM	NO-DIM
1.	
3.	
2.	3.
1.	2.

An

1
COM
EN
AND
MEV
4.
10
END

Note: The data-heading keyword FLAG is not used in a COMMON section.

5. Errors or resolutions given in different units over an energy range are entered as follows:

EN-RSL	EN-RSL
KEV	PER-CENT
20.	
20.	
	10.
20.	

6. Two or more unresolved masses (for mass yields) are entered as follows:

MASS	MASS
NO-DIM	NO-DIM
135.	136.

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COMMON SECTION

This section is identified on the transmission file as that information between the system identifiers COMMON and ENDCOMMON. (See page 3.7 for explanation of numerical fields on COMMON and ENDCOMMON records).

In the common data table only one number is entered for a given field, and successive fields are not integrally associated with one another.

The data-heading keyword DATA and its derivatives is not used in the COMMON section, except for those derivatives which contain the suffix -ERR.

An example of a common data table is shown below with its associated COMMON and ENDCOMMON records.

1	12	23	34	45	56	66
COMMON						
EN	EN-ERR	4	3	E-ERR		
MEV	MEV	E	MEV	MEV		
2.73	0.16	MEV	1.98	0.21		
ENDCOMMON		3				

An example of a common data table with more than 6 fields:

1	12	23	34	45	56	66
COMMON						
EN	EN-ERR	7	EN-PSL	6	E-LVL	ANG
ANG-ERR		EN-PSL		E-LVL		
MEV	MEV	MEV	MEV	MEV	MEV	ADEG
ADEG						
4.1	0.05	0.1	3.124	3.175	90.	
10.						
ENDCOMMON		3				

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DATA SECTION

This section is identified on the transmission file as that information between the system identifiers DATA and ENDDATA. (See page 3.8 for an explanation of numerical fields on DATA and ENDDATA records.)

In the DATA table, all entries on a record are integrally associated with an individual point. If more than six fields are used, the point data is continued on successive records (maximum of 3 records or 18 fields). The following record or records are then associated with the next point.

Every line in a data table gives data information. This means, for example, that a blank in a field headed DATA is only permitted when another field contains the data information on the same line, e.g., under DATA-MAX. In the same way, each independent variable occurs at least once in each line (e.g., either under data headings E-LVL or E-LVL-MIN, E-LVL-MAX, see example on page 5.10). Supplementary information, such as resolution or standard values, is not given on a line of a data table unless the line includes data information. Blanks are permitted in all fields.

An example of a point data table is shown below with its associated DATA and ENDDATA records.

1	12	23	34	45	56	66
DATA		4	9			
ANG	ANG-ERR	DATA	DATA-ERR	DATA-MAX		
ADEG	ADEG	MB/SR	MB/SR	MB/SR		
10.4	0.8	243.	8.7			
22.9	1.2	127.	4.2			
39.1	0.9			83.2		
59.1	0.7	14.8	2.9			
83.	1.0	19.2	3.4			
112.	1.3	21.2	4.1			
173.	1.1	16.8	3.8			
ENDDATA		9				

Field Sequence in a DATA Table

The preceding example illustrates the simplest type of table representing the dependent variable DATA as a function of the independent variable ANG (one-dimensional table). The rules for multi-dimensional tables require a distinction between four data categories occurring in data tables, namely

- independent variables (EN, EN-MIN, EN-RES, E, ANG, ...);
- dependent variables (DATA);
- associated quantities (EN-ERR, ANG-RSL, DATA-ERR, ...);
- additional information (MONIT, MISC, FLAG, HL, ...).

The division between different categories and families within categories is defined in dictionary 24 (data-heading-keyword dictionary). (See page 7.14).

DATA tables are arranged as follows:

- all fields with independent variables precede fields with dependent variables. Fields to the left of the first dependent-variable field are considered as independent-variable fields, or independent-variable associated quantities.
- fields with additional information are, preferably, placed after the last dependent-variable field, but, if they refer to a specific field, they may be placed next to it.

Note: Some data-heading keywords may be used either as independent variables or as additional information.

- fields with associated quantities are placed right after the field to which they refer.

If the COMMON section is included, the EXFOR table will then look as follows.

```
COMMON  
  
ENDCOMMON  
DATA  
  independent variable(s)      dependent variable(s)  
  + associated quantities    + associated quantities  
                                + additional information  
ENDDATA
```

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Line sequence of a DATA Table

1. One-dimensional tables (one independent variable)

The values of the independent variable increase or decrease monotonically throughout the table.

2. Multi-dimensional tables (more than one independent variable)

If fields for more than one independent variable are needed they are arranged so that the rate with which the numbers change within each field increases from left to right. Obviously, this rule does not apply to associated-quantity fields. Values in a given independent-variable field increase or decrease monotonically until the value in the preceding independent-variable field changes or the end of the table is reached.

Example

DATA	EN	EN-ERR	ANGLE	ANGLE-ERR	DATA
	MEV	MEV	ADEG	ADEG	MB/SR
	1.	.02	35.	10.	-
	1.	.02	60.	10.	-
	1.	.02	90.	10.	-
	2.	.02	30.	5.	-
	2.	.02	60.	5.	-
	2.	.02	90.	5.	-
	3.	.03	30.	5.	-
	3.	.03	60.	5.	-
	3.	.03	90.	5.	-

ENDDATA

Alternatively, this table may be given in the "vector common data" formalism using pointers; see page 6.2.

A slight complication arises with families of independent variables referring to basically the same quantity, as, for instance, the fields referring to excitation energies of the residual nucleus in the following example. In this case, the monotonicity rule applies to the sequence of numbers consisting of the first (left-most) non-blank value within the group on each line.

Example

```
DATA
EN      E-LVL      E-LVL      E-LVL-MIN   E-LVL-MAX   DATA
MEV     MEV        MEV        MEV         MEV        B
3.0     0.506
3.0     0.720      0.725
3.0     0.81
3.0     0.990      0.998
3.0           1.250
3.0     1.400      1.412
4.5     0.405
ENDDATA
```

Note to compilers: In general, the same value of the independent variable will not occur more than once. In the few cases that it does occur more than once (e.g., repetition of the measurement at same energy), it is advisable to give the reason in free text in the BIB section. (Otherwise, it may be interpreted as a data entry error or as inadvertent duplication.)

Chapter 6

LINKS BETWEEN BIB, COMMON AND DATA SECTIONS

Pointers

Different pieces of EXFOR information may be linked together by pointers. A pointer is a numeric or alphabetic character (1,2,...9,A,B,...Z) placed in the eleventh column of the information-identifier keyword field in the BIB section and in the data-heading keyword fields in the COMMON or DATA section.

Pointers may link, for example,

- one of several reactions with its DATA field;
- one of several reactions with a specific piece of information in the BIB section (e.g., ANALYSIS), and/or with a value in the COMMON section, and/or with a field in the DATA section;
- a value in the COMMON section with any field in the DATA section.

In general, a pointer is valid for only one subentry. A pointer used in the first subentry applies to all subentries and has a unique meaning throughout the entire entry.

In the BIB section the pointer is given on the first record of the information to which it is attached and is not repeated on continuation records. The pointer is assumed to refer to all BIB information until either another pointer is encountered, or until a new keyword is encountered. This implies that pointer-independent information for each keyword appears first.

See also LEXFOR Pointers.

The use of pointers is restricted to the five cases given on the following pages.

1. Multiple Reaction Formalism (See page 8.R.10).

In certain cases (see LEXFOR Multiple Reaction Formalism) more than one code unit may be given under the REACTION keyword for a subentry, each unit having its own data field(s). Each data field is then linked to the appropriate code string by means of a pointer.

Example

```
BIB
REACTION  1(92-U-235(N,O),,EN)
           2(92-U-235(N,O),,J)
           3(92-U-235(N,TOT),,WID)
           4(92-U-235(N,F),,WID)

ENDBIB
COMMON
MOMENTUM L DATA-ERR  3DATA-ERR  4
NO-DIM      PER-CENT    PER-CENT
0.          8.          10.

ENDCOMMON
DATA
DATA        1DATA      2DATA      3DATA      4
EV          NO-DIM    MILLI-EV    MILLI-EV

ENDDATA
```

In the example above, the field headed 'MOMENTUM L' in the COMMON Section does not have a pointer and, therefore, relates to all fields of the DATA Section. The two fields headed 'DATA-ERR' in the COMMON Section are linked, by means of pointers, to fields of the DATA Section and to specific reaction units in the BIB Section.

2. Vector Common Data

Multi-dimensional tables may be coded using pointers. (See page 5.9 for alternate coding of multi-dimensional tables).

The following rules apply to the use of vector common data:

- If a pointer links a set of independent-variable data headings, (e.g., EN, ANG, E-LVL), one of which must appear in COMMON, all other pointers will also link with the same set of independent-variable data headings, i.e.; the following is forbidden:

```
E      1E      1E-MIN  2E-MAX  2
```

- Units referring to a given independent variable will be the same for all pointers.
- For a given independent variable, the number of data headings repeated for each pointer will be the same.
- The *vector common formalism* may not be combined with the *multiple reaction formalism*.

Example: COMMON

ANG	1ANG	1ANG	2ANG	2
ADEG	AMIN	ADEG	AMIN	
30.	30.	40.	0.	
ENDCOMMON				
DATA				
EN	DATA	1DATA	2	
MEV	MB/SR	MB/SR		

3. BIB/DATA Links

Pointers used for *multiple reaction* or for *vector common data* may also be used elsewhere in the BIB Section in order to link, for example, certain information under MONITOR, ANALYSIS, COMMENT, etc., to one of the multiple reactions or to one of the vector common data.

Example: REACTION (....)

COMMENT	1 Free text about first angle
	2 Free text about second angle

ENDBIB

COMMON

ANG	1ANG	2
ADEG	ADEG	
10.	20.	

ENDCOMMON

DATA

EN	DATA	1DATA	2
.....	

or: REACTION 1(....)
 2(....)
PART-DET 1(....)
 2(....)

Forbidden: REACTION (----)
MONITOR 1(----)
 2(----)
ENDBIB
COMMON
MONIT 1MONIT 2

4. BIB/BIB Links

Pointers may be used to link pieces of BIB information, all referring to the same REACTION.

Example: REACTION (....)
PART-DET 1(G).
 2(N).
DETECTOR 1(ABCDE).
 2(FGHIJ).

Note: If the *multiple-reaction* or *vector-common* formalism is used, BIB/BIB links are only used to link to existing pointers, as in (3) above.

5. Alternative results

Different results for the same quantity in the same experiment, e.g., by two different methods of analysis, may be entered in the same subentry, distinguished by the pointers. In this case, the code unit under the data specification keyword is repeated.

(See also LEXFOR Interdependent Data.)

Note: From a processing point of view, this is the same concept as *multiple reactions* described on page 6.2.

Example: REACTION 1(92-U-235(N,G),,WID)
 2(92-U-235(N,G),,WID)
ANALYSIS 1(AREA)
 2(SHAPE)

Links between Information-Identifier Keywords and Data-Heading Keywords

Certain information-identifier keywords and their codes require specific entries in the data (COMMON and DATA Sections), and vice versa. These cases are listed, below, according to the information-identifier keyword. See Chapter 8 for details on the coding of information-identifier keywords.

The following shorthand is used throughout this section.

- Particle is used to mean particle, nuclide or radiation.
- Data-heading keywords as given are understood to include their derivatives (e.g., for DATA, the headings DATA-CM, DATA-APRX, etc., are also included).

1. REACTION

The coded information under the keyword REACTION:

- a) defines the data coded in the DATA section under the dependent variable data-heading keyword DATA. The dependent variable data headings are not used in the COMMON section; associated quantities for the dependent may, however, appear in the COMMON section, e.g., DATA-ERR. At least one dependent variable data field will be present in each DATA section.
- b) requires the presence, or absence, of certain families of independent variables (see page 7.14). The family code for a given data-heading keyword is given in Dictionary 24, column 66.

Incident Projectile Energy (Family A) or Incident Projectile Momentum (Family M) is always present except in the following cases when it is forbidden:

- if SF2 of REACTION contains 0 (zero);
- if resonance energy is given (see below).

KT, EN-DUMMY, or EN-MEAN are used when the quantity field contains the modifier MXW, SPA or FIS. See also page 6.8 (4. INC-SPECT).

See also LEXFOR Incident-Projectile Energy and Spectrum Average.

Resonance Energy (Family C) is specified for resonance parameters (flagged Dictionary 36, see page 7.17). It is coded either under the data heading EN-RES, or, if coded under REACTION (specified by the code EN given in REACTION SF6), under the heading DATA.

See also LEXFOR Single-Level Resonance Parameters.

Secondary Energy (Family E) is coded when:

- a) REACTION SF5 contains the modifier code PAR
- b) REACTION SF6 contains the code DE or SPC

See also page 6.9, 5. EN-SEC, and LEXFOR Secondary Particles.

Angle of Outgoing Particle (Family G) is coded when REACTION SF6 contains the code DA, except in the case of Legendre or cosine coefficients, see below. (For angles in degrees and minutes see page 5.4.)

See also LEXFOR Angle.

Legendre or cosine coefficient Number (Family N) is coded when REACTION SF8 contains the code LEG or COS.

See also LEXFOR Fitting Coefficients.

Half-life (Family 6) is coded if SF4 of the REACTION keyword contains a product with a metastable state extension (see page 8.3), and the half-life is not coded under DECAY-DATA.

See also LEXFOR Half-lives.

Momentum (t) (Family 2) will be coded when:

- REACTION SF6 contains the code RED.
- REACTION SF6 contains the code STF.

It is coded either under the data heading MOMENTUM L, or, if coded under REACTION (specified by the code L in REACTION SF6), under the heading DATA.

See also LEXFOR Quantum Numbers.

Variable Nucleus

In the case of the processes specified below, the data table may contain yields or production cross sections for several nuclei, which are entered as variables in the data table.

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In this case either SF1 or SF4 of the REACTION keyword contains one of the following codes:

- ELEM - If the Z (Mass number) of the reaction product is given in the DATA table.
- MASS - If the A (atomic weight) of the reaction product is given in the DATA table.
- ELEM/MASS - If the Z and A of the reaction product are given in the COMMON section or DATA table.

The nuclei are entered in the data table as variables under the data headings ELEMENT and/or MASS with units NO-DIM.

If the data headings ELEMENT and MASS are present, a third field with the data-heading keyword ISOMER is used when isomer states are specified:

- 0. = ground-state (used only if nuclide has also an isomeric state)
- 1. = first metastable state
or, the metastable state when only one is considered
- 2. = second metastable state

Decay-data for each entry under ELEMENT/MASS/(ISOMER) and their related parent or daughter nuclides may be given in the usual way under the BIB keyword DECAY-DATA. Entries under the data headings ELEMENT/MASS/(ISOMER) are linked to entries under DECAY-DATA (and RAD-DET, if present) by means of a decay flag (see pages 6.10, 8.D.1, and LEXFOR Flags). If the half-life is the only decay data given, this may be entered in the DATA table under the heading HL.

Restrictions of use: Only SF1 or SF4 may become variable by using this formalism.

The formalism of the *variable nucleus* may be used:

for SF1 only when
- SF8 contains the code PN (delayed-neutron emission probability)

for SF4 only when
- SF3 contains one of the process codes
 X - production of the product nuclei specified
 F - fission
 XN - variable number of neutrons (see page 6.8)
 YP - variable number of protons (see page 6.8)

See also LEXFOR Reaction Products.

Variable Number of Emitted Nucleons

In the case where mass and element distributions of product nuclei have been measured and the Z and/or A of the reaction product acts as an independent variable, the sum of outgoing neutrons and protons may be entered as variables in the data table. In this case SF3 of the REACTION keyword contains at least one of the following codes:

XN - variable number of neutrons given in the data table.

YP - variable number of protons given in the data table.

The numerical values of the multiplicity factors X and Y are entered in the data table under the data headings N-OUT and P-OUT, respectively.

See also LEXFOR Particles.

REACTION Ratios

If a REACTION combination contains the separator ' // ', signifying that the numerator and denominator of a ratio have different values for one or more independent variables, then the data table will contain at least one independent variable pair with the data heading extensions '-NM' and '-DN' (see Dictionary 24).

Example:

```

BIB
REACTION (((92-U-238(N,F)ELEM/MASS,CUM,FY,,FIS)/
           (92-U-238(N,F)42-MO-99,CUM,FY,,FIS))//)
           (((92-U-235(N,F)ELEM/MASS,CUM,FY,,MXW)/
           (92-U-235(N,F)42-MO-99,CUM,FY,,MXW)))
RESULT      (RVAL)
-----
ENDBIB
COMMON
EN-DUM-NM  EN-DUM-DN
MEV        EV
  1.0      0.0253
ENDCOMMON
DATA
ELEMENT    MASS      DATA
-----
ENDDATA

```

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2. MONITOR

MONITOR is always present when the data-heading keyword MONIT is coded.

If more than one monitor is given MONIT1, MONIT2, etc., the data headings are repeated as codes under the keyword MONITOR; otherwise, MONIT1 refers to the first monitor, MONIT2 to the second, etc. See Standards for coding example.

The data-heading keywords EN-NRM, E-NRM and ANG-NRM are used only when the keyword MONITOR is present.

See also LEXFOR Standards.

3. ASSUMED

When assumed values are given in the data under the data-heading keyword ASSUM, they are defined under the keyword ASSUMED.

See also LEXFOR Assumed Values.

4. INC-SPECT

When the data-heading keyword EN-DUMMY is used (i.e., when the reaction code contains the modifier MXW, FIS or SPA), the spectrum is defined in free text under the keyword INC-SPECT.

See also LEXFOR Spectrum Average.

5. EN-SEC

When the data is a function of the secondary energy of more than one particle (i.e., the headings E1,E2, etc., are used), the particles are defined in coded form under the keyword EN-SEC.

A secondary energy which is not defined refers to the particle specified in the reaction code. See LEXFOR Particles.

6. HALF-LIFE

When more than one half-life is coded in the DATA section under the data-heading keywords HL1, HL2, etc., these are defined in coded form under the information-identifier keyword HALF-LIFE.

A half-life which is not defined under this keyword refers to the reaction product (or residual nucleus).

See also LEXFOR Half-lives.

7. ERR-ANALYS

This keyword is always present when a data-heading keyword having the modifier -ERR is used.

If more than one data-heading keyword having a modifier of the type -ERR exists, then the data-heading keyword is always repeated as a code under the keyword ERR-ANALYS.

See also LEXFOR Errors.

8. FLAG

This keyword is always present when the data-heading keyword FLAG is used in the DATA section. (There may be more than one field with the data heading FLAG, see page 5.5).

DATA fields headed by the keyword FLAG contain fixed point numbers. These are all repeated as codes under the information-identifier keyword FLAG.

See also LEXFOR Flags.

9. MISC-COL

This keyword is present when the data-heading keyword MISC is used in the data section. (MISC is never used in the COMMON section).

If the keywords MISC1, MISC2, etc., are used, they are repeated as codes under the keyword MISC-COL.

See also LEXFOR Miscellaneous.

10. DECAY-DATA, RAD-DET

The keyword DECAY-DATA is always present when the data-heading keyword DECAY-FLAG is used in the DATA section.

DATA fields headed by the keyword DECAY-FLAG contain fixed point numbers. These are repeated as codes under the information-identifier keyword DECAY-DATA, and may also be repeated under the keyword RAD-DET.

See also LEXFOR Flags.

11. MOM-SEC

When the data is a function of the secondary linear momentum of more than one particle (i.e., the headings M1, M2, etc., are used), the particles are defined in coded form under the keyword MOM-SEC.

A secondary linear momentum which is not defined refers to the particle specified in the reaction code. See LEXFOR Secondary Particles.

12. EMS-SEC

When the data is a function of the secondary effective mass of more than one particle (i.e., the headings EMS1, EMS2, etc., are used), the particles will be defined in coded form under the keyword EMS-SEC.

A secondary effective mass which is not defined refers to the particle specified in the reaction code. See LEXFOR Secondary Particles.

10. LEVEL-PROP

The keyword LEVEL-PROP is always present when the data-heading keyword LEVEL-FLAG is used in the DATA section.

DATA fields headed by the keyword LEVEL-FLAG contain fixed point numbers. These are repeated as codes under the information-identifier keyword LEVEL-PROP.

See also LEXFOR Flags.

Cross-References by Data-Heading Keyword to Information-Identifier Keyword.

Data-heading Keyword	Family*	Information-Identifier Keyword	Page
EN	A	REACTION	6.5
EN-DUMMY, KT		REACTION	6.5
		INC-SPECT	6.9
EN-NRM		MONITOR	6.9
EN-RES	C	REACTION	6.5
E	E	REACTION	6.6
E1, E2, etc.		EN-SEC	6.9
EMS1, EMS2, etc.		EMS-SEC	6.11
MOM-SEC1,MOM-SEC2, etc.		MOM-SEC	6.11
E-NRM		MONITOR	6.9
ANG	G	REACTION	6.6
ANG-NRM		MONITOR	6.9
MOM	M	REACTION	6.6
NUMBER	N	REACTION	6.6
DATA		REACTION	6.5
MONIT		MONITOR	6.9
ASSUM, ASSUM1, etc.		ASSUMED	6.9
ELEMENT	I	REACTION	6.7
MASS, ISOMER	J	REACTION	6.7
N-OUT	O	REACTION	6.8
P-OUT	P	REACTION	6.8
HL	6	REACTION	6.6
HL1, HL2, etc.		HALF-LIFE	6.10
FLAG		FLAG	6.10
DECAY-FLAG		REACTION	6.7
LEVEL-FLAG		DECAY-DATA, RAD-DET	6.11
		LEVEL-PROP	6.11
MOMENTUM L		REACTION	6.6
MISC, MISCI, etc.		MISC-COL	6.10
-ERR		ERR-ANALYS	6.10

* As given by a flag in Column 66 of Dictionary 24.

Chapter 7

DICTIONARIES

Dictionary Transmission Files

Dictionary transmission files have much the same format as an EXFOR data transmission file.

The first record is a TRANS record as described on page 3.3. For the transmission file identification, "9" is used as the originating center identification, although in column 67 the center identification "3" is used throughout the file.

The last record is an ENDTRANS record as described on page 3.3, except that N1 is blank, and N2 contains the number of dictionaries transmitted. Trailing records to fill up the last block are repetitions of the ENDTRANS record.

Each dictionary is identified by a dictionary identification number ranging between 001 and 099.

The beginning and the end of a dictionary are identified by two system-identifier records:

1. DICTION

This record is the first one of each dictionary. The N1 and N2 fields are interpreted as:

N1 - The dictionary identification number
N2 - Date of last alter (year, month, day - YYMMDD).

Column 34-66 - contents of the dictionary in free text.

The record identification (columns 67-79) contains "30000" in columns 67-71, the dictionary number in columns 72-74, and the record sequence number "00001" in columns 75-79.

2. ENDDICTION

This record is the last one of each dictionary. The N1 field is interpreted as:

N1 - Number of records in the dictionary, excluding the DICTION and ENDDICTION records.

The record identification is the same as in the DICTION record, except that the record sequence number is "99999".

| Note: A dictionary transmission file will always include all dictionaries.

3.

Format of Dictionaries

The dictionaries contain explanations for all keywords and codes used in EXFOR. The format of the dictionaries is, in general, similar to that of the BIB Section in EXFOR entries. There are 4 keyword dictionaries:

4.

Dict. 1 System-identifier keywords;

Dict. 2 Information-identifier keywords to be used within the BIB Section;

Dict.24 Data-heading keywords;

Dict.25 Data-unit keywords;

5.

the latter two contain keywords used in the COMMON and DATA Sections as data headings.

6.

Other dictionaries define codes used within the BIB Section under specific information-identifier keywords (see the Table of Dictionaries on page 7.10).

7.

The dictionaries contain the following items of information:

1. The keyword or code to be defined is given, left adjusted, in the first field, which is usually contained in columns 1-11, but is longer in some cases. In general, keywords must not be longer than 10 characters; some may be longer; some are restricted to a length of 3 or 5 characters. (See page 7.10).
2. The explanation is contained in the explanation field which usually starts in column 12 (sometimes in column 23) and usually (with some exceptions) ends in column 66 of the first record. The explanation may be given
 - in free text,
 - or in an "expanded form"
 - or in an "expanded form" followed by free text.

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3. The expanded form may be used to replace the code in an edit program, so that the EXFOR user may read the entries without having to consult the dictionaries to find the meaning of the codes. Expanded forms which are self-explanatory and easy to remember are provided in certain dictionaries (see page 7.10). The expanded form is enclosed in parentheses; the opening parenthesis is given in the first column of the explanation field (usually column 12). Only one set of parentheses may be associated with a dictionary entry. The expanded form is, in general, restricted to the length of the explanation field of one record; but, for certain dictionaries (see page 7.10), the expanded form may continue, within the explanation field, onto following records.
4. The free text may immediately follow the closing parenthesis of the expanded form or, if no expanded form is given, begin in the first column of the explanation field. It may continue, within the explanation field, onto any number of records. The free text may include parentheses, but a left parenthesis which is part of the free text must not be entered in the first column of the explanation field (where it would signal the presence of an expanded form).
5. An obsolete flag (O) in column 80 indicates that the keyword or code given in the same record is not permitted on new transmissions but may still exist in entries which were transmitted previously. An explanation is given in free text as to why the code is obsolete and which code (if any) is replaces it. Obsolete codes remain in the dictionary until all cooperating centers have removed them from their files.

An extinct flag (X) in column 80 indicates that the code given designates an extinct institute, journal, or report series. The code is still valid on transmissions, but will occur only in entries of old data.

6. The record identification field (columns 67-79) of a dictionary record contains "30000" in columns 67-71, the dictionary identification number in columns 72-74 with leading zero(s), and in columns 75-79 the record sequence number with leading zeros.
7. Other coded information is included in some of the dictionaries (e.g., the country of origin for journal codes, certain flags for checking purposes in the case of data-heading keywords). For detail see the dictionaries themselves, and pages 7.11-17.

The order of entries in each dictionary has been chosen for ease of use by compilers. It is the prerogative of each center to rearrange the dictionary for their own purposes, e.g., for optimum computer use, if they wish.

Some example of dictionaries are shown below, omitting columns 67-80:

DICTION	2	760609 INFORMATION IDENTIFIER KEYWORDS
TITLE	KEYWORD OBLIGATORY EXCEPT WHEN NOT RELEVANT.	
	FREE TEXT ONLY.	
AUTHOR	KEYWORD + ALL NAMES IN PARENTHESES OBLIGATORY.	
INSTITUTE	KEYWORD + CODES INFORMATION IN PARENTHESES OBLIGATORY.	
	SEE DICTIONARY 3 FOR INSTITUTES.	
EXP-YEAR	KEYWORD OPTIONAL. IF KEYWORD PRESENT, THEN TWO DIGIT YEAR IN PARENTHESES OBLIGATORY.	
REFERENCE	KEYWORD + CODED INFORMATION IN PARENTHESES OBLIGATORY. UP TO 6 SUBFIELDS IN CODE. SEE DICTIONARY 4 FOR REFERENCE-TYPE SEE DICTIONARY 5 FOR JOURNALS SEE DICTIONARY 6 FOR REPORTS SEE DICTIONARY 7 FOR CONFERENCES AND BOOKS	

DICTION	5	760414 JOURNALS
AAA	(ASTRON.AND ASTROPHYS.) ASTRONOMY AND ASTROPHYSICS 2GER	
AAB	(AN.ACAD.BRASIL.CIENC.) ANAIS DA ACADEMIA BRASILEIRA 3BZL	
	DE CIENCIAS	
AAF	(ANN.ACAD.SCI.FENN.SER.A6) ANNALES ACADEMIAE 2SF	
	SCIENTIARUM FENNICAESERIES A6:PHYSICA	
ABS	(MEM.ACAD.ROY.BELG.CL.SCI.) MEMOIRES DE L'ACADEMIE 2BLG	
	ROYAL DE BELGIQUE,CLASSE DE SCIENCES	
AC	(ANAL.CHEM.) ANALYTICAL CHEMISTRY 1USA	
ACA	(ANAL.CHIM.ACTA) ANALITICA CHIMICA ACTA 2NED	
ACH	(ANGEWANDTE CHEMIE) 2GER	
ACJ	(ACTA CHEM.SCAND.) ACTA CHEMICA SCANDINAVICA 2DEN	
ACR	(ACTA CRYSTALLOGR.) ACTA CRYSTALLOGRAPHICA 2DEN	
	CONTINUED 1970 IN PARTS A AND B	
ACR/A	(ACTA CRYSTALLOGR.,PART A) ACTA CRYSTALLOGRAPH(CA, 2DEN	
	PART A, STARTED WITH VOL.26 IN 1970	
ACR/B	(ACTA CRYSTALLOGR.,PART B) FROM VOL.26(1970) 2DEN	

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Alterations to Dictionaries

The format of dictionary update records and the resulting alterations (actions) are described in the following:

First record:

Column 1 - 5 ALTER
6 - 16 blank
17 - 22 Date of update (yyymmdd)
23 - 44 blank
45 - 80 Free text. Contains the date of the run and reference to relevant CP-Memo(s).

Last record:

Column 1 - 8 ENDALTER
9 - 11 blank
12 - 80 Free text

Standard records:

1. Change

Column 1 - 11 Same as column 1 - 11 of the record to be changed
12 - 66 New text to replace old text
67 - 79 ID of record to be changed
80 'C'

Action: The record having the specified ID has the old text (Column 12 - 66 replaced by the new text (if column 1 - 11 agree) and flagged as a change (C). The obsolete/extinct flag remains unaltered.

2. Delete

Column 1 - 11 Same as column 1 - 11 of the record to be deleted
12 - 66 Free text, e.g., reason for deletion and/or reference to relevant CP-Memo
67 - 79 ID of record to be deleted
80 'D'

Action: The record having the specified ID is deleted (if Column 1 - 11 agree), and the preceding record flagged.

3. Insert

a) Single insertion

Column 1 - 66 Text of record to be inserted
67 - 79 ID of record after which insert is to be made
80 'I'

b) Several consecutive insertions

First record as above.

Continuation records:

Column 1 - 66 Text of record to be inserted
67 - 74 As (a) above.
75 - 80 Continuation number, starting with 2, no leading zeros.

Action: The records are inserted following the record having the ID specified on the first insert record, and each inserted record is flagged (I).

c) Insertion of a new dictionary

First record:

Column 1 - 7 'DICTION'
21 - 22 Dictionary number
35 - 66 Free text (title of dictionary)
67 - 79 '300000NN00001' (NN = dictionary number)
80 'I'

Dictionary records:

Column 1 - 66 Dictionary information
67 - 74 '300000NN' (NN = dictionary number)
75 - 80 blank

Last record:

Column 1 - 10 'ENDDICTION'
11 - 66 blank
67 - 79 '300000NN99999' (NN = dictionary number)
80 blank

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4. Obsolete

Column 1 - 11 Same as column 1 - 11 of the record to be obsoleted.
12 - 66 Free text, e.g., reason for obsolescence and/or
reference to relevant CP-Memo.
67 - 79 ID of record to be obsoleted.
80 'O' (letter O).

Action: The record having the specified ID has the obsolete flag set to 'O'
(if column 1 - 11 agree). The alter flag remains unchanged.

Notes:

1. Records may be in any order, except for the ALTER and ENDALTER records, which are first and last, respectively; however, for a multiple insertion, the records will be in the correct order by continuation number.
2. The date field on the ALTER record is normally blank. The facility for inserting a date is included in case of emergency (such as the master file being destroyed). In such a case, an identical master can be regenerated by inserting the date of the previous updates in this field and using the previous update records.
3. If a specific code (as opposed to its associated text) is to be changed, the record must be deleted and the new code and text inserted. (Changes of code rarely happen.)
4. In order to remove an obsolete code the record must be deleted, and the same record inserted, without the O.
5. A record cannot be inserted and obsoleted at the same time. It must be inserted and then obsoleted at the next update run.

Procedure for Updating and Transmitting Dictionaries

Responsibilities for maintaining the dictionaries are outlined in the Protocol, Section F.

a) Introduction of new codes and dictionary alterations

Dictionary alterations include additions, corrections and deletions (complete deletions or adding of the "obsolete" flag, see page 7.5).

The cooperating centers may propose new codes or any other dictionary alteration by means of CP-Memos. The proposal should include the code and explanation to be entered in the dictionary and, if appropriate, a corresponding Manual entry (e.g., LEXFOR entry) and/or a pertinent bibliographic reference.

The center responsible for updating the dictionaries is also responsible for checking the consistency of proposed alterations with other codes and with the EXFOR Manual. The cooperating centers should assist by checking, within their respective areas, the up-to-date status of the dictionaries for laboratories and bibliographic references. Some latitude is allowed in the formulation of a proposed dictionary entry, but the meaning must not be changed without the approval of the originating center. In questionable cases, the other centers should be consulted.

A proposed dictionary alteration which appears to be trivial (*inconsequential*) will be added to the dictionaries within a week after receipt. Other proposals, which appear less trivial (*consequential*, in particular, alterations to Dictionaries 1, 2, 4, 16, 24, 28-36 or any alterations which may entail changes in computer programs) will be entered into the dictionaries only after approval by the centers.

If a center uses a new dictionary code in a data transmission prior to its inclusion in the relevant dictionary, the center must be prepared to correct the entry and retransmit it, if the new code is not approved.

In general, a dictionary alteration becomes effective upon its transmission to the cooperating centers. Entries compiled or transmitted earlier need not be updated according to later dictionary alterations, except when the contrary is explicitly agreed.

b) Routine Transmission of Dictionaries

Each dictionary update is transmitted to all cooperating centers in the form of a listing of the input records. Such update pages are numbered sequentially.

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At least every three months, or whenever a major alteration is made, the center responsible will transmit to the cooperating centers, as they prefer (see page 9.8):

- either the complete dictionary file on magnetic tape
- or a listing of the dictionary updates performed since the last transmission.

A dictionary transmission tape will have a label attached indicating the transmission file identification.

It is the responsibility of each center to verify that EXFOR information is compiled in accordance with the latest version of the dictionaries.

Table of Dictionaries

Number	Name	Code length	Expansion provided
1.*	System-Identifier Keywords	≤ 10	-
2.*	Information-Identifier Keywords	≤ 10	yes
3.*	Institutes	5 to 7	yes*
4.*	Reference Type	1	yes
5.*	Journals	≤ 6	yes
6.*	Reports	≤ 11	-
7.*	Conference and Books	≤ 10	yes*
8.	Elements	≤ 6	yes
9.*	Chemical Compounds	7 to 10	yes
10.**	Process/Parameter (Quantity SF1)	≤ 3	-
11.**	Function (Quantity SF2)	≤ 3	-
12.**	Modifier (Quantity SF3)	≤ 3	-
13.*	Particle (PART-DET, RAD-DET, etc.)	≤ 3	yes
14.*	Quantity (SF1 - 4)	≤ 18	yes*
15.	History	1	yes
16.	Status	≤ 5	yes
17.	Ref-Ref (SF1)	≤ 1	yes
18.	Facility	≤ 5	yes
19.	Incident Source	≤ 5	yes
20.	Additional Results	≤ 5	yes
21.	Method	≤ 5	yes
22.	Detectors	≤ 5	yes
23.	Analysis	≤ 5	yes
24.*	Data-Heading Keywords	≤ 10	-
25.*	Data-Units Keywords	≤ 10	-
27.*	Nuclides	≤ 10	-
28.*	Incident Particles (REACTION SF2)	≤ 3	yes
29.*	Product Particles (REACTION SF3)	≤ 3	yes
30.*	Process (REACTION SF3)	≤ 3	-
31.*	Branch (REACTION SF5)	≤ 5 ¹	-
32.*	Parameter (REACTION SF6)	≤ 3	-
33.*	Particles Considered (REACTION SF7)	≤ 3	yes
34.*	Modifiers (REACTION SF8)	≤ 3	-
35.	Data-Type (REACTION SF9)	≤ 5	yes
36.*	Quantities (REACTION SF5-8)	≤ 44	yes*
37.*	Result	≤ 5	yes
41.**	Conversion table of Quantity (Dict.14) to REACTION formalism	≤ 18	yes
42.	Cinda Quantities	≤ 3	yes

* Additional information given on the following pages.

** Additions to these dictionaries require NRDC approval.

** Obsolete

¹ Normally limited to 3-character code.

* Expansion may extend to follow-up records. In all other cases, expansion is restricted to the length of the explanation field of one record.

Additional information on specific dictionaries**Dictionary 2. Information-Identifier Keywords**

The first record for each keyword in columns 1-11 has the following format:

Columns 12-33: Expansion

34-44: Code designating whether keyword is required

REQ - required

XREQ - required except where not relevant

AREQ - one of these codes required

BREQ - each of these keywords is obligatory when relevant,
but at least one of them must be present

OBS - keyword obsolete; may exist in older entries

45-55: definition of coded information

RCODE - code required

OCODE - optional

OCODE+ - optional; if given, may be repeated in free text

**56-66: Pointer to dictionary used, '+' indicating additional
coded information**

Any following records contain free text information in columns 12-66.

Obsolete codes are marked by an 'O' in column 66.

Dictionary 3. Institute

The 7 character code ABBBCCC is constructed as follows:

A = service-area code, 1, 2, 3 or 4 as defined among neutron data
centers (see page 2.2)

BBB = country code

CCC = lab code (may be less than 3 characters, left adjusted)

The 3 character lab codes include all laboratory, university, institute,
agency and commission codes in use by the data centers, and must be unique.

Where the code identifies only a country, the information in the country-code
field (columns 2-4) is repeated in the lab-code field (columns 5-7), as for
example: ICANCAN (CANADA)

For this reason, it is forbidden to introduce a lab code which is identical
to an existing country code and vice-versa.

Obsolete codes are marked with an 'O' in column 80; extinct codes are
marked by an 'X' in column 80 (see page 7.3). The code which replaces it, if
any, is given in all cases.

The dictionary is sorted by the code, thus grouping together the institutes
for each area and country.

Note: The 3 character lab code is used in CINDA.

Dictionary 4. Type of reference

This dictionary is in the standard format except that columns 58-61 of the explanation field are reserved for the term "DICT n" pointing to the dictionary number 'n' which contains the reference codes to be used with the given reference type. Columns 58-61 are blank when no dictionary applies.

Dictionary 5. Journals

The actual journal code is restricted to 4 characters or less. Where journals are subdivided into parts, the part is included in the dictionary with the journal code, and separated from it by a slash, as for example:

..D/A = Nuclear Data, Part A.

Such codes are restricted to 6 characters.

The area code and country code (country of publication) are in columns 63 to 66.

The expanded form follows the commonly adopted style for journal titles, in particular, *INIS: Authority List for Journal Titles*, IAEA-INIS-11. However, some abbreviations have been expanded for clarity.

Obsolete codes are marked by an 'O' in column 80; extinct codes are marked by an 'X' in column 80 (see page 7.3).

The dictionary is sorted by codes.

Note: The journal codes are also used by CINDA.

Dictionary 6. Reports

Each code in the dictionary consists of the alphanumeric character string which precedes the actual report number. The final character of the codes given in the dictionary is always a hyphen (-), except in a few cases where the report codes are 11 characters and the 12th character a hyphen. In such cases the hyphen is dropped in the dictionary.

The 7-character institute code (as in Dictionary 3) of the institute at which the report was issued is given in columns 60 to 66.

Obsolete codes are marked by an 'O' in column 80; extinct codes are marked by an 'X' in column 80 (see page 7.3).

The dictionary is sorted on this institute code and, within the institute code, by report code.

Note: Report codes are, in general, identical with those used in CINDA.

Dictionary 7. Conferences and Books

Conference codes are composed of the year of the conference given in the first 2 digits of the code, followed by the place of the conference, which may have up to 6¹ characters.

Examples: 66PARIS
82ANTWER

Book codes are up to 8* characters long and give a concise short title of the book, or the family name of the first author.

In the dictionary, books, sorted alphabetically by code, precede conferences, which are sorted alphabetically by code, within year.

Note: The codes in this dictionary are also used by CINDA, which is restricted to 8-character codes. For this reason, additions to this dictionary should, whenever possible, be restricted to 8 characters.

Dictionary 9. Chemical Compounds

The general compound code 'CMP' can be combined with any element in the form (Z-S-CMP) without entry in this dictionary, which only lists special cases.

The actual compound codes (e.g. OXI for oxide) are restricted to three characters.

The codes are sorted by atomic number.

Note: Chemical compound codes are also used in CINDA

Dictionary 15. Status

This dictionary is in the standard format except that column 66 of the explanation field is reserved for flag which indicates which codes may be followed by an accession number field. 'S' indicates the code may be followed by an accession number field; 'R' indicates that the code is always followed by an accession number field.

***Some older codes may have a total length of 10 characters.**

Dictionary 24. Data-Heading Keywords

These keywords are used in the COMMON and DATA sections, as data headings for defining the contents of fields.

No expanded form of the codes is given.

Codes should be unique within Dictionary 24 and 25, i.e., data heading codes should not be identical to any data unit code.

For rules concerning the sequence of fields, see page 5.8.

Column 66 is reserved for a flag.

| Obsolete codes are marked with an 'O' in column 80.

This flag is used for checking purposes and defines the category and the family (or independent variable type) within each category, according to the scheme in the following table.

Family	FLAGS		Category
	Variables	*Associated Quantities	
Incident Energy	A	B	
Resonance Energy	C	D	
Secondary Energy ¹	E	F	
Angle of outgoing particle	G	H	
Product Charge	I	*	
Product Mass	J	*	
Secondary linear momentum	L	*	1
Linear Momentum	M	*	
Coefficient number	N	*	
Neutrons out	O	*	
Protons out	P	*	
Secondary effective mass	S	*	
THICKNESS	K	*	
FLAG	Z	*	
TEMP	8	9	
HL	6	7	
J	4	*	
Parity	0	*	

* No headings exist.

Category 1 pertains to independent variables.

Category 2 pertains to additional information which in certain cases may act as an independent variable.

¹Except E-LVL-INT and E-LVL-FIN

²Associated quantities are those data-heading keywords which contain the characters ERR or RSL.

Dictionary 25. Data-Unit Keywords

The data units are entered in the COMMON and DATA section below the data heading to define the units for the contents of each field.

Codes are unique within Dictionary 24 and 25, i.e., data unit codes may not be identical to any data heading unit code.

The format of the dictionary is as follows:

Column 1 - 10 code

11 blank

12 - 44 explanation of code (no expanded form given)

45 - 48 dimension code

49 - 55 blank

56 - 66 conversion factor

The dimension code provides a cross-link with Dictionary 36, (Quantity Dictionary) where the dimension code is also given (see page 7.17). This facilitates computerized cross-checks for consistency of quantities and units in a table.

The conversion factor is a floating point number which may be used for transforming units with the same dimension to standard units, namely:

energies to electron-volts;

angles to degrees;

time to seconds;

length to meters;

cross sections to barns.

Dictionary 27. Nuclides

The format of the dictionary is:

Column 1-11 nuclide code

12-26 flags in defined positions, enclosed in parentheses.

Free text may be given on successive records, starting in column 12.

1. The nuclide code has the format Z-S-A

where Z is the charge number, up to 3 digits, no leading zeros;

S is the element symbol; 1 or 2 characters;

A is the mass number; up to 3 digits, no leading zeros; a single zero denotes natural isotopic composition.

2. Columns 12-26 have the following structure:

Column 12 '('
13-23 Each column contains either a flag or blank:
13 used for REACTION SF1 (SF2=0)
 '1' indicates validity,
 'X' indicates a warning for unusual use.
14 used for REACTION SF2.
 '2' indicates validity.
15 used for REACTION SF3, REACTION SF4, REACTION SF7, HALF-LIFE,
 DECAY-DATA, DECAY-MON, RAD-DET, PART-DET and EN-SEC.
 '3' indicates validity,
 'Z' indicates validity except for REACTION SF3, PART-DET and
 EN-SEC; i.e., those cases where the particle codes are used
 instead of the corresponding nuclide codes.
16 used for REACTION SF1 (SF2=0).
 '4' indicates validity.
17 used to indicate a fission product
 'F' indicates validity.
17-21 are presently unused.
22 used for CINDA
 'C' indicates validity,
 'T' indicates validity for theoretical work only.
23 used to indicate a stable isotope.
 'S' indicates stability.
24-25 isomer field:
 either blank, indicating that the nuclide has no isomeric
 states,
 or a number, right justified, indicating the maximum number
 of metastable states (i.e., number of isomeric states not
 including the ground state).
26 ')'.
The flags given in this dictionary cover the normal cases. A number of special rules as described in Chapter 8 under REACTION, DECAY-DATA, etc., must also be considered.

This dictionary is not intended as a *Chart of the Nuclides*. Rare or short-lived nuclides, and, respectively, flags in column 13-25, will be added only when the nuclide is entered into EXFOR or CINDA.

Dictionary 34. Modifiers (REACTION)

An expanded form is only given for those modifiers (at the beginning of the dictionary) which may be included in the REACTION code, but are not included in the codes in Dictionary 36.

Dictionary 36. Quantities (REACTION)

The format of this dictionary is as follows:

Column 1 - 18 quantity code
19 - 21 dimension code
22 flag
23 - 66 expanded form and free text.

1. The quantity code is composed of the codes for the REACTION subfields 5 to 8. All meaningful combinations of the subfield codes that are in use are included. Note, however, that these quantity codes do not include the general modifiers from the beginning of Dictionary 34.
2. The dimension code provides a cross-link to Dictionary 25 (units dictionary), where the dimension code is also given (see page 7.15). This facilitates computerized checks of whether quantities and units given in a table are consistent.
3. Resonance parameters are flagged with a '.' in column 22.
4. The expanded form is a short definition of the quantity. It may be used for edited output to users.
5. If the quantity code length is >18 characters, the code is continued on the same record, followed by blanks and '9' in column 66. The dimension code and the expansion follow on the next record in their assigned fields. Maximum code length = 44 characters.
6. Obsolete codes are marked with an 'O' in column 80.

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Chapter 8

INFORMATION-IDENTIFIER KEYWORDS AND CODING RULES

This section gives the rules for the use of the information-identifier keywords and the structure of the codes associated with them. It does not, in general, give any information about specific codes from any dictionary, nor does it go into details of the physics content or additional free text explanations which may be required. For such information, the user should refer to LEXFOR.

Pages 2 and 3 of this chapter give general rules for keywords and codes.

Pages 4 and 5 contain some specific rules for the use and coding of each keyword.

The remaining pages contain detailed rules for the coding of each keyword. The keywords are ordered alphabetically and the pages are numbered accordingly.

The information given under each keyword has the following structure;

1. Use.
2. Requirements
3. Code format
4. Format for 2 or more codes or code strings
5. Additional information

See also Chapter 4 for a discussion of codes and free text.

Use of Codes

Codes for use with a specific keyword are found in the relevant dictionary. However, for some keywords, the code string may include retrievable information other than a code from one of the dictionaries.

In general, codes given in the dictionaries may be used singly or in conjunction with one or more codes from the same dictionary. Two options exist if more than one code is used:

- a.) two or more codes within the same set of parenthesis, separated by a comma; for example:

KEYWORD (CODE1,CODE2) + free text

- b.) each code on a separate record, enclosed in its' own set of parenthesis starting in column 12, followed by free text, for example:

KEYWORD (CODE1) + free text ...
free text ...
(CODE2) + free text

Both of these options, or a combination of the two, are allowed, in general. However, for some keywords, the coded string (within the parentheses) may include retrievable information in addition to a code from the dictionary, in which case, only (b) is permitted.

See the last section of this chapter for explicit coding formats and rules for each keyword.

Embedded blanks

For many information-identifier keywords, embedded blanks are explicitly forbidden in the code. With those exceptions, embedded blanks in the coding are allowed if they follow a code from the dictionary. They are not permitted preceding any code.

Examples: STATUS (DEP) Yes
STATUS (DEP ,COREL) Yes
STATUS (COREL, DEP) No
STATUS (DEP, 10048007) No

See detailed coding rules under each keyword.

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Coding for nuclides and compounds

Nuclides appear in the coding of many keywords. The general code format is Z-S-A-X, where:

Z is the mass number; up to 3 digits, no leading zeros

S is the element symbol; 1 or 2 characters (Dictionary 8)

A is the atomic weight; up to 3 digits, no leading zeroes. A single zero denotes natural isotopic composition (limited to special cases as given under the specific keyword).

X is an isomer code denoting the isomeric state (this subfield may be omitted)

X may have the following values:

G for ground state (of a nucleus which has a metastable state)

M if only one metastable state is regarded

M1 for the first metastable state

M2 for the second, etc.

T for sum of all isomers (limited to use within an isomeric ratio in SF4 of the REACTION string)

Exceptions to this coding are noted on the pages for each keyword.

Valid nuclide codes are given in Dictionary 27 (see page 7.15).

See also LEXFOR Elements.

Compounds may in some cases replace the nuclide code. The general format for coding compounds is either the specific compound code, taken from Dictionary 8, or the general code for a compound of the form Z-S-CMP. (e.g., 26-FE-CMP).

See LEXFOR Compounds for further information.

Information-Identifier Keyword Categories

Detailed coding rules for each information-identifier keyword are given on the following pages. The keywords can be grouped in certain categories, which are shown on the next page.

The second and third columns of the table show that some of the keywords are:

- obligatory: these must be present in either subentry 001 or in all other subentries.
- obligatory, except when not relevant: these must usually be present, however, occasionally they are not relevant and may be absent; see the detailed coding rules.
- obligatory for specific data-heading keywords: these must be present when certain data headings are present in the COMMON or DATA section (see the detailed coding rules), otherwise, they are optional.
- all other keywords are optional.

The fourth and fifth columns of the table indicate whether coded information and/or free text is obligatory. For certain keywords coded information is obligatory, for others optional. In general, the contents of the coded information should not be repeated in free text, since the coded information is either self-explanatory, as in the case of AUTHOR, or the codes are designed to be expanded by an editing program as described on page 4.2. For others, the compiler may indicate, as described on page 4.3, whether or not the editing program should expand the code.

It should be noted that the table serves only as an aide-memoire, and does not replace the detailed coding rules given on the subsequent pages.

Keyword Sequence

The sequence of information-identifier keywords is left to the discretion of the compiler. However, it is recommended that the bibliographic information (e.g., INSTITUTE, REFERENCE, AUTHOR, TITLE) be given first, followed by the physics information (e.g., REACTION, METHOD) with the bookkeeping information (e.g., STATUS, HISTORY) at the end.

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Keyword	The presence of the keyword is O=obligatory X=obligatory when relevant	obligatory with the data heading	when keyword present, coded information is	coded information repeated in free text
Bibliography				
TITLE	X		(free text only)	-
AUTHOR	O		obligatory	no
INSTITUTE	O		obligatory	no
EXP-YEAR			obligatory	no
REFERENCE	O		obligatory	no
REL-REF			obligatory	no
MONIT-REF			obligatory	no
Data Specification				
REACTION	O		obligatory	no
RESULT	X		obligatory	no
Related Data				
MONITOR	X	MONIT, etc.	obligatory	no
ASSUMED		ASSUM, etc.	optional	no
DECAY-DATA		DECAY-FLAG	optional	no
DECAY-MON			obligatory	no
PART-DET			obligatory	optional
RAD-DET			obligatory	no
HALF-LIFE		HLL, etc.	optional	no
EN-SEC		E1, etc.	optional	no
EMS-SEC		EMSI, etc.	optional	no
MOM-SEC		M1, etc.	optional	no
MISC-COL		MISC, etc.	optional	no
FLAG		FLAG	obligatory	no
Physics				
INC-SOURCE		optional	optional	
INC-SPECT		EN-DUMMY	(free text only)	-
SAMPLE			(free text only)	-
METHOD			optional	optional
FACILITY	one of these is obligatory		optional	optional
ANALYSIS			optional	optional
DETECTOR			optional	optional
CORRECTION			(free text only)	-
COVARIANCE			optional	no
ERR-ANALYS	X	--ERR1, etc.	optional	no
Other				
ADD-RES			optional	optional
COMMENT			(free text only)	-
CRITIQUE			(free text only)	-
Bookkeeping				
STATUS	X		optional	no
HISTORY	O		obligatory	no

ADD-RES

1. Used to give information about any additional results obtained in the experiment, but which are not compiled in the data tables.
2. Presence is optional. May contain free text or coded information and free text.
3. If coded information is given, it may be in either of the general forms, see page 8.2, with code(s) from Dictionary 20.

ANALYSIS

1. Used to give information as to how the experimental results have been analysed to obtain the values given under the heading 'DATA' which actually represent the results of the analysis. See also LEXFOR Analysis.
2. At least one of the keywords METHOD, FACILITY, DETECTOR or ANALYSIS is always present with coded information. Within this restriction, coded information for ANALYSIS is optional.
3. Coded information, if given, may be in either of the general forms, see page 8.2, with code(s) from Dictionary 23.

ASSUMED

1. Used to give information about values assumed in the analysis of the data, and about COMMON or DATA fields headed by ASSUM or its derivatives. See also LEXFOR Assumed values.
2. Presence is obligatory when such headings are present and coded information is required. May be used with free text only, if these headings are not present.
3. The format of the code is:

(heading,reaction,quantity)

Heading field contains the data heading to be defined.

Reaction field and the quantity field are coded exactly the same as for the keyword REACTION.

4. In the case of more than one assumed data heading (ASSUM1, ASSUM2, etc.) to be defined, each must be coded on a separate record, starting in column 12.

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AUTHOR

1. Used to give the authors of the work reported. See also LEXFOR Author.
2. Presence is obligatory. Must have coded information.
3. Authors' names are entered in the normal way of writing a name, i.e., A.B.NAME, each name separated by a comma. Hyphenated family names, 2-character initials (as in the transliteration of some Cyrillic characters), and any other deviations from the normal name structure are permitted. For a family name modified by 'Junior', JR is entered following the family name and separated from it by a blank.

All names are entered between one set of parenthesis. Blanks are permitted between author's names (i.e., after a comma), but are not permitted following initials.

Authors' names may be continued on the next record, but names should not be broken, i.e., the last character on the line to be continued should be a comma.

Examples:

AUTHOR (A.B.JONES,L.POZA-LOBO,JA.M.IVANOV,NGO-DINH-LONG,
A.MORALES AMADO)

AUTHOR (W.W.HAVENS JR)

For transliteration of author names given in Cyrillic characters, see LEXFOR Author.

COMMENT

1. Used to give pertinent information which cannot logically be entered under any other of the keywords available. See also LEXFOR Comment.
2. Presence is optional. Contains only free text.

CORRECTION

1. Used to give information about corrections applied to the data in order to obtain the values given under 'DATA'. See also LEXFOR Correction.
2. Presence is optional. Contains only free text.

COVARIANCE

1. Used to give covariance information provided by the experimentalist, or to flag the existence of a covariance data file. See also LEXFOR Covariance.
2. Presence is optional. Contains either free text only or the code (COVAR), which indicates the existence of a covariance file, followed by free text.

See Appendix B for the Covariance Data File format.

CRITIQUE

1. Used to give comments on the quality of the data presented in the data table. See also LEXFOR Comments.
2. Presence is optional. Contains only free text.

DECAY-DATA

1. Used to give the decay data for any nuclide occurring in the reaction measured as assumed or measured by the author for obtaining the data given. See also LEXFOR Decay-Data.

Decay data relevant to the monitor reaction are coded under the keyword DECAY-MON and not under DECAY-DATA.

2. Presence is optional, but obligatory when the keyword RAD-DET is present. Free text may be given or coded information, with or without free text.

If the keyword DECAY-DATA is present, the keyword HALF-LIFE is not used. See also LEXFOR Half-Lives.

3. The general format of the coding string consists of three major fields which may be preceded by a decay flag:

((flag)nuclide,half-life,radiation)

Embedded blanks are permitted in the code only at the beginning of a field or subfield. A code string may be broken for continuation onto the next record, but the break must come at the end of a field or subfield, i.e., the comma separating the fields should be the last character on the line.

Flag. The general format of the code is (n.), where n will have a numerical value which appears in the data section under the Data-Heading Keyword DECAY-FLAG.

The flag may be omitted, in which case its parentheses are also omitted. See also LEXFOR Flags and page 6.10.

Nuclide field. The general format of the code is Z-S-A-X, except that when the ground state of a nuclide is given, the use of the extension 'G' is optional. See page 8.3.

Permitted nuclei are indicated in Dictionary 27 by a '3' in column 15.

Half-life field. This field contains the actual half-life of the nuclide specified.

This field may be omitted, in which case the following comma must be included, unless the radiation field is also omitted, in which case the closing parenthesis immediately follows the nuclide.

It is coded as a number, readable in an E11.4 format (see page 5.3, no blanks are allowed), followed by a unit which consists of a code from Dictionary 25 with the dimension TIME; no embedded blanks are allowed.

Example: 2.45MIN
3.6E+03YR

Radiation field. This field may be omitted, in which case the closing parenthesis immediately follows the half-life. This field may also be repeated, each radiation field being separated by a comma. Absence of any subfield must be indicated by including the separating comma; trailing commas are not included.

The field consists of three subfields:

(nuclide,half-life,SF1,SF2,SF3)

SF1. Type-of-radiation.

A code from Dictionary 13.

Where two or more different decay modes are possible and are not distinguished in the measurement, two or more codes may be given, each separated by a slash. (See *Example b*, following page).

SF2. Energy

The energy of the radiation in keV, coded as a floating-point number (see page 5.3, no blanks permitted); no units are given in the code.

In the case of two or more unresolved decays, two or more energies, or a lower and upper energy limit, are given, each separated by a slash. (See *Example f* and LEXFOR Decay Data.)

SF3. Abundance.

The abundance of the observed radiation per decay.

Coded as a floating-point number (see page 5.3, no blanks permitted).

4. If decay data is given in coded form for more than one nuclide, each is coded on a separate record, starting in column 12.

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Examples of coding for DECAY-DATA

- a. DECAY-DATA (40-ZR-89-M) (half-life and radiation omitted) In this case, information on the decay data for the nucleus specified is given in free text)
- b. DECAY-DATA (60-ND-140,3.3D) (radiation field omitted)
(59-PR-140,,B+/EC,,0.500) (half-life and radiation SF2 omitted)
- c. DECAY-DATA (25-MN-50-G,0.286SEC,B+,6610.) (radiation SF3 omitted)
- d. DECAY-DATA (25-MN-50-M,1.76MIN,DG,785.,,B+) (two radiation fields, the 2nd with SF2 and SF3 omitted)
- e. DECAY-DATA ((1.)60-ND-138,5.04HR,DG,328.,0.065) (decay flag, all fields and subfields present)
- f. DECAY-DATA (60-ND-138-M,5.5HR,DG,708./738.,0.64) (the abundance given is the total abundance of both gamma rays)
- g. DECAY-DATA (60-ND-139-G,30.0MIN,B+,,0.257,DG,405.,0.055) (two radiation fields)
(60-ND-139-M,5.5HR,DG,738.,0.37,DG,982.,0.29,
DG,708.,0.27,DG,403.,0.03,B+,,0.006) (five radiation fields, extending over 2 records)

This last example could be entered in the following way for improved readability:

```
DECAY-DATA (60-ND-139-G,30.0MIN,B+,,0.257,  
              DG,405.,0.055)  
              (60-ND-139-M,5.5HR,DG,738.,0.37,  
              DG,982.,0.29,  
              DG,708.,0.27,  
              DG,403.,0.03,  
              B+,,0.006)
```

DECAY-MON (REACTION formalism)

1. Used to give the decay data assumed by the author for any nuclide occurring in the monitor reaction used.
2. Presence is optional; may only be used if the keyword MONITOR is present. Coded information is obligatory, with or without free text.
3. The coding rules for DECAY-MON are exactly the same as those for DECAY-DATA (see page 8.D.1), except that the flag field is not permitted.

DETECTOR

1. Used to give information about the detector(s) used in the experiment. See also LEXFOR Measurement Techniques.
2. At least one of the keywords METHOD, FACILITY, DETECTOR or ANALYSIS is always present with coded information. Within this restriction, coded information for DETECTOR is optional, except that, if a relevant code is given in the dictionary, then it is used.
3. If coded information is given it may be in either of the general forms, see page 8.2, with code(s) from Dictionary 22, but see exception below.
4. If the code 'COIN' is used, then the codes for the detectors used in coincidence follow within the same parenthesis;
e.g. (COIN,NAICR,NAICR).

In this case any other detectors used are coded on a separate record, starting in column 12.

EMS-SEC

1. Used to give information about secondary squared effective mass of a particle or particle system, and to define secondary-mass fields given in the data table. See LEXFOR Secondary Particles.
2. Keyword is, in general, optional, but is obligatory when the data-heading keywords EMS1, EMS2, etc., are used in the data. Free text may be given or coded information, with or without free text.
3. The format of the coded information is:

(heading,particle)

Heading Field. This field contains the data heading or the root of the data heading to be defined. Root means that the data heading given will also define the same heading followed by -MIN, -MAX or -APRX.

Particle Field. This field contains the particle or nuclide to which the data heading keyword refers. The code is:

either a particle code from Dictionary 13.

or a nuclide coded in the standard format as described on page 8.3.

Permitted nuclei are indicated in Dictionary 27 by a '3' in column 15.

4. If more than one effective mass data-heading keyword is defined, each is coded on a separate record, starting in column 12.

Example: EMS-SEC (EMS1,N)
(EMS2,P+D)

EN-SEC

1. Used to give information about secondary energies, and to define secondary-energy fields given in the data table. See LEXFOR Secondary Particles.
2. Presence is, in general, optional, but is obligatory when the data-heading keywords E1, E2, etc., are used in the data. Free text may be given, or coded information, with or without free text.
3. The format of the coded information is:

(heading,particle)

Heading Field. Contains the data heading or the root of the data heading to be defined. Root means that the data heading given also defines the heading followed by -MIN, -MAX or -APRX.

Particle Field. Contains the particle or nuclide to which the data-heading keyword refers. The code is:

either a particle code from Dictionary 13.

or a nuclide coded in the standard format as described on page 8.3.
Permitted nuclei are indicated in Dictionary 27 by a '3' in column 15.

4. If more than one secondary-energy data-heading keyword is defined, each is coded on a separate record, starting in column 12.

Example: EN-SEC (E1,G)
(E2,N)
(E-EXC,3-LI-7)

ERR-ANALYS

1. Used to explain the sources of uncertainties and the values given in the COMMON or DATA sections under data headings of the type ERR- or -ERR. See also LEXFOR Errors.
2. Presence is obligatory, except when not relevant. May contain free text or coded information with free text. However, if only one heading is to be defined, the coded information may be omitted. See also page 6.9, Links between BIB, COMMON and DATA, 7. ERR-ANALYS.

3. The coded information is of the form:

(heading.correlation factor) free text

Heading field. Contains the data heading or the root of the heading to be defined. Root means that the data heading given also defines the heading preceded by + or -.

Correlation Factor Field. Contains the correlation factor, coded as a floating point number. This field is optional and is used only with systematic data uncertainty headings of the form ERR-I, etc. If this field is not given, the trailing comma is omitted.

4. If two or more error fields are given, then the data headings are given as codes under this keyword, each on a separate record, starting in column 12, and followed by free text explanation.**Example:**

BIB

...
ERR-ANALYS (EN-ERR) followed by explanation of energy error
(ERR-T) followed by explanation of total uncertainty
(ERR-S) followed by explanation of statistical
uncertainty

ENDBIB

NOCOMMON

DATA

EN	EN-ERR	DATA	ERR-T	ERR-S
MEV	MEV	MB	MB	PER-CENT
...

EXP-YEAR

1. Used to define the year in which the experiment was performed when it differs significantly from the date of the references given. (*Example:* classified data published years later).
2. Presence is optional, but if present, it must have coded information.
3. The format of the code is (yy) where yy is the last two digits of the year, e.g., (65).

FACILITY

1. Used to define the main apparatus used in the experiment. See also LEXFOR Measurement Techniques.
2. Keyword must be present except when not relevant. At least one of the keywords METHOD, FACILITY, DETECTOR or ANALYSIS must be present with coded information. Within this restriction, coded information for FACILITY is optional.
3. If coded information is given it may be in either of the general forms, see page 8.2, with code(s) from Dictionary 18, or the facility code from Dictionary 18 may be followed by an institute code from Dictionary 3, which specifies the location of the facility. When two or more codes are given under the keyword INSTITUTE, then a facility code is always be followed by the appropriate institute code.
4. When the second form of coding is used and more than one facility is given, then each is coded on a separate record, starting in column 12.

Example: (CHOPF,1USACOL)
(SPECC,1USABNL)

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FLAG

1. Used to provide information to specific lines in a data table. See also LEXFOR Flags.
2. Presence is optional, but, if present, it must have coded information. Always present if flags are used in the data table.
3. The format of the code is a fixed-point number which appears in the DATA section under the data heading FLAG. The code must be followed by a free text comment. See also page 8.9, Links between BIB, COMMON and DATA, 8. FLAG.
4. If two or more codes are given, each is coded on a separate record, starting in column 12, followed by a free text explanation of the meaning of the flag.

Example:

```
BIB
...
FLAG      (1.) Data averaged from 2 runs
          (2.) Modified detector used at this energy
ENDBIB
...
DATA
EN       DATA      FLAG
KEV     MB        NO-DIM
1.2     123.      1.
2.3     234.      2.
3.4     456.      2.
ENDDATA
```

More than one FLAG field may be coded, see page 5.5.

HALF-LIFE

1. Used to give information about half-life values and to define half-life fields given in the data table. See also LEXFOR Half-lives.
2. Presence is optional, with or without coded information. However, coded information is always included when the data-heading keywords, HL1, HL2, etc., are given in the COMMON or DATA sections.
3. The general coding format is:

(heading,nuclide)

Heading field. Contains the data-heading keyword to be defined.

Nuclide field. The general format of the code is Z-S-A-X, see page 8.3. Permitted nuclei are indicated in Dictionary 27 by a '3' in column 15.

4. If two or more half-lives are given, each is coded on a separate record, starting in column 12.

See LEXFOR Half-lives for a coding example.

Note: Decay data, including the half-life, is preferably coded under the keyword DECRY-DATA or DECRY-MON, as appropriate.

HISTORY

1. Used to document the handling of an entry or subentry. See also LEXFOR History.
2. Presence is obligatory with coded information.
3. The general format of the code is (yymmddX), where:

yymmdd: date (year,month,day) on which some action was taken on the entry or subentry;
X: a code from Dictionary 15 indicating what action was taken. X may be omitted.
4. Each item of coded information is coded on a separate record, starting in column 12.

INC-SOURCE

1. Used to give information on the source of the incident particle beam used in the experiment. See also LEXFOR Measurement Techniques and Incident-Particle Energy.
2. Presence is optional. May contain either free text, or coded information and free text.
3. Coded information, if given, may be in either of the general forms, see page 8.2, with code(s) from Dictionary 19, but see exception below.
4. If the code 'POLNS' is used, the code for the polarized source, if given, must follow within the same set of parenthesis.

In this case other sources are coded on a separate record, starting in column 12.

INC-SPECT

1. Used to provide information on the characteristics and resolution of the incident-projectile beam. See also LEXFOR Incident-Projectile Energy.
2. Presence is optional, except that it is required when the quantity modifiers MXW, SPA or FIS are present under REACTION (see page 6.8). See also LEXFOR Incident-Projectile Energy and Spectrum Average. No coded information.

INSTITUTE

1. Used to designate the laboratory, institute or university at which the experiment was performed, or with which the authors are affiliated. See also LEXFOR INSTITUTE.
2. Presence is obligatory with coded information.
3. The coded information is given in either of the general forms, see page 8.2, with code(s) from Dictionary 3.

Where the institute code is less than 7 characters, trailing blanks may be omitted, however, embedded blanks must be included, as they are considered part of the code.

Examples: INSTITUTE (1USAGA,1USALAS)
INSTITUTE (2FR SAC)

LEVEL-PROP

1. Used to give the information on the spin and parity of excited states.
2. Presence is optional, but, if present, includes coded information.
3. The general format of the coding string consists of three major fields which may be preceded by a decay flag:

((flag)nuclide,level identification,level properties)

Embedded blanks are permitted in the code only at the beginning of a field or subfield. A code string may be broken for continuation onto the next record, but the break must come at the end of a field or subfield, i.e., the comma separating the fields should be the last character on the line.

Flag. The general format of the code is (n.), where n will have a numerical value which appears in the data section under the Data-Heading Keyword LEVEL-FLAG.

The flag may be omitted, in which case its parentheses are also omitted. See also LEXFOR Flags and page 8.10. If the flag is omitted, a level identification field will be present.

Nuclide field. The general format of the code is Z-S-A-X, except that when the ground state of a nuclide is given, the use of the extension 'G' is optional. See page 8.3. This field must be present.

Permitted nuclei are indicated in Dictionary 27 by a '3' in column 15.

Level identification field. Contains the identification of the level whose properties are to be specified, preceded by the field identifier.

If the field is not present, its' separating comma is omitted. If there is no flag field present, one of these fields will be present.

Level Energy. The energy of the excited state in MeV, preceded by the field identifier 'E-LVL='. It is coded as a floating-point number (see page 5.3, no blanks permitted) which will have a numerical value which also appears in the data section under the Data-Heading Keyword E-LVL. No units are given in the code.

Level Number. The level number of the excited state, preceded by the field identifier 'LVL-NUMB='. The format of the code is 'n.' where n will have a numerical value which also appears in the data section under the Data-Heading Keyword LVL-NUMB.

Level properties field. Contains the spin and/or parity for the excited state specified, preceded by a field identification.

At least one of the fields must be present. If the field is not present, its' separating comma is omitted.

Spin. The spin for the level specified, preceded by the field identifier 'SPIN=', and coded as a floating point number (see page 5.3, but no blanks). In the case of uncertain spin assignment, two or more spins may be given, each separated by a slash.

Parity. The parity of the level specified, preceded by the field identifier 'PARITY+'. Coded as +1. or -1.

Examples

```
LEVEL-PROP (82-PB-206,E-LVL=0.,SPIN=0./1.,PARITY=+1.)  
           (82-PB-206,E-LVL=1.34,SPIN=3.,PARITY=+1.)
```

```
LEVEL-PROP ((1.)82-PB-206,SPIN=0./1.,PARITY=+1.)  
           ((2.)82 -PB-206,SPIN=3.,PARITY=+1.)
```

```
LEVEL-PROP (82-PB-207,LVL-NUMB=2.,SPIN=1.5,PARITY=-1.)
```

METHOD

1. Used to describe the experimental technique(s) employed in the experiment. See also LEXFOR Measurement Techniques.
2. Presence is obligatory, except when not relevant. At least one of the keywords METHOD, FACILITY, DETECTOR, ANALYSIS must be present with coded information. Within this restriction, coded information for METHOD is optional.
3. If coded information is given it may be in either of the general forms, see page 8.2, with code(s) from Dictionary 21.

MISC-COL

1. Used to define fields in the COMMON or DATA sections headed by MISC and its derivatives. See also LEXFOR Miscellaneous.
2. Presence is optional, but must be present if miscellaneous fields are given in the data table. Free text may be given, or coded information plus free text.
3. The format of the code is a miscellaneous data heading from Dictionary 24, e.g., MISC.
4. If more than one miscellaneous field is given, then the data headings must be repeated as codes for this keyword, enclosed in parentheses starting in column 12, followed by free text explanation.

Example: (MISC1) Free text
 (MISC2) free text

See also page 6.10, Links between BIB, COMMON and DATA, 9. MISC-COL.

MOM-SEC

1. Used to give information about secondary linear momentum, and to define secondary-momentum fields given in the data table. See also LEXFOR Secondary Particles.
2. Presence is, in general, optional, but is obligatory when the data-heading keywords MOM-SEC1, MOM-SEC2, etc., are used in the data. Free text may be given or coded information, with or without free text.
3. The format of the coded information is:

(heading,particle)

Heading Field. Contains the data heading or the root of the data heading to be defined. Root means that the data heading given will also define the same heading followed by -MIN, -MAX or -APRX.

Particle Field. Contains the particle or nuclide to which the data-heading keyword refers. The code is:

either a particle code from Dictionary 13.

or a nuclide coded in the standard format as described on page 8.3.

Permitted nuclei are indicated in Dictionary 27 by a '3' in column 15.

4. When more than one linear-momentum data-heading keyword is to be defined, each must be coded on a separate record, starting in column 12.

Example: MOM-SEC (MOM-SEC1,26-FE-56)
 (MOM-SEC2,26-FE-57)

MONITOR

1. Used to give information about the monitor (standard reference data) used in the experiment and to define information coded in the COMMON and DATA sections under the data heading MONIT, etc. See also LEXFOR Standards.
2. Presence is obligatory, except when not relevant. Information may be entered either in free text, or in coded form with or without free text. However, coded information is always included when the corresponding data is given in the COMMON or DATA sections. See page 6.8, Links between BIB, COMMON and DATA, 2. MONITOR.

RAD-DET

1. Used to give information about the radiations and/or particles and nuclides observed in the reaction measured when it is not clear from the information coded under the keywords REACTION and/or DECAY-DATA which radiation has been detected. See also LEXFOR Particles.
2. Presence is optional, but, if the particle is not evident from the REACTION code, it must be specified either under this keyword, or under PART-DET or DECAY-DATA. If the keyword is present, coded information is obligatory, with or without free text.

Note: If this keyword is present the keyword DECAY-DATA must also be present.

3. The general format of the code is: ((flag)nuclide,radiation)

No embedded blanks are permitted in the code.

Flag Field. The general format of the code is (n.), where n has the numerical value which appears in the data section under the data-heading keyword DECAY-FLAG.

This field may be omitted, in which case its parentheses are also omitted.

See also LEXFOR Flags and page 6.10, Links between BIB, COMMON, AND DATA, 10. DECAY-DATA, RAD-DET.

Nuclide field. The general format of the code is Z-S-A-X, see page 8.3.

Permitted nuclei are indicated in Dictionary 27 by a '3' in column 15.

Radiation field. Consists of one or more codes from Dictionary 33, each separated by a comma.

4. Two or more nuclides. The information for each nuclide is coded on a separate record, each code starting in column 12. Pointers may be used to link the RAD-DET codes with variable product nuclei coded in the DATA table and with DECAY-DATA codes.

Examples:

- a) RAD-DET (98-CM-240,A)
- b) RAD-DET (25-MN-52-G,DG)
- c) RAD-DET (25-MN-52-M,DG,B+)
- d) RAD-DET (48-CD-115-G,B-)
(49-IN-115-M,DG)
- e) RAD-DET 1(94-PU-237-M1,SF)
2(94-PU-237-M2,SF)
- f) RAD-DET ((1.)48-CD-115-G,B-)
((2.)49-IN-115-M,DG)

MONIT-REF

1. Used to give information about the reference source of the standard (monitor) data used in the experiment.
2. Presence is optional, but, if present, includes coded information. Used only when the keyword MONITOR is present.
3. The general format of the code contains 3 main fields which may be preceded by a heading field:

((heading)subaccession#,author,reference)

Embedded blanks are not permitted with the code. However, there may be embedded blanks within an authors name (see coding rules under AUTHOR, page 8.A.2).

Heading field. Contains the data heading of the field in which the monitor value is given. The heading may be omitted, in which case, its' parentheses are omitted.

Subaccession Number Field. EXFOR subaccession number of monitor data. Cnnnn001 refers to the entire entry Cnnnn. Cnnnn000 refers to a yet unknown subentry within the entry Cnnnn. This field may be omitted, but the following comma is always included.

Author Field. The first author (coded as under AUTHOR), followed by '+' when more than one author exists. This field may be omitted, but the following comma is always included.

Reference Field. Is always present and may contain up to 6 subfields, coded exactly as under REFERENCE. (See pages 8.R.11 - 8.R.16).

4. For more than one monitor reference, each is coded on a separate record, starting in column 12. Entries under MONIT-REF and MONITOR may be linked:
 - a.) using pointers (see page 6.4, BIB/BIB links)
 - b.) using the data headings MONIT1, MONIT2, etc.

Examples: MONIT-REF ((MONIT1)B0017005,J.GOSHAL,J,PR,80,939,50)
((MONIT2),A.G.PANONTIN+,J,JIN,30,2017,68)

PART-DET

1. Used to give information about the particles detected directly in the experiment. (The keyword RAD-DET is used for decay particles, see page 8.R.1). Particles detected in a standard/monitor reaction are not coded under this keyword. See also LEXFOR Particles.
2. Presence is optional, but, if the particle is not evident from the REACTION code, it must be specified either under this keyword, or under RAD-DET or DECAY-DATA. If the keyword is present, coded information is obligatory.
3. The code is:
either a code from Dictionary 13
or, for particles heavier than alpha particles, a code of the form
Z-S-A-X, see page 8.3. Permitted nuclei are indicated in
Dictionary 27 by a '3' in column 15.
4. Two or more particles detected. More than one code may be given in either of the general forms, see page 8.2. Particles detected pertaining to different reaction units within a reaction combination are coded on separate records in the same order as the corresponding reaction units. (See page 8.R.9 for examples of reaction combinations.)

RAD-DET

1. Used to give information about the radiations and/or particles and nuclides observed in the reaction measured. See also LEXFOR Particles.
2. Presence is optional, but, if the particle is not evident from the REACTION code, it must be specified either under this keyword, or under PART-DET or DECAY-DATA. If the keyword is present, coded information is obligatory, with or without free text.

Note: If this keyword is present the keyword DECAY-DATA must also be present.

3. The general format of the code is: ((flag)nuclide,radiation)

No embedded blanks are permitted in the code.

Flag Field. The general format of the code is (n.), where n has the numerical value which appears in the data section under the data-heading keyword DECAY-FLAG.

This field may be omitted, in which case its parentheses are also omitted.

See also LEXFOR Flags and page 6.10, Links between BIB, COMMON, AND DATA, 10. DECAY-DATA, RAD-DET.

Nuclide field. The general format of the code is Z-S-A-X, see page 8.3.

Permitted nuclei are indicated in Dictionary 27 by a '3' in column 15.

Radiation field. Consists of one or more codes from Dictionary 33, each separated by a comma.

4. Two or more nuclides. The information for each nuclide is coded on a separate record, each code starting in column 12. Pointers may be used to link the RAD-DET codes with variable product nuclei coded in the DATA table and with DECAY-DATA codes.

Examples:

- a) RAD-DET (96-CM-240,A)
- b) RAD-DET (25-MN-52-G,DG)
- c) RAD-DET (25-MN-52-M,DG,B+)
- d) RAD-DET (48-CD-115-G,B-)
(49-IN-115-M,DG)
- e) RAD-DET 1(94-PU-237-M1,SF)
2(84-PU-237-M2,SF)
- f) RAD-DET ((1.)48-CD-115-G,B-)
((2.)49-IN-115-M,DG)

REACTION

1. Used to specify data which is presented in the DATA section in fields headed by DATA (and similar headings such as DATA-MIN, DATA-MAX, etc.).
2. Presence is obligatory with coded information, with or without free text.
3. A REACTION unit consists of three major fields:

(reaction,quantity,data-type)

Embedded blanks within a REACTION unit are not permitted.

4. More than one REACTION unit may be given as a *Reaction Combination* or in the *Multiple-reaction Formalism*.

Detailed coding rules are given on the following pages.

Reaction field 8.R.3

SF1. Target Nucleus
SF2. Incident particle
SF3. Process
SF4. Reaction product

Quantity field 8.R.7

SF5. Branch
SF6. Parameter
SF7. Particle considered
SF8. Modifier

Data-type field. 8.R.8

SF9. Data type

Reaction Combinations 8.R.9

Multiple-Reaction Formalism 8.R.10

8.R.2

SF1-4 Reaction field. The reaction field consists of 4 subfields, separated by commas or parentheses (not interchangeable).

(SF1(SF2,SF3)SF4,quantity,data-type)

SF1. Target nucleus. The general format of the code is:

either Z-S-A-X, as described on page 8.3 with the following exceptions:
A = 0 denotes natural isotopic mixture; X may not have the value G

Permitted nuclei are indicated in Dictionary 27 either by a '1' in column 13, or, if SF2 contains a zero, a '4' in column 16.

or Z-S-CMP, see page 8.3.

or, when the target nucleus is entered into the data table using the heading codes ELEMENT, MASS and ISOMER (*Variable Nucleus Formalism*), SF1 contains the code ELEM/MASS.

Use of this formalism is restricted to the cases specified on page 8.7.

Example: (ELEM/MASS(0,B-),,PN)

See LEXFOR Target Nucleus for details.

SF2. Incident projectile.

Contains:

either a particle code from Dictionary 28

or, for particles heavier than alpha, a code in the form Z-S-A (isomer field omitted), see page 8.3. Permitted nuclei are indicated in Dictionary 27 by a '2' in column 14.

SF3. Process.

Contains one of the following:

a.) a process code from Dictionary 30, e.g., TOT.

For use of the process codes XN and YP, see page 6.8, Variable Number of Emitted Nucleons. See also LEXFOR Particles

b.) a particle code from Dictionary 29 which may be preceded by a multiplicity factor, whose value may be 2-99.

Examples: A

4A

Note: In the few cases where the multiplicity factor may exceed 99, the Variable Number of Emitted Nucleons Formalism may be used, see page 8.8.

- c.) for particles heavier than alpha, a code in the form Z-S-A-X, see 8.3, (the atomic weight (A) may not have the value zero). Permitted nuclei are indicated in Dictionary 27 by a '3' in column 15. No multiplicity factor is allowed; instead the nuclide code is repeated, if necessary.

Examples: 8-0-16
8-0-16+8-0-16

- d.) combinations of a.), b.) and c.), with the codes connected by '+'. Outgoing particles are ordered starting with the 'lightest' at the left of the subfield (i.e. in the same order as in Dictionary 29), followed by the Z-S-A-X formatted codes, in Z, A order, followed by process codes given in the same order as given in Dictionary 30.

An exception to this order is when SF5 contains the code 'SEQ', which indicates that the particles and/or processes are ordered in the sequence in which the reaction proceeds. (See LEXFOR Particles).

Examples: HE3+8-0-16
A+XN+YP

Notes on SF3

Gammas are coded only:

- for a capture process, e.g., (P,G)
- when they are needed to define the partial reaction considered, e.g., (N,G+F),SEQ.

In all other cases, gammas are considered as self-evident and are, therefore, not coded, e.g., (P,N) is coded, not (P,G+N). Compare SF7, Particle Considered, page 8.R.8.

If SF5 contains the branch code 'UND' (undefined), the particle codes given in SF3 represent only the sum of emitted nucleons, implying that the product nucleus coded in SF4 has been formed via different reaction channels. The code '(DEF)' in SF5 denotes that it is not evident from the publication whether the reaction channel is undefined or defined.

For details see in LEXFOR Particles.

Note: The code 'UND' is presently used only for charged particle reaction data.

For coding of SF3 in the case of scattering see LEXFOR Scattering.

SF4. Reaction Product

Definition: In general, the heaviest of the products is defined as the reaction product (also called residual nucleus). In the case of two reaction products with equal mass, the one with the larger Z is considered as the "heavier" product. Exceptions or special cases are:

- a.) If SF5 contains the code SEQ, indicating that the sequence of several outgoing particles and/or processes coded in SF3 is meaningful, the nuclide to be coded in SF4 is the heaviest of the final products. This may not be the heaviest of all products.

Example: 5-B-10(N,A+T)2-HE-4,SEQ,SIG

- b.) It is undefined if a nuclear quantity is given (i.e., SF2 contains the code 0) or if SF3 contains the process code TOT, ABS or NON.
- c.) If the reaction specifies a resonance parameter, as defined in Dictionary 36 by a period in column 22, the reaction product is taken as undefined.
- d.) For certain reactions which are implicit sums, the reaction product may or may not be defined.
- 1.) Where no specific reaction product is considered it is undefined. This may occur if:
- SF3 contains the process code F.
 - SF3 contains a combination of the process code X with a particle code, e.g., (P,G+X),SEQ.
 - the reaction is measured on a target of natural composition.
- 2.) Where emission cross sections, production cross sections, product yields, etc., are given for specified nuclides, particles or gammas, the product considered is defined as the reaction product (even if this is not the heaviest of several reaction products). This may occur if:
- SF3 contains the process code F, X, XN or YP.

Coding: This subfield:

either is blank, cases b, c and d.i. preceding. The following comma is always present.

Examples: (92-U-235(N,F),,SIG)
(26-FE-56(N,EL),,WID)
(40-ZR-0(N,G),,SIG)

or contains a code in the form Z-S-A-X as described on page 8.3.

Permitted nuclei are indicated in Dictionary 27 by a '3' in column 15.

If light particles or gammas are defined as the reaction product, these are coded in SF4 using the Z-S-A formalism (i.e., the particle codes A, HE3, T, D, P, N, G are not used in SF4). The code 0-G-0 is used for gammas.

Example: (28-NI-0(N,X)0-G-0,,SIG) gamma production cross section

For a target nucleus with A=0 (natural isotopic composition), if the process is scattering (see LEXFOR Scattering), then A=0 is given for the product nucleus in SF4; otherwise, A=0 is forbidden for SF4.

In the case of isomeric ratios and sums the isomer code may consist of a combination of codes separated by a slash or a plus sign. The use of these separators is algebraic, e.g., M1+M2/G. The code T is used to denote the sum over all isomers. (See page 8.3).

Note: The code 'RAT' or 'SUM' is always given in SF6 when the arithmetical '/' or '+' appears in the isomer extension in SF4.

Example: (51-SB-123(N,G)51-SB-124M1+M2/T,,SIG/RAT)

See LEXFOR Isomeric Ratios.

Examples: (92-U-235(N,F)54-XE-124,CUM,FY)
(39-Y-89(P,3N+P)39-Y-87-M1+M2,,SIG/SUM)
(28-NI-0(N,X)0-G-0,,SIG)

or, when the reaction product is entered into the data table using the heading codes ELEMENT, MASS and ISOMER (see page 6.6, Variable Nucleus), SF4 contains the code:

ELEM - If the data heading ELEMENT is used in the DATA table

MASS - If the data heading MASS is used in the DATA table

ELEM/MASS - If the data headings ELEMENT and MASS are used in either the COMMON section or the DATA table.

Example: (92-U-235(N,F)ELEM/MASS,CUM,FY)

Use of the formalism is restricted to those cases specified on page 6.7.

SF5-8 Quantity field. The coding consists of 4 subfields each separated by a comma.

(reaction,SF5,SF6,SF7,SF8,data-type)

Any subfield may contain a combination of codes from the same dictionary, separated by a slash.

If a subfield is omitted, the extra separating comma is included.

Example: (reaction,,SF6,SF7,SF8,data-type)

Only certain combinations of codes in the quantity field are meaningful. These are listed in Dictionary 36. Note that if two or more codes are entered in a subfield, they will be in the same sequence as in Dictionary 36. 'General quantity modifiers', which are not entered into Dictionary 36, may be added to at the end of SF8 (see LEXFOR General Quantity Modifiers).

SF5. Branch.

Indicates a partial reaction if, for example, only one of several energy levels or particle groups has been considered.

Code(s) from Dictionary 31.

SF6. Parameter.

Contains information about the reaction parameter given, such as, integral or differential cross section.

Code(s) from Dictionary 32.

SF7. Particle considered.

Provides particle code(s) indicating to which of several outgoing particles the quantity refers.

The particle considered can be omitted if there is no ambiguity. For integral data this subfield is generally not used. (See LEXFOR Particles.)

For a quantity describing the correlation between outgoing particles, the particles are entered, separated by a slash.

It should be noted that the particle considered is not necessarily identical with the particle detected if, for example, the angular distribution of an outgoing particle has been deduced from a recoil particle detected.

Code(s) from Dictionary 33.

SF8. Modifier.

Contains information on the representation of the data, for example, relative data, fitting coefficients, etc. General quantity modifiers should trail other modifiers.

Code(s) from Dictionary 34.

SF9. Data-type field.

Indicates whether the data given are experimental, theoretical, evaluated, etc.

This field may be omitted, in which case the trailing commas, are also omitted, e.g., (reaction,,SF8). If the field is omitted, the data are experimental.

Code(s) from Dictionary 35.

If two or more codes are given they are separated by a slash.

See also LEXFOR Data Type.

Reaction Combinations

In order to deal with experimental data sets referring to complex combinations of materials and reactions, the code units defined in this section can be connected into a single machine-retrievable field, with appropriate separators and properly balanced parentheses. In all cases of combined units, parentheses are used in exactly the same manner as in FORTRAN to define algebraic operations.

The permitted separators are:

- + (Plus): Sum of 2 or more quantities.
- (Minus): Difference between 2 or more quantities
- * (Times): Product of 2 or more quantities
- / (Over): Ratio of 2 or more quantities
- // : Ratio of 2 quantities, where the numerator and denominator refer to different values for one or more independent variables.
- = (Also): Tautologies (See LEXFOR Tautologies for usage)
- , (And): Obsolete, but may be found in older NND entries. Used for multiple representations of the same quantity, which are now coded using pointers.

The complete reaction combination must be enclosed in parentheses.

The general form of these combinations are:

$$\begin{aligned} & ((-----)+ (-----)) \\ & ((-----)- (-----)) \\ & ((-----) * (-----)) \\ & ((-----)/ (-----)) \\ & ((-----)/ / (-----)) \\ & ((-----)= (-----)) \end{aligned}$$

A code unit is not broken for continuation on the next record. The separator appears last on any record, with the first parenthesis of the next code unit beginning in column 12 of the next record. Thus blanks may follow a separator if the reaction combination is continued on the next record.

Examples: $((92-U-235(N,F),,SIG)/(79-AU-197(N,G)79-AU-198,,SIG))$

$$(((28-N1-58(N,N+P)27-C0-57,,SIG)+(28-N1-58(N,D)27-C0-57,,SIG))/\\(13-AL-27(N,A)11-NA-24,,SIG))$$

Note that the reaction combination formalism is not used for certain frequently occurring sums, ratios and products for which specific quantity codes have been introduced. (See LEXFOR Ratios, Sums, Products).

Multiple Reaction Formalism

Pointers may be used with this keyword, in which case the code fields associated with each pointer may be a reaction unit or a reaction combination. (See page 6.1 for general information on pointers).

The use of the *multiple reaction formalism* is restricted to specific classes of data which are subject to the following constraints.

1. The incident projectile and the target nucleus are constant.
2. Quantities are functions of the same independent variables.
3. Quantities are integrally related to each other.

For the specific classes of data which may be coded using the *multiple reaction formalism*, see LEXFOR Multiple Reaction Formalism.

See page 6.2 for coding example.

REFERENCE

1. Used to give information on references which contain information about the data coded. Other related references are not coded under this keyword (see REL-REF, MONIT-REF). See LEXFOR Reference.
2. Presence is compulsory with coded information, with or without free text.
3. The general coding format consists of 3 main fields:

(reference type, reference, date)

No embedded blanks are allowed

Reference Type. Always present. Contains a code from Dictionary 4.

Reference. Consists of up to four subfields depending on reference type. The first subfield is always present. The order of the subfields in the code is important and is always maintained, though some subfields may be omitted. If a subfield is omitted, the extra separating comma is included, except in the case:

- a) of a parenthesised subfield
- b) when the omitted subfield is the page number

See reference types on following pages for specific coding rules for each subfield.

Date. Always present. Contains a code of the form YYMMDD (year, month, day, each two digits). The month and day may be omitted.

4. Where there is more than one reference, each reference is coded on a separate record, starting in column 12. The main reference is given first.
5. If a document has more than one identification, each may be coded within one set of parenthesis, each code being in parentheses and separated from the other codes by '=' (an equal sign). The primary code is given first. (See LEXFOR Reference for the definition of primary reference.)

Example: ((R,USNDC-7,143,7306)=(R,EANDC(US)-181,143,7306))

The rules for continuation records are the same as those given under Reaction Combinations, page 8.R.9.

6. The free text on the record following the closing parenthesis of the code string is reserved for a "mini-comment" giving further information about the reference.

Examples: GRAPH ONLY
ABSTRACT

7. In the few cases (particularly with abstracts), when two works are referenced which appear on the same page of a journal or report, the following practice is followed:

- a) If a paper number or paragraph number is available it is enclosed in parentheses following the page number.

Example: (J,XYZ,8,888(1122),6912)
(J,XYZ,8,888(1573),6912)

- b) If this is not possible then the order in which they appear on the page is used.

Example: (J,XYZ,8,888(1),6911)
(J,XYZ,8,888(2),6911)

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Following are the specific coding rules for each reference type.

Type of Reference = B or C; Books and Conferences

The reference field may contain up to 4 subfields: code, volume, part, page (paper number).

General coding forms:

(B or C,Code,Volume,(Part),Page(paper#),Date)
(B or C,Code,Volume,Page(paper#),Date)
(B or C,Code,,Page(paper#),Date)
(B or C,Code,,Date)

Code subfield. Contains a code from Dictionary 7.

Volume subfield. May have any content, except commas or parentheses.

Part subfield. If present, is enclosed in parentheses and may have any content, except commas or parentheses. If omitted, the following comma is also omitted.

Page (paper number) subfield, if present, contains:

the page number which must be numeric
and/or
the paper number, enclosed in parentheses, which may have any content,
except commas or parentheses.

If omitted, the following comma is omitted.

Examples:

- a) (C,67KHARKOV,,(56),6702) = 1967 Kharkov Conference Proceedings,
paper number 56, February 1967.
- b) (C,66WASH,1,456,6603) = 1966 Washington Conference Proceedings
Volume No. 1, page 456, March 1966.
- c) (B,ABAGJAN,,123,64) = Book by Abagjan, page 123, published
in 1964.
- d) (B,MARION,4,(1),157,60) = Book by Marion, Volume 4, part 1,
page 157, published in 1960.
- e) (C,77KIEV,,7404) = 1977 Kiev Conference, page and paper
number unknown.

Type of Reference = J: Journals

The reference field may contain up to 4 subfields: code, volume, issue#, page.

General coding forms: (J,Code,Volume,(Issue#),Page,Date)
(J,Code,Volume,Page(Paper#),Date)

Code subfield. Contains a code from Dictionary 5.

Volume subfield. Contains the volume number and may have any content, except commas or parentheses.

Issue# subfield. If present, contains the issue number, enclosed in parentheses and may have any content, except commas or parentheses. If omitted, the following comma is also omitted.

Page (paper#) subfield. If present, contains:

the page number which must be numeric
and/or
the paper#, enclosed in parentheses, which may have any content, except commas or parentheses.

If omitted, the following comma is also omitted.

Examples:

- a) (J,PR,104,1319,5612) = Phys. Rev. Volume 104, page 1319, December 1956
- b) (J,XYZ,5,(2),89,6602) = Journal XYZ, Volume 5, issue#2, page 89, February 1966

Type of Reference = P or R or S; Reports

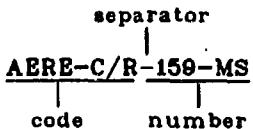
The reference field for reports may contain up to 3 subfields, code number, volume/part, page.

General coding forms: (Type,Code-number,Date)
(Type,Code-number,Page,Date)
(Type,Code-number,(Volume/part),Page,Date)

Code-number subfield. Contains:

- a.) a code taken from Dictionary 6.
- b.) the number, which may have any format, but does not contain a comma, for example: 3058-39, 4648-MS, 66-12-9, 630-1X-A/PR

The separator between the code and the number is a hyphen. Since the code and the number may both contain hyphens, the separator is defined as the first hyphen which is followed by a digit or an opening parenthesis, for example:



The hyphen acting as separator is included in Dictionary 6, except when the code itself is 11 characters long.

Volume or part subfield. If present, is enclosed in parentheses and may have any content, except commas or parentheses. If omitted, the following comma is also omitted.

Page subfield. If present, should be numeric. If there are two works on a page they may be distinguished as described on page 8.R.12; for example: 123(1) and 123(2). If omitted, the following comma is also omitted.

Examples:

- a) (R,UCRL-5341,5808) = UCRL report number 5351, published in June 1958.
- b) (R,JINR-P-2713,6605) = Dubna report, series P, number 2713, published in May 1966.
- c) (P,WASH-1068,185,6603) = WASH progress report number 1068, page 185, published in March 1966.
- d) (R,BNL-325,(2ED,SUPPL.2,VOL.2A),6602) = an extreme but well-known example for the Volume or Part field

Type of Reference = T, or W; Thesis or Private Communication

The reference field may contain up to 2 subfields: author, page

General coding forms: (W or T,Author,Date)
(W or T,Author,Page,Date)

Author subfield. Contains the family name of the first author.

Page subfield. If present, must be numeric. If omitted, the following comma is also omitted.

Examples:

- a) (W,BENZI,661104) = private communication from Benzi received on November 4, 1966.
- b) (T,ANONYMOUS,58,6802) = Thesis by Anonymous, page 58, published in February 1968.

REL-REF

1. Used to give information on references related to, but not directly pertaining to, the work coded. See also LEXFOR Reference.
2. Presence is optional, but, if present, will have coded information, with or without free text.
3. The general format of the code contains four main fields.

(code, subaccession#, author, reference)

Embedded blanks are not permitted within the code.

Code field. Always present. Contains a code from Dictionary 17.

Subaccession# field. Optional. Contains the EXFOR subaccession number for the reference given, if it exists. Cnnnn001 refers to the entire entry Cnnnn. Cnnnn000 refers to a yet unassigned subentry within the entry Cnnnn.

If this field is omitted, the following comma is always included.

Author field. Optional. Contains the first author, coded as under AUTHOR, followed by + when more than one author exists. If this field is omitted, the following comma is present.

Reference field. Always present. Contains up to 8 subfields coded as under the keyword REFERENCE. (See pages 8.R.11 - 8.R.16).

Example:

(C,B9999001,A.B.NAME+,J,XYZ,5,(2),90,7701)=Critical remarks by A.B.Name, et al.,
in journal XYZ, volume 5, issue #2,
page 90, January 1977.

RESULT

1. Used to describe commonly used quantities that are coded as REACTION combinations.
2. Presence is obligatory when relevant. Contains a code from Dictionary 37, with or without free text. Only one code is entered for each REACTION combination.
3. If more than one code is entered, each will be on a separate record, preceded by the relevant pointer.

SAMPLE

1. Used to give information on the structure, composition, shape, etc., of the measurement sample.
2. Presence is optional. Contains only free text information.

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STATUS

1. For use of this keyword see LEXFOR Status.
2. Presence is obligatory when relevant. May contain coded information and/or free text.
3. The coded information is entered in:
 - a.) either of the general forms, see page 8.2., with codes from Dictionary 16.
 - b.) as coded information with two fields: (code,subaccession#)

Code Field. Contains a code from Dictionary 16.

Subaccession# Field. Contain a cross-reference to an EXFOR subaccession number. Cnnnn001 refers to the entire entry Cnnnn. Cnnnn000 refers to a yet unassigned subentry within the entry Cnnnn.

This field is only permitted for the codes SPSDD, DEP, COREL, OUTDT, and RNORM.

The subaccession number field is always be included for these codes, with the following exceptions:

- the codes SPSDD and OUTDT, where, in some cases, no cross-reference may exist.
- older subentries for which this field was not entered.

Example: (SPSDD,10048009) - means that the present subentry is superseded by subentry 10048009.

4. For case 3.b, if more than one status code or a cross-reference to more than one subaccession number is given, each is coded on a separate record, starting in column 12.

Examples:

- 1.) STATUS (DEP,12345002)
(DEP,12345004)
- 2.) STATUS (DEP,34567004)
(APRVD)

5. For use of the following codes see the corresponding LEXFOR entries:

COREL - Interdependent Data
DEP - Dependent Data
UNOBT - Unobtainable Data

TITLE

1. Used to enter a title for the work referenced. See LEXFOR TITLE.
2. Presence is obligatory except when not relevant. Information is given in free text only.

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Chapter 9

COMMUNICATIONS, UPDATING, AND ALTERATIONS

Procedure for files received with errors

There are 2 distinct cases.

1. If a file can not be physically read, in part or whole, then the originating center should be requested to send another identical file, which should be done with minimum delay.
2. If there are errors (format, structure, etc.) in one or more entries, then the originating center should be notified of the errors by 4C- or CP-Memos with the usual distribution.

Alterations to EXFOR entries

1. Alterations to EXFOR entries are transmitted only by the originating center and are included in the regular EXFOR transmissions.
2. When an entry is altered, those subentries which have been altered will be transmitted to all other centers accompanied by the retransmission of the first subentry. The minimum unit transmitted is a subentry (NOT just the altered records). When individual altered subentries are transmitted, the appropriate ENTRY and ENDENTRY records are included. All corrections will be properly marked with alter flags (see page 2.5) and documented with an appropriate entry under HISTORY.

The altered subentries will have a 'C' in column 80 of the SUBENT record and include the revised date of last update in the N2 field.

Serious corrections (for example, those involving the COMMON or DATA section, or essential BIB keywords such as REACTION, MONITOR, etc.) will be transmitted as quickly as possible. Less serious corrections can be made and transmitted as workloads permit.

(Compare LEXFOR HISTORY).

The ENTRY record will include the revised date in the N2 field and the alter flag 'C' in Column 80.

3. Subentries added to a previously transmitted entry are transmitted accompanied only by the retransmission of the first subentry; other unchanged subentries need not be retransmitted.

Subentries to be inserted will have an 'I' in Column 80 of the SUBENT record.

Deletion of Entries and Subentries

1. Any entry or subentry for deletion will have an '=' in Column 80 of the relevant ENTRY or SUBENT record. If an entire entry is deleted, at least NOSUBENT records will be included for each subentry.
2. The following keywords are always included in the BIB for an entry or subentry to be deleted:

REFERENCE
TITLE
AUTHOR
INSTITUTE
REACTION
HISTORY

The ENDBIB record is usually followed by NOCOMMON, NODATA.

3. A mnemonic 'D' to be attached to the date under HISTORY, indicates the date of the deletion. Free text is always be included, justifying the deletion.
4. Column 80 alter flags are used throughout the 'deleted' entry or subentry as usual.
5. The accession number of the deleted entry (subentry) will never be used for another entry (subentry).

Retransmission of subentries which have been combined into one subentry

In the case of a retransmission of a series of subentries (X through Y) which have been combined into one table, the following simplified flagging system may be used:

1. Entered under HISTORY in the combined subentry:

(yymmddA) Subentries X through Y combined

2. For subentries X+1 through Y, NOSUBENT records containing the subentry number in the N1 field and an '=' in Col. 80 are transmitted.

Updating of Manual Pages

The updating of manual pages (EXFOR Systems Manual and LEXFOR) follows the rules outlined in the Protocol, Section I. These are specified and supplemented by the following agreed-upon procedures:

1. Wherever possible proposals affecting the content of the EXFOR Manual will contain proposals for specific wording to be inserted in the manual.
2. Suggestions for additions to LEXFOR will be accompanied by adequate explanation and documentation to help in preparing LEXFOR entries.
3. Any proposals for new quantity terms will be supported by the expansion, a full explanation of its use and limits, a list of corresponding Dictionary 36 entries, and a reference.
4. An explanatory LEXFOR entry will be submitted together with a proposed new dictionary code, if appropriate.
5. A change in EXFOR dictionaries, LEXFOR or the EXFOR Systems Manual will not oblige centers to change existing entries (whether they have been transmitted or not) unless stated explicitly in the proposal and approved by the data centers.
6. Updated pages of the EXFOR Manual will be issued as soon as possible.
7. The center responsible for updating the manual may introduce editorial changes, however, proposed manual wordings submitted in CP-Memos will be entered in the manual substantially unchanged, unless an objection is expressed in due time. This center is also responsible for maintaining the internal consistency of the manual; that means, e.g., to check whether an agreed proposal entails changes (cross-references, etc.) in other parts of the manual.
8. A non-editorial change on a manual page, as compared to its previous version, is marked by a vertical line in the left-hand margin.

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Inter-center Memos

Discussion among the cooperating centers on the subjects of data compilation, the EXFOR system and its further development, EXFOR Manual and Dictionaries, and EXFOR transmission files, are continued by means of memos, which are called:

4C-Memos, when dealing with neutron data or other Four-Center matters only;
CP-Memos, when dealing with CPND and the generalized EXFOR system.

Such memos are sequentially numbered in the form

Memo 4C-p/m respectively Memo CP-p/m

where n is the Originating Center Identification (see page 2.2), and m is the sequential memo number within each n series.

CP-Memos are distributed to the cooperating centers listed on page 9.5-9.6. Other compiling groups are informed, as needed, by their center of contact.

Such memos should conform to the following general format:

1. Contents of each memo will be summarized in a covering-page index.
 2. Each subject should begin on a new page to facilitate distribution to the appropriate staff at each center for action.
 3. Items requiring agreement of the cooperating centers should be flagged with a special symbol in the index and on the appropriate page.
 4. The memo number will appear on each page.
 5. All proposed changes and additions to the dictionaries, EXFOR Systems Manual, and LEXFOR should contain (where possible) a revised entry in the format of the appropriate document in addition to the usual documentation.
 6. In case of disagreement the originating center is responsible for collecting the points of agreement and issuing a final wording in the format of the appropriate document(s).
 7. Proposals which do not evoke discussion will be entered after 4 weeks by the center responsible for maintenance of manuals, dictionaries, etc.
 8. Updated manual pages documenting changes and additions will be issued to all centers as soon as possible.

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The addresses of the cooperating centers and groups are:

CAJaD	Dr. F.E. Chukreev Center for Nuclear Structure and Reaction Data of the USSR State Committee on the Utilization of Atomic Energy I.V. Kurchatov Institute of Atomic Energy Moscow, USSR
CJD	Dr. V.N. Manokhin Center for Nuclear Data Fiziko Energeticheskij Institut Obninsk, Kaluga Region, USSR
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Other centers or groups which have been represented at meetings and which have expressed interest in cooperation are:

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Physical Structure of Exchange Tapes

1. 9-Track EBCDIC with density 800, 1600 or 6250 BPI, as each center prefers (see below).
2. No multi-volume files.
3. Unlabeled files (in the sense of standard computer labels).
4. No tape-mark at the beginning of the file.
5. Tape-mark at the end of the file.
6. Blocking factor up to 40. Because some centers have difficulty in processing a physical block of less than the specified length at the end of a file, each center must make sure that the physical block containing the ENDTRANS record is made up to 40 logical records as necessary. Trailing records to fill up the last block are repetitions of the ENDTRANS record.
7. Each tape should have a label attached to the outside with the transmission number (TRANS Cnnn) written on it, where C is the center-identification code and nnn is the sequential transmission number (see page 3.3).

Magnetic tape formats for EXFOR and Dictionary transmissions

Required magnetic tape formats for receiving EXFOR and Dictionary transmissions have been specified by the following centers and groups:

Center	Tape Format
NNDC	EBCDIC 9-track 800, 1600, 6250 bpi
NEA-DB	EBCDIC 9-track 800, 1600, 6250 bpi
NDS	EBCDIC 9-track 1600, 6250 bpi
CJD	EBCDIC 9-track 800 bpi*
CAJaD	EBCDIC 9-track 800 bpi
RIKEN	EBCDIC 9-track 1600, 6250 bpi
IAE-CP	EBCDIC 9-track 800 bpi

* Tapes sent to CJD should contain a dummy file of at least 100 records at the beginning of the tape.

Appendix A

OBSOLETE INFORMATION-IDENTIFIER KEYWORDS

The following information-identifier keywords are no longer legal for use in EXFOR transmission files. However, since some centers may still have such data in their internal files, they are included in this appendix.

CMPD-QUANT

1. Used (in pre-1978 neutron data only) to specify the data which is presented in the DATA section in fields headed by DATA and RATIO (and similar headings such as DATA-MIN, DATA-MAX, etc.) when the quantity defined refers to a target which is a chemical compound, alloy or mixture. See also LEXFOR Compounds.
2. One of the following keywords must be present; they are mutually exclusive: REACTION, ISO-QUANT, CMPD-QUANT, NUC-QUANT. CMPD-QUANT must have coded information with or without free text.
3. A CMPD-QUANT unit consists of two major fields: (compound,quantity) Embedded blanks are not allowed within a CMPD-QUANT unit.

Compound Field

The general format of the code is Z-S-XXX, see page 8.3.

Quantity Field

The coding for this field is the same as for ISO-QUANT, see page A.2.

GEOMETRY

1. Used (in pre-1972 neutron data entries only) to give information about the experimental geometry.
2. Keyword is optional and contains free text only.

ISO-QUANT

1. Used (for neutron data entries initiated pre-1978 only) to specify the data which is presented in the DATA Section under the headings DATA and RATIO (and similar headings such as DATA-MIN, DATA-MAX, etc.) when the quantity defined refers to a target nucleus. The incident particle is always a neutron.
2. One of the following keywords must be present; they are mutually exclusive: REACTION, ISO-QUANT, CMPD-QUANT, NUC-QUANT. The keyword ISO-QUANT must have coded information.
3. An ISO-QUANT-unit consists of two major fields,

(target-nucleus,quantity)

Embedded blanks are not permitted within an ISO-QUANT unit.

The detailed coding for each field follows.

Target nucleus field. The isotope compiled is the target nucleus.

The general format of the code is Z-S-A-X, see page 8.3; except that:

A=0 denotes natural isotopic composition

X may not have the value G.

Quantity field. The coding consists of 4 subfields, each separated by a comma.

(target-nucleus,SF1,SF2,SF3,SF4)

Any subfield may contain a combination of codes from the same dictionary, separated by a slash.

If a subfield is omitted, the extra separating comma must be included, except that trailing commas are omitted.

e.g.(target-nucleus,SF1,SF2,,SF4)
(target-nucleus,SF1)

Only certain combinations of codes in the quantity field are meaningful. These are listed in Dictionary 14. Note that if two or more codes are entered in a subfield, they must be in the same sequence as in Dictionary 14. (See page A.6 for a description of Dictionary 14.)

SF1. Process/parameter designator

Specifies the nuclear (or collective) process under study and/or parametric quantity derived for the nucleus under study by the experiment.

Code(s) from Dictionary 10.

SF2. Function designator

Specifies the aspect or parameter studied or a useful collective term.

Code(s) from Dictionary 11.

SF3. Modifier designator

This subfield provides flags to indicate departure from the standard meaning of SF1 and SF2 or provides a combination of process/parameters and functions.

Code(s) from Dictionary 12. Note that the codes at the beginning of Dictionary 12 which may be included in SF3 are not included in the code combinations in Dictionary 14.

SF4. Particle designator

Provides particle code(s) indicating to which of several outgoing particles the quantity refers.

Code(s) from the first part of Dictionary 13.

The particle designator can be omitted if there is no ambiguity. For a quantity describing the correlation between outgoing particles, two particle designators are entered, separated by a slash.

Examples: INL,DA/DE double differential inelastic scattering cross-section

NNP,DA,,P angular distribution of protons from (n,np)
reaction

4. For ISO-QUANT combinations, see Reaction Combinations, page 8.R.9.

5. Multiple ISO-QUANT

Pointers may be used with this keyword, in which case the code fields associated with each pointer may be an ISO-QUANT unit or an ISO-QUANT combinations. (See page 8.1 for general information on Pointers.)

The use of multiple ISO-QUANT is restricted to specific classes of data, see LEXFOR Multiple Reaction Formalism.

N-SOURCE

1. Used (for entries originating pre-1985) to give information on the source of the incident particle beam used in the experiment. It has been replaced by INC-SOURCE.
2. Keyword is optional. May contain either free text or coded information and free text.
3. Coded information, if given, may be either of the general forms, see page 8.2, with code(s) from Dictionary 19, but see exception below.
4. If the code 'POLNS' is used, the code for the polarized source, if given, must follow in the same parenthesis. In this case other sources must be coded separately, starting in column 12.

NUC-QUANT

1. Used (for NND entries originating pre-1978 only) to specify the data which is presented in the DATA section in fields headed by DATA and RATIO, (and similar headings such as DATA-MIN, DATA-MAX etc.) when the quantity defined does not refer to a target nucleus.

See LEXFOR Nuclear Data

1. One of the following keywords must be present; they are mutually exclusive: REACTION, ISO-QUANT, CMPD-QUANT, NUC-QUANT. This keyword must have coded information.
2. The coding rules for NUC-QUANT are identical to those for ISO-QUANT (see pages A.2 - A.3). The isotope field contains the code for the nucleus to which the data is pertinent instead of the target nucleus.

RESID-NUC

1. Used (only in NND entries originating pre-1978 and coded using the -QUANT formalism) to define the residual nucleus for a reaction defined under the keyword ISO-QUANT. See LEXFOR Residual Nucleus.
2. Keyword is optional. May have coded information with or without free text.
3. The general format of the code is Z-S-A-X (A may not have the value 0), see page 8.3.

STA

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STANDARD

1. Used (only in NND entries originating pre-1978 and coded using -QUANT formalism) to give information about the standard reference data used in the experiment and to define standard information coded in the COMMON and DATA sections. See LEXFOR Standards.
2. Keyword is obligatory, except when not relevant. Information may be entered either in free text only or in coded form with or without free text. However, coded information must be included when the corresponding data is given in the COMMON or DATA sections. See page 6.8, Links between BIB, COMMON and DATA.
3. If coded information is given the coding rules for STANDARD are identical to those for the corresponding -QUANT, i.e., ISO-QUANT, CMPD-QUANT or NUC-QUANT.
4. Two or more standards given in coded form.

Each standard must be coded on a separate record, starting in column 12. The respective STAND field may be linked to the STANDARD codes:

either using pointers

Example: ISO-QUANT 1(AAAAAAAA)
 2(BBBBBBBB)
 STANDARD 1(CCCCCCCC)
 2(DDDDDDDD)
 DATA
 EN DATA 1DATA 2STAND 1STAND 2

or using the Data-heading Keywords STAND1, STAND2, etc., where STAND1 refers to the first code entered under STANDARD, STAND2 to the second, etc. This formalism may be used when two or more standards are given for one ISO-QUANT.

Example: ISO-QUANT (AAAAAAA)
 STANDARD (CCCCCC)
 (DDDDDDDD)
 DATA
 EN DATA STAND1 STAND2

5. Bibliographic references and EXFOR accession number of the standard data given is only entered in free text under STANDARD when data is coded using the -QUANT formalism.

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Dictionaries for use with QUANT formalism

Dictionary 12. Modifiers

An expanded form is given, at the beginning of the dictionary, only for those modifiers which are not included in the codes in Dictionary 14, general quantity modifiers.

Dictionary 14. Quantity

The format of this dictionary is as follows:

column 1 - 18 quantity code
column 19 - 22 dimension code
column 23 - 66 expanded form and free text.

1. The quantity code is composed of the codes for the quantity subfields given in Dictionaries 10 - 13. All meaningful combinations of the subfield code that are in use are included.

Note, however, that these quantity codes do not include the general modifiers RAW, REL, FCT, AV, SPA, MXW, FIS, from the beginning of Dictionary 12. If more than one of these codes apply their sequence is arbitrary.

2. The dimension code provides a cross-link to Dictionary 25 (Units Dictionary), where the dimension code is also given. This facilitates computerized consistency checks between quantities given in a table and their units.
3. The expanded form is a short definition of the quantity. (It may be used for edited output to customers.)

For the expansion, the following conventions have been adopted:

- a. "differential cross-section" means differential with respect to angle of outgoing particle.
- b. "double differential" means differential with respect to angle and energy of outgoing particle.
- c. "energy distribution" or "spectrum" means differential with respect to energy of outgoing particle.
- d. * means "multiply"; / means "divide".

May 1983

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Dictionary 41. Conversion table of quantities

This dictionary is used to convert the quantity in the -QUANT formalism, as given in Dictionary 14, to the REACTION formalism. There is a one-to-one correspondence between Dictionaries 14 and 41.

The format of the dictionary is as follows:

Column 1 - 18 quantity code in -QUANT formalism, as given in Dictionary 14

19 - 22 Z/A difference between product nucleus and target nucleus; used for computing the product nucleus from the target nucleus, e.g., "-1+0" for the (n,p) reaction; blank when product nucleus is not coded under REACTION.

23 - 66 equivalent REACTION code enclosed in parentheses, excluding target nucleus and, usually, product nucleus; for the product nucleus the code -G (or -M, etc.) may be given to indicate an isomeric state extension to be added to the product nucleus.

Covari
record
record

Comm

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Data

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End

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See a

Appendix B

COVARIANCE DATA FILE FORMAT

Covariance data may be stored as a separate covariance file. There are three record types in the covariance file: a comment record, a data record and an end record.

Comment Record Format:

Column 1 'C'
2 - 9 Data set number
10 Blank
11 - 80 Comment which includes covariance type and format

Data Record Format

Column 1 'D'
2- 9 Data set number
10 Blank
11 - 80 Data (format given on 'C' record)

End Record Format

Column 1 'E'
2 - 9 Data set Number

See also LEXFOR Covariance

July 1988

LEXFOR

INTRODUCTION

LEXFOR is the compiler's section of the EXFOR Manual. The contents are arranged similar to a lexicon in alphabetic order by subject heading. As distinct from the EXFOR Systems Manual, LEXFOR includes information essential for compilers using EXFOR, and is not relevant to programmers, that is:

- physical definitions of codes defined in the EXFOR Systems Manual and its dictionaries,
- practical examples of how to use the EXFOR system,
- physical background information required for preparing high-quality EXFOR entries,
- any other information that may be helpful to compilers.

The responsibility for updating LEXFOR is outlined in the Protocol, Section G. Proposals for additions or changes should be communicated in the usual way by CP-Memos. Where such proposals do receive unanimous NRDC approval, different views on matters of minor importance may all be included in LEXFOR as far as these views are in agreement with the EXFOR Manual and do not cause ambiguities in the definitions of codes.

The LEXFOR subject headings are given at the top of each page. Each subject heading starts with a new page for the sake of easier updating.

Examples of data-specification coding are given using the REACTION formalism only, since the -QUANT is now obsolete and is no longer used for compilation. The compiler is referred to Dictionary 41 for equivalent -QUANT codes.

July 1988

ABSORPTION

Absorption

Definition: The sum of all energetically possible interactions excluding elastic and inelastic scattering.

REACTION Coding: ABS in REACTION SF3

Sum rules: Absorption = total minus scattering
= nonelastic minus inelastic

For fissile isotopes at thermal energies below reaction (e.g., n,2n) thresholds:

Absorption = capture plus fission

Note: Absorption is a sum cross section. It should only be used where two or more reactions are energetically possible. Where absorption is, throughout an experimental data set, identical with the (n, γ) reaction, it should be coded as (n, γ). (See also Tautologies).

Examples:

The frequently so-called "hydrogen absorption cross section" must clearly be coded as (n, γ), because no other neutron-absorbing reaction besides (n, γ) is possible.

The thermal "absorption cross section" for gold may well be coded as (n, γ), since the energetically possible (n,p) and (n, α) cross sections are negligible in comparison with the measurement uncertainty of the (n, γ) cross section. However, this cannot be considered as a general guide since there is no Au(n,p) measurement to confirm it.

Disappearance Cross Section

The disappearance or removal cross section is defined in CINDA as the cross section for all neutron-induced processes producing no emergent neutron, that is (n, γ) + (n,p) + ... It differs from the absorption cross section in that it does not include (n,2n), (n,np), etc.

Note other meanings of "removal" in reactor physics and shielding physics.

ACTIVATION

July 1988

Activation

Definition: Activation is the production of a radioactive residual nucleus as a result of a reaction, which is determined by measuring a specific decay radiation emitted by the product nucleus.

The activation cross section can be identified with a specific reaction or reactions. The data given should then be coded under the appropriate reaction, e.g., (n,γ) or (n,p) .

The code 'ACTIV' (activation) is entered under the information-identifier keyword METHOD.

The decay information used in the analysis of the data given should be specified under the appropriate keywords (see Decay-Data).

Compilers should take special care when coding activation cross sections to nuclei which have metastable states to specify what has actually been measured. See Isomeric States.

Sum reaction: Frequently, the activation cross section is given for an element with natural isotopic composition, or for some other mixture of isotopes, where two or more different parallel neutron reactions with different isotopes lead to the same radioactive residual nucleus. In such a case, the appropriate sum of reactions should be entered. (See Sums).

July 1988

ALPHA

Alpha

Definition: Radiative capture-to-fission cross section ratio $\sigma_{n,\gamma}/\sigma_t$.

REACTION coding: (N,ABS),,ALF

at resonance energy: (N,ABS),,ALF,,RES

See also Single-Level Resonance Parameters

Note: The REACTION process code 'ABS' is entered, since capture and fission are considered.

LEXFOR A.3

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Analysis

The information-identifier keyword ANALYSIS can be used by the compiler to enter all relevant information as to how the experimental results have been analyzed to obtain the values (given under 'DATA') which actually represent the result of the analysis. In particular, this keyword is used for deduced data such as resonance parameters. If the raw data used for the analysis have also been entered in EXFOR, a cross-reference to those sets should be given in the free text. If important assumptions were made (e.g., negative resonances), these should be specified either directly or by reference. For example, extrapolation and interpolation should be given only with appropriate references. (See also Assumed Values, Dependent Data).

Resonance parameters require an entry under ANALYSIS explaining how they have been obtained. "Single level" or "multi-level" must be given in coded form. A more precise definition of the analysis is desirable in free text, at least in the form of a cross-reference to the literature in which a description of the analysis can be found.

The keyword ANALYSIS should not be used for information on any analysis made on the data set to obtain theoretical conclusions. Such information can be noted under the keyword COMMENT. See also Corrections.

See also EXFOR 8.A.1, ANALYSIS.

July 1988

ANGLE

Angle

Secondary-Particle Angle

The angle of the secondary particle(s) with respect to the incident-projectile beam may be entered either as angle in degrees or as a cosine (units given as NO-DIM). An angle given in degrees and minutes must be entered in two separate fields with the data heading repeated. See EXFOR 5.4.

Data-heading keywords:

ANG = angle in lab system
ANG-CM = angle in center-of-mass system
COS = cosine of angle in lab system
COS-CM = cosine of angle in center-of-mass system

and other codes given in Dictionary 24 with the flag G.

Angular Error and Resolution

Numerical values for the angular error or resolution may be entered in the COMMON or DATA section using data headings from Dictionary 24 with the family code H, e.g., ANG-RSL, COS-ERR. Further information can be given in free text under ERR-ANALYS, see page 8.E.2. See also Errors, Resolution.

Angular Correlation

REACTION Coding: Quantities defining the angular correlation between two or more emitted particles or radiations are coded with the parameter code COR in SF6 (parameter). The angles given are defined by the particles specified in the REACTION code in either the process field (SF3) or the particle considered field (SF7).

Example:

(.....(N,N+P).....,COR) neutron-proton correlation in the (n,np) reaction:

The angles are coded in the COMMON or DATA section using the data headings ANG1, ANG2, etc., in the same order in which the particles are specified in the REACTION string.

ASSUMED

July 1988

Assumed Values

The DATA table should contain under the data-heading keyword DATA (and its derivatives) only values obtained from the experiment. It is, however, also important that numerical values used for the derivation of the experimental results also be given in EXFOR in coded form. Values assumed by the author, including values taken from another source, should be entered.

Reference cross sections used for normalization should be entered under the keyword MONITOR. (See Standards).

Decay Data should be entered under the keyword DECAY-DATA. See Decay Data.

Assumed values for which a data-heading keyword exists should be coded under that data heading in the COMMON or DATA sections, e.g., spin (SPIN J), resonance energy (EN-RES), and half-lives, other than those entered under DECAY-DATA, (HL).

All other assumed values for which a quantity code exists may be entered under the data heading ASSUM in the COMMON or DATA section and defined in the BIB section under the keyword ASSUMED. See EXFOR, 8.A.1.

Following are some examples of data to be coded using the keyword ASSUMED.

1. Data on a compound consisting of more than one element: a cross section is calculated for one of the elements by assuming the cross section for the other(s).
2. A cross section measured for several isotopes: a cross section is given for the natural element by assuming a value for those isotopes which were not measured.
3. A resonance width assumed in order to deduce other resonance parameters.

July 1968

AUTHOR

Author

The author(s) of a data set are entered under the information-identifier keyword AUTHOR, all names between one set of parentheses and separated by a comma. The sequence of the names should be the same as in the publication.

See EXFOR 8.A.2 for coding format.

If a data set has several references with varying co-authors, all co-authors may be entered.*

Some East-European authors spell their names, and, in particular, their initials differently depending on whether they publish in their own language or in English. Gyulia (Hungarian) = Julius (English). Hristov (Bulgarian) = Christoph (English). If this is detected at all, the spelling in the author's own language should be preferred.

For the transliteration of Cyrillic names the following list should be used.

A	b	B	Г	Д	Е	Ж	З	И	Й	К	Л	М	Н	О	П	Р
A	B	V	G	D	E	ZH	Z	I	Y	K	L	M	N	O	P	R
C	T	У	Ф	Х	Ц	Ч	ш	щ	ж	б	бл	в	д	ю	я	
S	T	U	F	KH	TS	CH	SH	SHCH	'	Y	'	E	YU	YA		

This list had been made according to the ISO prescriptions, amended for computer usage with respect to accents, with the exception that different systems are not allowed in parallel (as is the case with the new ISO prescriptions). For instance the earlier transliterations JU and JA are allowed in the new ISO as well as YU and YA.

This scheme corresponds to the official U.S.S.R. transliteration scheme with the exception of b which is represented as ".

*NDS will enter all authors.

Average Resonance Parameters

For average resonance parameters the energy range over which the data were averaged must be specified under the data-heading keywords EN-MIN and EN-MAX. When specified, the parameters ℓ and J are given under the data-heading keywords MOMENTUM L and SPIN J; see under Quantum Numbers.

1. **Average Widths:** The average of the resonance widths of a specified type in a specified energy range.

REACTION Coding: quantity modifier 'AV' in SF8

Example:

(....(N,EL),,WID/RED,,AV) Average reduced neutron width

2. **Average Level-Spacing:** The average energy distance (D) between nearest-neighbor compound-nucleus resonances of total spin J caused by neutrons of orbital angular momentum ℓ .

If the J and ℓ values of the resonances are not determined, then D is understood to indicate the observed level spacing.

REACTION Coding: parameter code 'D' in SF6

Example: (....(N,O),,D)

Authors may apply statistical tests to evaluate the number of missed resonances. This information should be given under ANALYSIS.

3. **Fermi-gas model parameters:** See under Nuclear Quantities

4. **Strength Functions:** The strength function (S) is defined as the ratio of the average reduced neutron width to the average level spacing for compound-nucleus resonances of specified ' J ' and ' ℓ '.

If ℓ is known, but J is not known, the strength function given is defined as:

$$S^1 = \langle g\Gamma_n^1 \rangle / (2\ell+1) D^1$$

If J and ℓ are not known, then S is understood to be the observed strength function.

REACTION Coding: parameter code 'STF' in SF6

Example: (... (N,EL),,STF)

July 1988

CAPTURE

Capture

Definition: A reaction in which the incident projectile is absorbed by the target nucleus which then emits electromagnetic radiation.

REACTION coding: 'G' in REACTION SF3 (Process)

Note: This process is often called "absorption", which is defined in EXFOR as a sum cross section; see Absorption.

CENTER-OF-MASS

July 1983

Center-of-Mass System

The indication whether data are given in laboratory system or center-of-mass system is given within the data-heading keywords, not within the quantity codes. All quantities are understood to represent the laboratory system, unless the data headings are modified by 'CM', as for example:

EN-CM = incident particle energy in center-of-mass (CMS)
E-CM = energy of outgoing particle in CMS
COS-CM = cosine of angle in CMS
NUMBER-CM = heading for the coefficient number, when the Legendre or cosine fit refers to an angle given in CMS, independent of whether the fit has been made to an angular distribution in CMS or whether it has first been made to an angular distribution in the laboratory system and then converted to CMS.
DATA-CM = heading for data which are in CMS with respect to at least one variable.

See also others given in Dictionary 24.

The compiler may convert data from the center-of-mass system to the laboratory system, but should document such conversions in free text under INC-SPECT, STATUS or HISTORY

Note: Only one representation (i.e., either laboratory or center-of-mass) for each parameter should be coded as a variable in the data table. Other representation may be added under the data heading MISC if considered desirable by the compiler. In case of doubt the laboratory system is preferred.

Comments

Information-Identifier Keyword COMMENT

Free text comments may be entered under the keyword COMMENT, such as:

- Miscellaneous information which cannot logically be entered under other available keywords.
- Author's statements about the data, e.g., whether they agree with theory or with other data.
- Compiler's or evaluator's comments (see also CRITIQUE, below).

Any information which does not originate with the author must be clearly labeled, e.g., "COMMENT BY THE COMPILER...", and unambiguously separated from author's comments, for example, by including it between quotation marks or by inserting a blank line between author's and compiler's comments.

Free text comments, other than the cases given above, related to any other information-identifier keywords do not belong under the keyword COMMENT. They should be entered under the appropriate keyword.

Information-Identifier Keyword CRITIQUE

The keyword CRITIQUE may be used for free text comments on the quality of the data entered, as given by the compiler or by an evaluator.

The reference from which evaluator's comments are taken should be entered under the keyword REL-REF. See Reference.

Note: Such comments should be called to the attention of the author, when possible.

Information-Identifier Keyword FLAG

The keyword FLAG is used to link free text comments in the BIB section with specific lines in the DATA section. See Flags.

Compounds

For coding chemical compounds under the keyword REACTION, see EXFOR page 8.3.

In general, chemical compounds are coded by combining the code CMP with the element number and symbol of its main component, e.g., 26-FE-CMP for iron oxide or any other iron compound. More detailed information on the compound is given under the keyword SAMPLE. For a small number of materials of particular importance in neutron or reactor physics, special compound codes are used. These are listed in Dictionary 9. (See also EXFOR 7.13).

Example: 1-H-BNZ for benzene (C_6H_6).

Note: In CINDA, the compound codes are entered correspondingly in the S-A field. A more precise definition of the compound is given in the comment field.

Three rules must be kept in mind:

1. A more specific code has priority over a more general code.

Examples: a.) Zirconium hydrides are to be entered as 40-ZR-HYD and not as 1-H-CMP or 40-ZR-CMP.

b.) Water is to be coded as 1-H-WTR and not as 1-H-CMP.

2. For alloys (or other mixtures) the code CMP is combined with the element symbol of the major component, usually the one named first. For chemical compounds the code CMP is combined with the symbol of the primary element, usually the first one of the formula: $CaCO_3$ is coded as 20-CA-CMP, and not 6-C-CMP or 8-O-CMP.

3. If the compiler feels that two possible codes are equally relevant, the REACTION combination using the equal sign (tautology) may be used.

Examples: a.) Ammonium-hydrocarbon
((7-N-AMM,...)=(1-H-CXX,...))

b.) Brass, if it contains 50% Cu and 50% Sn
((29-CU-CMP,...)=(50-SN-CMP,...))

(In such cases two CINDA entries are made, one for each quantity).

Typical data on compounds entered are low-energy data, where chemical or crystalline binding forces affect the neutron cross sections; an example is the total cross section or thermal-scattering data of water. However, thermal scattering data for H_2 must be entered under the isotope 1-H-1, supplemented by an entry under the keyword SAMPLE. If, for example, the sample was a compound, e.g., PuO_2 , and, if the data given refer only to Pu, then the isotope must be given and not the compound.

July 1988

CORRECTION

Corrections

All relevant information about corrections applied to the measured data to obtain the values given under DATA should be entered as free text information under the information-identifier keyword CORRECTION.

Example: Multiple-scattering correction.

This may include information on:

- corrections that have been applied
- corrections that have not been applied
- corrections that are estimated to be negligible.

Corrections that are not mentioned by the author but are regarded by the compiler as relevant, are better entered under COMMENT (see Comments) where they must be clearly labelled as compiler's comments. Partial errors contributed by the uncertainties of the corrections are entered under ERR-ANALYS (see Errors).

Consideration, depending on the compiler's judgment: In general, the data resulting from the corrections applied by the author are compiled. However, evaluators frequently re-assess old data using improved corrections, because they may have better knowledge on the theory of the experiment than that which was available to the author at the time of the experiment. (This may concern items such as spectra shapes, detector-efficiency curves, etc.) In such cases, the re-assessed data are useful information to the user of EXFOR and should, therefore, be compiled. They would be labelled under STATUS as (RNORM).

Compare: Renormalization and STATUS.

LEXFOR C.5

COVARIANCE

July 1988

Covariance

Covariance matrices, if given by the experimentalist, should be included, where possible, either in structured form as free text under the keyword COVARIANCE or, for large matrices, stored on a separate covariance file.

Information-Identifier Keyword COVARIANCE

Only non-zero matrix elements need be given.

Example:

```
COVARIANCE VALUES GIVEN ONLY FOR ELEMENTS BELOW DIAGONAL OF
SYMMETRIC MATRIX ON SAME ENERGY GRID AS DATA.
1.0
0.98   1.0
0.90   0.97   1.0
0.70   0.82   0.93   1.0
0.54   0.68   0.83   0.96   1.0
0.64   0.75   0.85   0.92   0.95   1.0
```

The code 'COVAR' is used under the keyword COVARIANCE to signal the existence of a covariance file for that data set.

Example: COVARIANCE (COVAR) COMPLETE COVARIANCE MATRIX GIVEN IN
SEPARATE COVARIANCE FILE.

Covariance File

Data is stored in the experimentalists' original format with a header record which specifies the data set number to which the matrix belongs, the covariance type and the format. See EXFOR Appendix B for format.

Example:

```
C10034002 VALUES GIVEN ONLY FOR ELEMENTS BELOW DIAGONAL OF
C10034002 SYMMETRIC MATRIX ON SAME ENERGY GRID AS DATA.
C10034002 FORMAT(9E5.2)
D10034002 1.0
D10034002 0.98   1.0
D10034002 0.90   0.97   1.0
D10034002 0.70   0.82   0.93   1.0
D10034002 0.54   0.68   0.83   0.96   1.0
D10034002 0.64   0.75   0.85   0.92   0.95   1.0
D10034002 0.72   0.78   0.83   0.83   0.83   0.95   1.0
D10034002 0.64   0.67   0.69   0.69   0.68   0.83   0.93   1.0
E10034002
```

Cross sections

For the coding of cross sections see EXFOR page 8.R.2 (REACTION). See Dictionary 36 for a complete list of codes. Below, some cases requiring specific explanation are given.

Fission cross sections, see Fission.

Cross sections leading to isomeric states, see below and under Isomeric States.

See also LEXFOR entries for specific processes.

Independent and cumulative cross sections

The coding of cross sections requires special care when the formation of the residual nucleus can occur:

- by direct (independent formation), and/or
- via isomeric transition, and/or
- via radioactive decay from other nuclides.

The following examples are given in Reaction formalism:

Code	Application
,SIG	Independent formation of the product nucleus can be assumed, but no definitive statement is given by the author.
M+,SIG	Only the activity of the isomeric state specified is measured which includes, however, the partial feeding from a metastable state via isomeric transition. See also Isomeric States.
IND,SIG	Independent formation of the product nucleus. To be used only when formation via radioactive decay from other nuclides is possible and it is clearly specified by the author that it is excluded.
IND/M+,SIG	Formation of the product nucleus including independent formation and formation via isomeric transition.
(CUM),SIG	The inclusion of the formation via radioactive decay from other nuclides is assumed by the compiler, but no definitive statement is made by the author.
CUM,SIG	Cross section includes the formation via radioactive decay and isomeric transition.
CUM/M-,SIG	Cross section includes the formation via radioactive decay from other nuclides, but excludes the formation via isomeric transition.

CROSS SECTIONS

September 1989

Code Application

CUM/(M),SIG The cross section includes the formation via radioactive decay from other nuclides; the inclusion or exclusion of formation via isomeric transition is uncertain.

Note: In general, the branch codes IND and CUM should be used only for production cross sections (i.e., with the process codes F and X).

Cross section integral between specified energy limits

Definition:

$$\int_{E_1}^{E_2} \sigma dE$$

REACTION Coding: INT in SF8 (parameter).

Example: (....(N,F),,INT)

Units: cross section = energy, e.g., B=EV.

The energy limits are specified under the data-heading keywords EN-MIN and EN-MAX.

Such data may be coded only in the following cases:

1. When the data are normalized by means of an integral cross section over a specified energy range, the integral may be entered under MONITOR.
2. When the differential data are not available.
3. When the energy ranges given are commonly used for intercomparison of the data.

Generally, only data integrated by the experimentalist are compiled. Data which were not integrated by the experimentalist, should be entered with a comment clearly stating by whom they were integrated.

Compilation of such data is optional.

Note: This code is not to be used for integral measurements.

Spin-spin cross sections

Definition: $\sigma_{ss} = (\sigma_p - \sigma_a)/2$

where σ_p = cross section for neutron and target spins parallel

σ_a = cross section for incident-projectile and target spins antiparallel

REACTION Coding: 'SS' in SF8 (modifier)

Example: (....(N,TOT),,SIG,,SS)

July 1988

DATA

DATA

System-Identifier DATA

The system identifier DATA indicates the beginning of the data-table section in an EXFOR entry as distinct from the BIB section and the common-data section. See EXFOR page 3.8, Chapter 5 and the entry in Dictionary 1.

Data-Heading Keyword DATA

The data-heading keyword DATA is given at the head of the field in the data table which contains the information defined under the REACTION keyword.

For the following special cases the data headings given are used in place of DATA:

Upper limit	DATA-MAX
Lower limit	DATA-MIN
Approximate value	DATA-APRX

Data Type

The last subfield of the REACTION keyword (SF9) contains a code to indicate whether the data given are experimental, theoretical, evaluated, etc. If the data are experimental this field may be omitted.

Derived Data

Data which are not derived from the experimental data by the most direct method, but are, instead, calculated from other data obtained in the analysis of the experimental data, should be entered using the code 'DERIV' in SF9 (Data type) of the REACTION keyword.

Only values derived by the experimentalist from his own data should be entered in this way.

If the data from which the value given is derived are entered in EXFOR, a cross-reference should be entered under the STATUS code 'DEP', see STATUS.

At present, the following types of derived data may be entered in EXFOR:

- resonance integrals derived from resonance parameters or energy-dependent cross sections.
- thermal cross sections calculated from resonance parameters.
- angular distributions calculated from fitting coefficients.
- cross-section values (e.g., at 0.0253eV) derived from a smooth fit to measured points.

July 1988

DECAY DATA

Decay Data

Information-Identifier Keyword DECAY-DATA.

The following decay data pertinent to the table given in the DATA section, are entered in the coded form:

- decaying nucleus,
- half-life (value and unit),
- type of radiation,
- energy of radiation in keV,
- abundance of the radiation measured.

These data may be given for more than one decay mode. See EXFOR page 8.D.1 for coding rules.

Decay data are entered:

- in order to define a metastable state,
- when used as basic parameters for deducing the data given in the DATA section,
- as additional information resulting from or related to the experiment.

Free text explanation will often be desirable, for example, a statement on whether the decay data were obtained from the experiment or quoted from another source.

Where unresolved doublets (or multiplets) of γ -rays were used in the publication, the energies of all involved γ -rays, or at least the lowest and the highest energy, should be given, separated by a slash. Thus, two energy values given can mean a doublet or the borders of an energy range containing all (unresolved) γ -rays which were used for the analysis.

Example: DECAY-DATA (Z-S-A-X,3.1HR,DG,876./892.,0.80)

where 0.80 is the total abundance of the two γ -rays at 876 and 892 keV, or of all γ -rays lying between the limits 876 and 892 keV. For γ -rays, the photon abundance should be given, if known.

See also Flags.

Note: Half-lives may also be coded in the COMMON or DATA section, see Half-lives.

DECAY DATA

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Decay data assumed or measured by the author for a monitor (standard) reaction used in the experiment are entered under the Information-Identifier Keyword DECAY-MON. See EXFOR 8.D.4 for coding rules.

Decay Data for Variable Product Nuclei

In the case of variable product nuclei, where the reaction product is defined in the COMMON or DATA section using the data-heading keywords ELEMENT and MASS, the decay data information is coded as strings of information under the keyword DECAY-DATA using the data-heading keyword DECAY-FLAG. These strings may be linked to the relevant nuclei in the data table. In particular, when decay data are given for parent or daughter nuclides of the specified product, the data should be linked in this way. (See EXFOR 8.6 (Variable Nucleus) and 8.D.1).

More than one set of decay data information for a specific product may be entered by repeating the decay flag for each string.

Example:

```
DECAY-DATA ((1.)54-XE-125-G,16.8HR,....
             ((2.)54-XE-127-M,69 SEC,....
             ((2.)54-XE-127-G,36.4D,....
             ((3.)55-CS-127,6.25HR,....

ENDBIB
NOCOMMON
DATA
ELEMENT      MASS       ISOMER      DECAY-FLAG  DATA
NO-DIM        NO-DIM     NO-DIM      NO-DIM      ...
54.          125.        0.          1.          ...
54.          127.        0.          2.          ...
55.          127.        3.          3.          ...
...
```

Although half-life values are, preferable, coded using the keyword DECAY-DATA, if half-life values are the only type of decay information to be given, they may also be entered as a data field under the data-heading keyword HL (see Half-Lives).

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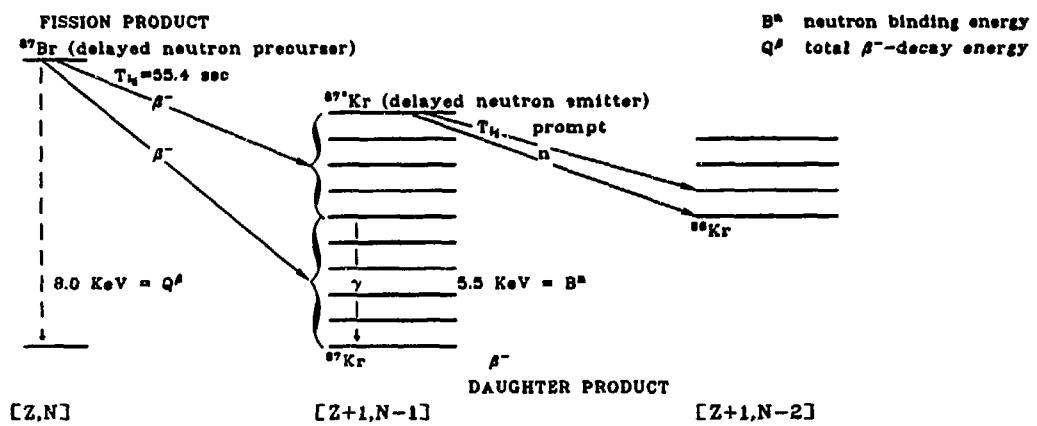
DELAYED FISSION NEUTRONS

Delayed Fission Neutrons

Theory:

In certain cases, a fission-product nucleus may decay by β^- decay to excited levels in the daughter nucleus which lie above the neutron binding energy. In this case, a delayed neutron may be emitted whose measured half-life is equal to that of the preceding β^- emitter (delayed neutron precursor). These half-lives are of the order of 0.1 to 60 sec, which is large compared to the period of prompt neutron emission ($<<4 \times 10^{-14}$ sec, see Fission Yield)

Schematic representation of delayed-neutron emission



Delayed-neutron groups

Delayed-neutron emission is usually represented by 8 delayed-neutron groups, distinguished by their half-lives. Each group is associated with, perhaps, several different precursor nuclides with similar half-life values (approximately 55 sec, 22 sec, 8 sec, 2 sec, 0.5 sec and 0.2 sec).

For further detail see:

- S. Amiel, *Fission Product Nuclear Data*, Vol. II, p.33 (1973).
- G.R. Keepin, *Physics of Nuclear Kinetics* (1985).
- E.K. Hyde, *The Nuclear Properties of Heavy Elements*, Vol. III. (1984).

DELAYED FISSION NEUTRONS

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Definitions and codes of quantities for data to be Compiled in EXFOR

Total average delayed fission neutron yield: ($\bar{\nu}_d = \bar{\nu}_t - \bar{\nu}_p$)

REACTION Coding: 'NU' in SF6 (Parameter) and 'DL' in SF5 (Branch)

a.) Absolute delayed neutron yield

Units: neutrons per fission (data-unit heading: NO-DIM)

Example: (....(N,F),DL,NU)

b.) Delayed neutron fraction ($\bar{\nu}_d/\bar{\nu}_t$): coded as a ratio with the units NO-DIM:

Example: ((....(N,F),DL,NU)/((....(N,F),,NU))

Partial delayed fission neutron yields

REACTION Coding: (....(N,F),DL/PAR,NU)

There are two main types of measurements:

a.) Delayed neutron Groups: coded using the average half-life of the group as an independent variable (with data heading HL which need not be explained in the BIB section).

- Relative abundance (or relative group yield): coded as the ratio with units NO-DIM. (The values for the six groups sum up to 1).
- Absolute group yield: coded with units PC/FIS (neutrons per 100 fissions) or NO-DIM (neutrons per fission).

b.) Yield of delayed fission neutrons associated with an individual precursor: coded with the precursor nucleus as an independent variable given under the data headings ELEMENT and MASS, usually with units PC/FIS, as above.

Delayed-Neutron Energy Spectrum for a Given Neutron Group

REACTION coding: (....(N,F),DL/PAR,DE,N)

Data are coded using the average half-life of the neutron group and the delayed neutron energy or energy range as independent variables.

The data may be given:

- a.) in percent - the data unit PC/FIS is used.
- b.) as a relative measurement - the quantity modifier REL and data units ARB-UNITS are used.

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DELAYED FISSION NEUTRONS

For the preceding quantities, the nucleus to be entered is the target nucleus before the absorption of the incident particle.

For spontaneous fission enter the fissioning nucleus and code as a nuclear quantity. See Fission.

Delayed-neutron Emission Probability (P_n value)

Definition: Neutron yield per β decay for a given nucleus. This is a decay quantity of the fission product nucleus and is independent of the fissioning target nucleus.

It is related to the fission yield by

$$P_n = \frac{\text{absolute delayed neutron yield}}{\text{cumulative yield}}$$

REACTION coding: (Z-S-A(0,B-)Z'-S'-A',,PN) for a single fragment

where Z-S-A is the fission product nucleus (precursor nucleus before β decay); Z'-S'-A' is the delayed-neutron emitting fission fragment.

or (ELEM/MASS(0,B-),,PN) for a series of fragments

the fission product nucleus is entered as a variable in the data table (see EXFOR 6.6, Variable Nucleus).

Units: PC/DECAY

For delayed neutron emission probabilities see for example:

Amarel, et.al., *J.Inorg.Nuc.Chem.*, 31, 577 (1969)

Tomlinson, et.al., *J.Inorg.Nuc.Chem.*, 33, 3809, (1971)

Asghar, et.al., *Nucl.Phys.A*, 247, 359, (1975)

Data not presently compiled in EXFOR

- The energy spectrum of all delayed neutrons together is time dependent, due to the contributions from the different half-life groups.
- The delayed-neutron equilibrium spectrum as found in a steady-state reactor

There are other delayed-neutron quantities which are not properties of the fissioning nucleus but decay properties of the fission-product nucleus which is the "precursor" of the delayed neutron. Quantities in this category which are presently not coded in EXFOR:

- the energy spectrum of the neutrons emitted by a specific precursor.

LEXFOR D.7

Dependent Data

Data that are deduced by a trivial operation from other data sets entered into EXFOR should be labeled with the code DEP under STATUS. Free text under STATUS and/or ANALYSIS should give information as to how the data were deduced. Cross-reference to the EXFOR entries from which the data were deduced must be coded as an eight-digit integer following the code, as follows:

(DEP,10048007)

See also EXFOR 8.8.2.

Examples:

- Alpha obtained from the ratio of two independent EXFOR subentries for fission and capture.
- Radiation width obtained from a subtraction of two independent EXFOR data entries of total width and elastic width.
- Legendre- or Cosine-coefficients, when the originally measured differential cross sections are also given in EXFOR.
- If the same data are given in two subentries in different representations, e.g., cross section and cross section times square-root of energy, one of them should have the status code (DEP).

The status code DEP should not be used when some data sets are mutually interdependent, as for example:

An experiment (Cabeil, AERE-R-5874,88) may yield simultaneously absorption and capture cross sections, and alpha, where all three interdependent quantities were derived from a common set of raw data. None of them should be labeled with the status code "DEP".

Compare: Interdependent Data and Data Type

Note: Do not confuse the use of the status code DEP with the use of the data type DERIV (derived data), see Data Type.

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DIFFERENTIAL DATA

Differential Data

See also Fitting Coefficients, Angle

Differential with respect to angle of emitted particle or radiation

1. Angular distribution of an emitted particle or radiation.

REACTION Coding: DA in SF8.

The angle of the emitted particle or radiation to the incident neutron beam is given as a variable in the COMMON or DATA sections.

Example:

(.....(N,N+P).....,DA,P) angular distribution of protons emitted in the (n,np) reaction

Unit type: DA (e.g., B/SR)

2. Relative Angular Distributions (Quantity modifier codes are given in REACTION SF8).

a) The values given represent the shape of the angular distribution given in arbitrary units.

Quantity Modifier: REL

Data units: ARB-UNITS

b) Ratios to the value at one angle:

$$\frac{d\sigma}{d\Omega}(\theta) / \frac{d\sigma}{d\Omega}(\theta_0) (= 1, \text{ when } \theta = \theta_0)$$

Quantity Modifier: RSD when $\theta_0 = 90^\circ$
REL when $\theta_0 \neq 90^\circ$

Data unit: NO-DIM

c) Ratios to the integrated cross section:

$$\frac{1}{\sigma} \frac{d\sigma}{d\Omega}(\theta)$$

Code as a ratio with data units 'NO-DIM'

Example: ((.....(N,EL).....,DA)/(.....(N,EL).....,SIG))

d) Values normalized such that their value over the integral equals 4π :

$$\frac{4\pi}{\sigma} \frac{d\sigma}{d\Omega} (\theta)$$

Quantity modifier: RS

Data units: NO-DIM

Differential with respect to energy of emitted particle or radiation

The energy spectrum of the outgoing particle or radiation

REACTION Coding: 'DE' in SF6 (Parameter)

| Unit type: DE (e.g., B/EV)

Example:

(.....(N,INL).....,DE,G) energy spectrum of inelastic neutron scattering
gammas

Differential with respect to energy and angle of emitted particle or radiation

The energy spectrum of the outgoing particle or radiation as a function of
angle

REACTION Coding: 'DA/DE' in SF6 (Parameter)

| Unit type: DAE (e.g., B/SR/EV)

Example:

(.....(N,INL).....,DA/DE) double differential inelastic scattering cross
section

Triple Differential Data

Triple differential data with respect to the energy and angle of one outgoing
particle or radiation and the energy of another outgoing particle or radiation.

REACTION Coding: 'DA/DE/DE' in REACTION SF6 (Parameter).

| Unit type: D3 (e.g., B/SR/EV/EV)

Example:

(.....(N,2N+P).....,DA/DE/DE,N/N/P) differential cross section with
respect to neutron energy and angle
and proton energy

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DIFFERENTIAL DATA

Particle Considered

The differential data given refers, in general, to the particle defined by REACTION SF3. If it is not evident to which outgoing particle the quantity refers, this is indicated in REACTION SF7 (Particle Considered). See Particles for the use of particle considered.

Center-of-Mass vs. Laboratory System

The indication whether the differential cross section, the angle, or the energy is given in the laboratory system or center-of-mass system is not specified within the quantity code but in the data headings; see Center-of-mass System.

Dosimetry Reaction Data

See also Standards.

Priority should be given to the compilation of cross section data for use in reactor neutron fission and fusion dosimetry.

A list of the 'most-needed' reaction data identified follows.

Activation Reactions (for use with neutron threshold detectors)

3-LI-6(N,X)HE PROD	28-NI-58(N,P)27-CO-58
5-B-10(N,X)HE PROD	28-NI-58(N,2N)28-NI-57 → 27-CO-57
7-N-14(N,P)6-C-14	28-NI-60(N,P)27-CO-60
9-F-19(N,2N)9-F-18	29-CU-63(N,A)27-CO-60
11-NA-23(N,G)11-NA-24	28-CU-63(N,2N)29-CU-62
11-NA-23(N,2N)11-NA-22	29-CU-63(N,G)29-CU-64
12-MG-24(N,P)11-NA-24	29-CU-65(N,2N)29-CU-64
13-AL-27(N,A)11-NA-24	30-ZN-64(N,P)29-CU-64
13-AL-27(N,P)12-MG-27	30-ZN-64(N,2N)30-ZN-63
15-P-31(N,P)14-SI-31	40-ZR-90(N,P)39-Y-90
16-S-32(N,P)15-P-32	40-ZR-90(N,2N)40-ZR-89
21-SC-45(N,G)21-SC-46	41-NB-93(N,INL)41-NB-93-M
21-SC-45(N,2N)21-SC-44	41-NB-93(N,2N)41-NB-92-M
21-SC-45(N,2N)21-SC-44-M	42-MO-98(N,G)42-MO-98 → 43-TC-98-M
22-TI-48(N,P)21-SC-46	45-RH-103(N,INL)45-RH-103-M
22-TI-47(N,N+P)21-SC-46	47-AG-109(N,G)47-AG-110-M
22-TI-47(N,D)21-SC-46	48-IN-115(N,INL)49-IN-115-M
22-TI-47(N,P)21-SC-47	49-IN-115(N,G)49-IN-116-M
22-TI-48(N,P)21-SC-48	53-I-127(N,2N)53-I-128
22-TI-48(N,N+P)21-SC-47	73-TA-181(N,G)73-TA-182
25-MN-55(N,2N)25-MN-54	74-W-186(N,G)74-W-187
25-MN-55(N,G)25-MN-56	79-AU-197(N,G)79-AU-198
26-FE-54(N,P)25-MN-54	79-AU-197(N,2N)79-AU-196
26-FE-54(N,A)24-CR-51	79-AU-197(N,3N)79-AU-195
26-FE-58(N,P)25-MN-56	79-AU-197(N,4N)79-AU-194
26-FE-58(N,G)26-FE-59	80-HG-199(N,INL)80-HG-199-M
27-CO-59(N,P)26-FE-59	90-TH-232(N,2N)90-TH-231
27-CO-59(N,A)25-MN-56	90-TH-232(N,G)90-TH-233 → 91-PA-233
27-CO-59(N,2N)27-CO-58	92-U-238(N,G)92-U-239 → 93-NP-237
27-CO-59(N,G)27-CO-60	

Fission Reactions

90-TH-232(N,F)	93-NP-237(N,F)
92-U-235(N,F)	94-PU-239(N,F)
92-U-238(N,F)	95-AM-241(N,F)

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ELEMENTS

Elements

Naturally occurring elements are, in general, entered with A=0. However, for monoisotopic elements, the atomic weight of the naturally occurring isotope is used. A list of monoisotopic elements follows.

<u>Z-S-A</u>	<u>Z-S-A</u>
4-BE-9	45-RH-103
9-F-19	53-I-127
11-NA-23	55-CS-133
13-AL-27	59-PR-141
15-P-31	65-TB-159
21-SC-45	67-HO-165
25-MN-55	69-TM-189
27-CO-59	79-AU-197
33-AS-75	83-BI-209
39-Y-89	90-TH-232
41-NB-93	

Nearly Monoisotopic elements may be entered with the A (mass number) of their main isotope in the case where there is no noticeable influence from trace isotopes on the data presented. This is generally the case for total and elastic scattering cross sections. However, special care should be taken with the capture cross section or in the case of partial cross sections which may lead to levels in one of the trace elements.

Following is a list of nearly monoisotopic elements:

<u>Z-S-A</u>	<u>Z-S-A</u>
1-H-1	8-O-16
2-HE-4	23-V-51
6-C-12	57-LA-139
7-N-14	73-TA-181

Note: Elements which do not occur naturally must be entered with the isotope number:

43-TC
61-PM
84 ≤ Z ≤ 89
91~PO
93≤Z

Superheavy elements which do not have an element symbol are coded using an * for the element symbol (e.g., 107---270). See Dictionary 8.

See also Target Nucleus.

Errors

See also Covariance.

Information-Identifier Keyword ERR-ANALYS

Free text explanation of the error sources and the numerical values of the uncertainties is given under the keyword ERR-ANALYS. In order to link the explanations to the numerical data given, the relevant data headings are in parentheses, starting in column 12, followed by free text; when only one data error is given, the data heading need not be given (see EXFOR 8.E.2). Free text should contain a statement of the error types included in the quoted uncertainties, and also those error types which are not included in the quoted uncertainties.

The numerical uncertainty values quoted in the COMMON or DATA section are of relevance only in conjunction with an appropriate entry under ERR-ANALYS, explaining the type of uncertainty and percentage of contributing uncertainties. Therefore, the compiler should be most careful in defining the information given and should be aware of the following aspects which are required for a precise definition of the uncertainty:

1. error-type

Such as:

- statistical or random uncertainty (uncorrelated)
- systematic uncertainties (may be correlated)
 - sample related: mass, geometric effects, multiple scattering, self-absorption.
 - detector related: efficiency, calibration
 - normalization: monitor cross section, flux determination

2. total error or partial error

For example, the statistical uncertainty, which is most often a partial along with other uncertainties, may be the total uncertainty if other sources of uncertainty are negligible.

3. shape of error function

Such as:

- Gaussian, symmetric
- triangular, symmetric
- unsymmetric, for example 8.5+0.5/-0.2

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ERRORS

4. error measure

Such as:

- standard deviation = half-width at half-maximum of Gaussian error distribution function
 - = 2/3 probability that the true value is within error bars
- confidence limits: when errors are given as confidence limits, various definitions exist, for example, 95% probability which corresponds to approximately two standard deviations.
- errors supposed not to exceed: approx. 100% probability value is within error bars.

5. error correlations: within systematic uncertainties and with other quantities measured in same experiment; see also Interdependent Data.

Data Uncertainties

Information on the uncertainties associated with the data compiled is entered in one of two ways depending on whether a complete analysis of the uncertainties has been done.

Where a detailed analysis of the uncertainties has not been done or the compiler does not have enough information to know if a complete analysis has been done, the uncertainties should be entered either:

1. in the COMMON or DATA section under the data-heading keyword DATA-ERR with an explanation in free text under ERR-ANALYS. If two or more errors of different types are given referring to the same data, data-heading keywords of the type DATA-ERR1 and DATA-ERR2 are used. Unsymmetric errors are identified using the data-heading keywords +DATA-ERR and -DATA-ERR.
2. as free text information under ERR-ANALYS.

Detailed error formats are used when a complete analysis of the uncertainties associated with the data has been given.

1. Error fields will be identified as statistical (uncorrelated), systematic (correlated) or total. The numerical values for the uncertainties are entered in the COMMON or DATA section under the headings ERR-S, ERR-T, ERR-I, etc. (see Dictionary 24). The definition of the different systematic uncertainties will be given in free text comments under ERR-ANALYS. Constant systematic uncertainties may, alternately, be entered in free text under ERR-ANALYS.

2. Only uncertainties which are one standard deviation (or the equivalent for systematic uncertainty) are entered in this format. If the author gives 2- or 3-sigma uncertainties, they should be converted to 1-sigma uncertainties. Other types of uncertainty information may be entered in free text.
3. The correlation factor for the systematic uncertainties should be coded under ERR-ANALYS following the data-heading code.

See example, following page.

Emphasis should be given to the compilation of detailed information on the uncertainties for experimental data on neutron cross sections for standards (see Standards) and dosimetry reactions (see Dosimetry Reaction Data) in new and retransmitted data sets. When the required error information for these data types is not given in the literature, every effort should be made to obtain it from the experimentalists.

Energy Uncertainties

Numerical values for the uncertainty in the monochromatic incident-neutron energy or the uncertainty of the mean energy in an incident-neutron spectrum may be entered in the COMMON or DATA section using data headings from Dictionary 24 with the family code B, e.g., EN-ERR. Further information can be given in free text under the information-identifier keyword ERR-ANALYS.

Note: The terms error and resolution are often misused in the literature. Distinguish between them where possible. See Resolution.

Other Uncertainties

Uncertainty in mean secondary energy: see Secondary Particles.

Uncertainty in mean angle: see Angle.

Uncertainty in standard: see Standards.

See index for information on other uncertainties.

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ERRORS

SUBENT 10921002

BIB

REACTION ((29-CU-63(N,A)27-CO-60,,SIG)/(92-U-238(N,F),,SIG))

ERR-ANALYS UNCERTAINTY IN NEUTRON ENERGY ABOUT 10 KEV.

(ERR-T) TOTAL ERROR

(ERR-S) STATISTICAL ERROR

SOURCES OF SYSTEMATIC UNCERTAINTIES

(ERR-1,1.0) GAMMA-RAY DETECTION EFFICIENCY.

(ERR-2,0.0) IRRADIATION GEOMETRY.

(ERR-3,1.0) URANIUM DEPOSIT, MASS, AND ISOTOPE CONTENT.

(ERR-4,1.0) EXTRAPOLATION CORRECTION FOR FISSIONS AND
CORRECTION FOR FINITE THICKNESS OF DEPOSIT

(ERR-5,1.0) CORRECTION FOR NEUTRON ABSORPTION IN
CU SAMPLE

(ERR-6,0.5) NEUTRON SOURCE CHARACTERISTICS.

COVARIANCE ONLY ABOVE DIAGONAL ELEMENTS OF SYMETRIC MATRIX ARE
GIVEN IN PERCENT ON SAME ENERGY GRID AS DATA.

100	17	19	28	23	14	13
100		37	39	45	28	23
100			42	48	29	26
100				50	31	28
100					35	30
100						22
						100

ENDBIB

COMMON

ERR-1 ERR-6
PER-CENT PER-CENT
1.5 1.5

ENDCOMMON

DATA

EN	EN-RSL-HW	DATA	ERR-T	ERR-S	ERR-2
ERR-3	ERR-4	ERR-5			
MEV	MEV	NO-DIM	PER-CENT	PER-CENT	PER-CENT
PER-CENT	PER-CENT	PER-CENT			
3.800	0.081	2.42	-04 13.	12.	3.3
1.0	0.2	1.8			
3.800	0.082	1.84	-04 22.	21.	2.6
1.0	0.2	1.8			
4.065	0.041	5.142	-04 6.5	4.7	2.0
1.0	1.5	1.8			
4.361	0.041	9.769	-04 5.7	3.8	2.0
1.0	0.7	1.8			
4.656	0.042	1.475	-03 5.6	3.6	2.0
1.0	1.0	1.8			
4.954	0.043	2.409	-03 5.0	2.4	2.0
1.0	1.2	1.9			
5.268	0.045	3.912	-03 8.7	7.5	1.7
1.3	1.0	1.9			

ENDDATA

LEXFOR E.5

July 1988

FISSION

Fission

See also Fission Yields, Fission-Neutron Spectra, Delayed Fission Neutrons.

Theory

The following definition applies in the low energy region and is based on currently accepted models.

Fission can occur either spontaneously or by the capture of an incident particle. In spontaneous fission, a nucleus exists in a highly excited and deformed state. In the case of capture, a particle is absorbed forming a highly excited nucleus which then undergoes deformation. If the nucleus is excited with sufficient energy such that the electrostatic repulsion will be greater than the surface forces holding the nucleus together, it may undergo scission.

At the scission stage the nucleus generally divides into two deformed and excited fission fragments having a mass greater than the mass of the incident projectile but not less than 7. This process is called *Binary Fission*.

Much less frequently, the nucleus divides into three fragments, where the size of the third fragment varies between a 'scission neutron' and a fragment similar in size to the other two fragments. This process is called *Ternary Fission*.

For further detail see:

E.K.Hyde, *The Nuclear Properties of Heavy Elements*, Vol. III (1964)

N.Feather, *Ternary Fission, Physics and Chemistry of Fission*, page 83,
Vienna (1969)

Compare: Reaction Mechanism

REACTION Coding: The fission process is coded using the process code 'F' in SF3.

Example: (...(N,F),,SIG) Neutron fission cross section

Special rules apply for the coding of the Reaction Product (see EXFOR 8.R.5).

Spontaneous Fission is specified by coding '0' in REACTION SF2 (incident projectile).

Example: (98-CF-252(0,F),,NU) Spontaneous fission of ^{252}Cf

FISSION

July 1988

Fission Fragments

For quantities related to the bulk of heavy or light fission products, the codes HF (heavy fragment) and LF (light fragment) are used in REACTION SF7 (particle considered).

Example: $(\dots(N,F),,AKE,HF)$ Average kinetic energy of heavy fragments

Fission Asymmetry

In the case of binary fission where the fission nucleus divides with high probability into two unequal fragments, the ratio of the mean mass of the heavier fission fragment to that of the light fission fragment is called the fission asymmetry.

REACTION Coding: $((\dots(N,F),,AP,HF)/(\dots(N,F),,AP,LF))$

See also Fission Yields.

Ternary Fission

REACTION Coding: 'TER' in REACTION SF5 (branch).

Examples:

$(\dots(N,F),TER,SIG)$ Ternary fission cross section

$(\dots(N,F),TER,DA,LCP)$ Angular distribution of light charged particles in ternary fission

Frequently, the ternary fission is further specified by the accompanying light particle, e.g. ' α -particle accompanied ternary fission'. Such information should be coded by specifying the light particle in REACTION SF4.

Example:

$(\dots(N,F)2-HE-4,TER,SIG)$ Cross section for α -accompanied ternary fission

Note: This is a partial cross section only for those ternary fissions accompanied by the light charged particles specified.

The ratio of binary to ternary fission may be coded using the codes 'BIN' and 'TER' in REACTION SF5 (branch) and the code 'RAT' in SF6 (data type).

Example: $(\dots(N,F),BIN/TER,SIG/RAT)$

Partial fission cross sections

The fission cross section is a sum cross section, for example:

$$(n,f) = \text{direct fission} + (n,n'f) + (n,2nf) + \dots$$

The partial fission cross sections are coded under the keyword REACTION as follows:

(n,n'f)	(N,N+F),SEQ,SIG
(n,2nf)	(N,2N+F),SEQ,SIG
(n, γ f)	(N,G+F),SEQ,SIG

Note: For the coding of a "direct fission only" cross section a new branch code (e.g., DIR) could be introduced for SF5 as soon as such a case occurs and is to be coded in EXFOR.

FISSION-NEUTRON SPECTRA

July 1988

Fission-Neutron Spectra

Theory

Fission-neutron spectrum data are fitted either to a Maxwellian or to a Watt spectrum or to one of several other defined spectra*.

The Maxwellian spectrum has the shape:

$$N(E) \sim \sqrt{E} \exp(-E/T)$$

where E is the energy of the fission neutron and T is the spectrum temperature given in MeV. Also often given are the average kinetic energy \bar{E} and the most probable energy E_p which are defined as:

$$\bar{E} = 3T/2$$

$$E_p = T/2 = \bar{E}/3$$

The Watt spectrum is based on the assumption that fragments emit neutrons with a Maxwellian spectrum in the center-of-mass system. The shape of the Watt spectrum is:

$$N(E) \sim \exp(-E/T) \sinh\left(\frac{2}{T}\sqrt{EE_f}\right)$$

where T is the spectrum temperature given in MeV but deviating from the temperature defined in the Maxwellian fit; E_f is a theoretical "fragment kinetic energy per nucleon". The average kinetic energy \bar{E} is defined here as:

$$\bar{E} = E_f + 3T/2$$

The numerical value of \bar{E} should be approximately the same disregarding the spectrum shape to which the data were fitted.

Fission spectrum average cross sections are defined as:

$$\sigma = \frac{\int \sigma(E)N(E)\sqrt{EdE}}{\int N(E)\sqrt{EdE}}$$

*More recently, a new fission neutron spectrum representation has been proposed by Madland and Nix, see reference 3.

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FISSION-NEUTRON SPECTRA

The knowledge of the shape of the fission spectrum is developing, and Maxwellian and Watt spectra are now considered only as rough approximations. Presently preferred is a "double Watt spectrum". The ^{252}Cf spectrum, which is more accurately known, suggests that none of the presently used fits is sufficient. Therefore, it is most important to compile point data of the energy distribution of fission neutrons. However, it is also desirable to compile mean-energy values because they are rather independent of the spectrum shape assumed and frequently needed for measurement analysis (detector response, etc.).

References

1. James Terrell, *Fission Neutron Spectra and Nuclear Temperature*, Phys. Rev. 113, p.527 (1959)
2. *Prompt Fission Neutron Spectra*, Vienna, 1979
3. D.G.Madland and J.R.Nix, Nuc.Sci.Eng., 81, 213 (1982)

Data to be compiled in EXFOR

1. Energy spectra of fission neutrons

In the literature, these data are usually called $\chi(E)$. Data are usually given in arbitrary units, which requires the 'REL' modifier in the REACTION code. In the normalized form $\int \chi(E) dE = 1$, data have the units of a reciprocal energy.

The data are functions of the outgoing-neutron energy (E), and incident-projectile energy (EN).

Examples:

- (....(N,F),PR,DE,N) Energy spectrum of prompt fission neutrons
- (....(N,F),DL,DE,N) Energy spectrum of delayed neutrons
- (....(N,F),DL/PAR,DE,N) Energy spectrum for a specific delayed-neutron group

2. Fitting parameters of fission-neutron spectra

Since the average kinetic energy E is the only quantity which is comparable in all fits, EXFOR entries should be made for this quantity.

Example:

- (....(N,F),PR,AKE,N) Average kinetic energy of prompt neutrons

Details of the fit and of the spectrum shape assumed should be given under ANALYSIS.

FISSION-NEUTRON SPECTRA

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- 3. Fission-neutron spectrum averaged cross sections are entered with the modifier FIS.**

It must be evident in the EXFOR entry whether the data were:

- measured directly. The method should be specified under METHOD. The kind of spectrum and the nuclide and incident-projectile energy from which the fission-neutron spectrum is produced should be specified under INC-SPECT.
- calculated by integrating a measured cross-section curve over an assumed fission-neutron spectrum. This is specified using the code 'DERIV' in REACTION SF9. An entry should also be made under ANALYSIS. It is essential to give the assumed spectrum type and its parameters, as well as how the fit was made (e.g., in a $N(E)$ -versus- E scale or in a $N(E)/\sqrt{E}$ -versus- E scale).

See Spectrum Average for specification of incident spectrum.

See also Delayed Fission Neutrons.

Fission Yields

See also Fission.

Theory

The fragments formed at the scission stage by a nucleus undergoing fission are called primary, initial, or pre-neutron emission fragments.

The primary fragments repel each other, obtain their full kinetic energy (e.g., 90 MeV), emit prompt neutrons ($<4 \cdot 10^{-14}$ sec) and gamma rays ($<10-11$ sec), are slowed down in the surrounding medium, and stopped. These fragments are called secondary, final, post-neutron-emission fragments, or primary fission products (the emitted γ -rays may cause conversion β 's and X-rays).

The primary products undergo (after .01 sec and more) a series of β -decays forming secondary products, and end up in stable nuclei. For certain products the emission of delayed neutrons competes with the β -decay process. In most of these stages mass yields and charge dispersions are measured as well as energy distributions.

The terms "fragments" and "products" are not clearly distinguished. Most frequently the border-line between fragments and products varies, and often the word "fragments" is used as an overall term, including all stages of decay.

Fission fragments are often specified only by their mass, including all Z-numbers, so that the fragment yield remains constant during β decay. Fission products are usually specified by Z and A. A specified fission product is obtained in two ways: either immediately from fission (primary yield) or from the decay of another fission product. Thus, the total amount of a specified fission product varies with time. Very short-lived fission products may nevertheless be most important, because some have extremely high capture cross sections ($10E+6$). Finally, all decay to stable end-products, partially via metastable states. For odd A-numbers, only one stable end product exists that is significantly formed in fission; for even A-numbers, one or two exist.

For further information see:

A.C.Pappas and J.Alstad, *Symp. of the Physics and Chemistry of Fission*, Vienna (1969), page 669 - review article

W.H.Walker, *IAEA Panel of Fission-product Nuclear Data*, Bologna, (1973)
- method of yield measurement

Coding

REACTION Coding: Fission yields are specified by coding 'FY' in SF8. The yield type is specified in SF5 (Branch) (see under specific type of yield, following pages).

1. Absolute yields. (Fissions and fission fragments are counted independently.)

Units: percent per fission (unit code: PC/FIS).

2. Relative yields.

REACTION Coding: modifier REL in SF8

Units: ARB-UNITS

The sum of the yield for all fission products will, in general, add up to 200%, i.e., 100% for each of the two fragments formed. Since in ternary fission more than two fragments are formed per fission, the yields for all fragments sum up to a bit more than 200%. However, emission of light particles in ternary fission does not change the sum of yields in the binary fission mass range usually measured, and other mass splits in ternary fission are negligible, therefore, relative yield measurements may be normalized to 200% if the measurement was made for a sufficient large number of fragments. If this is done, the data table may include some values that have not been measured but obtained by interpolation; such values must be labelled by flags.

The fission product considered can be coded either in REACTION SF4 or as a variable in the data table.

Examples for product nuclei coded within the REACTION code:

(92-U-235(N,F)54-XE-124,,FY) = yield of the fission product ^{124}Xe
(92-U-235(n,F)54-XE-133-G,CUM,SIG) = cumulative production cross section for
the fission product ^{133}Xe

Examples for coding product nuclei as variables in the DATA tables:

(92-U-235(N,F)ELEM/MASS,,FY) = yield of specified product nuclei which are
given in the DATA table under the data headings
ELEMENT, MASS and ISOMER (if applicable).
(92-U-235(N,F)MASS,CHN,FY) = chain yield of several mass numbers given in
the DATA table under the data heading MASS.

See Reaction Product and EXFOR 6.6 (Variable Nucleus) for details.

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FISSION YIELDS

Yield data to be compiled in EXFOR

1. Primary fission-fragment yield. The primary yield per fission of fission-fragment mass A before prompt neutron emission. It may also be called pre-neutron-emission fragment-mass distribution. In all experimental techniques corrections for some prompt neutrons already emitted cannot be avoided.

SF5 Code: PRE

Example: (....(N,F)ELEM/MASS,PRE,FY)

2. Secondary fission-fragment yield. The secondary yield per fission of fission-fragment mass A after prompt-neutron emission, but before β decay and delayed-neutron emission. It may also be called post-neutron-emission fragment-mass distribution.

SF5 Code: SEC

Example: (....(N,F)ELEM/MASS,SEC,FY)

3. Independent fission-product yield. The direct or independent yield per fission of a primary fission product specified by Z and A, after prompt neutron emission, but before β -decay and delayed-neutron emission, including only the direct yield and not the yield obtained from decay of other fission products.

SF5 Code: IND

Example: (....(N,F)ELEM/MASS,IND,FY)

Sum rule: The independent yield is equal to the sum over all Z (for one A) of the secondary yield.

Note: Experimental data for independent yields of the product Z,A include a portion yielding from the delayed-neutron emission of the product Z,A + 1 or from the beta decay of the product Z-1,A, if separation times are not short against the relevant decay times. Corrections are required and should be mentioned under the keyword CORRECTION. Fragment-mass yields are not affected by beta decay but only by delayed-neutron emission.

FISSION YIELDS

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4. Cumulative fission-product yield: the cumulative yield per fission of a fission product specified by Z and A, after prompt-neutron emission, including the independent yield plus the yield from decay of other fission products.

SF5 Code: CUM

Example: (....(N,F)ELEM/MASS,CUM,FY)

Sum rules:

CUM,FY for the β -decaying product Z-1,A
+ IND,FY for product Z,A

= CUM,FY for product Z,A, if the products Z-1,A and Z,A+1 are not delayed-neutron emitters.

The following events may add to the cumulative yield of the fission-product Z,A in its ground state:

- independent yield from fission
- β decay from product Z-1,A in ground state
- β decay from product Z-1,A in a metastable state
- delayed-neutron emission from product Z,A + 1
- internal transition from a metastable state of product Z,A

In addition, the product Z,A may be formed from neutron capture in the product Z,A-1, which is not included in the "cumulative yield".

The cumulative yield is often given for an isomeric state of a fission-product Z,A; this is entered in EXFOR by means of flags, see EXFOR 6.7.

5. Total chain yield. The total chain yield per fission of fission-fragment mass A is the sum of the cumulative yields of all stable fission products having the same mass A. When only one stable fission product per mass A exists, the total chain yield for mass A is identical with the cumulative yield of the stable end product Z,A.

SF8 Code: CHN

Example: (....(N,F)MASS,CHN,FY)

6. Fractional yields.

The distribution of charge Z within a given fragment mass chain A is called charge dispersion. It can empirically be approximated by a Gaussian distribution with a most probable charge Z_p (see following). The fractional independent yield of a fission product (after prompt neutron emission) is given by:

$$P(Z) = (c\pi)^{-1/2} \exp[-(Z-Z_p)^2/c]$$

whereas the fractional cumulative yield is given by

$$\sum_{n=0}^Z P_n = \frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^{Z+1} \exp\left[\frac{-(n-Z_p)^2}{2\sigma^2}\right] dn$$

The parameters c and σ are widths of the distributions related by:

$$c \approx 2(\sigma^2 + 1/12)$$

For charge dispersion, fractional yields are defined only as ratios to total chain yield.

Reference:

A.C. Wahl, et al., *Phys. Rev. B126*, page 1112 (1962)

REACTION coding:

The REACTION is coded as an explicit ratio and is followed by the keyword RESULT.

The fractional independent fission-product yield is defined relative to the total chain yield. The code FRIND is entered under RESULT.

The fractional cumulative fission-product yield is defined relative to the total chain yield. The code FRCUM is entered under RESULT.

In all cases, the data are entered as ratios with values from 0 to 1 and data units NO-DIM.

Examples:

```
REACTION ((92-U-235(N,F)ELEM/MASS,IND,FY)/
           (92-U-235(N,F)MASS,CHN,FY))
RESULT (FRIND)

REACTION ((92-U-235(N,F)ELEM/MASS,CUM,FY)/
           (92-U-235(N,F)MASS,CHN,FY))
RESULT (FRCUM)
```

FISSION YIELDS

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7. Most probable charge

The most probable initial charge Z_p for a given mass chain.

REACTION Coding: ZP in SF6

Example:(N,F)MASS,,ZP)

Note: The Gaussian width parameter has been assumed to be approximately constant for all A chains, as given by Wahl, et al. Therefore Z_p has sometimes been determined from a single fractional yield measurement. However, there is evidence for a variation of c and σ with mass A, and they may be determined together with Z_p . Therefore, the Gaussian width parameter used should be explained (value or reference).

8. Most Probable Mass

The most probable mass A_p is the mean mass for a given element.

REACTION Coding: AP in SF6

Example:(N,F)ELEM,,AP)

9. Charge yields

The charge yield (or elemental yield) is defined as the sum of the independent yields for all products with a specified Z.

REACTION Coding: CHG in SF6

Example:(N,F)MASS,CHG,FY)

Charge Distribution

The following definition of charge distribution (primary charge function) is now generally accepted: distribution of primary charge about Z_p as a function of primary mass. This quantity is deduced, either from other quantities (charge dispersion, mass distribution), or from instrumental measurements of fragment mass (kinetic energy) and X-rays, both methods involving uncertain corrections for prompt-neutron emission. As this quantity is mainly of interest for studies of the fission process, but not in applied fields, no codes are proposed.

10. R-values

An R-value is a ratio of measurement results for 2 different energies or energy spectra (one of which is considered to be a monitor reaction), each of which is relative to the same standard reaction.

Example:

$$R = \frac{(^{144}\text{Ce}/^{90}\text{Mo} \text{ from } ^{238}\text{U fission by fast neutrons})}{(^{144}\text{Ce}/^{90}\text{Mo} \text{ from } ^{238}\text{U fission by thermal neutrons})}$$

REACTION Coding:

The REACTION is coded as an explicit ratio, followed by the keyword RESULT.

Example:

```
REACTION (((92-U-238(N,F)ELEM/MASS,CUM,FY,,FIS)/
           (92-U-238(N,F)42-MO-99,CUM,FY,,FIS))/
           ((92-U-238(N,F)ELEM/MASS,CUM,FY,,MXW))
           (92-U-238(N,F)42-MO-99,CUM,FY,,MXW)))
RESULT      (RVAL)
```

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FITTING COEFFICIENTS

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Fitting Coefficients

Coefficients obtained from a fit to a differential cross section may be coded into EXFOR by entering the type of expansion used to fit the data in REACTION SF8 and specifying the representation used.

The data for a given energy is entered with the coefficient number given under the data heading NUMBER or NUMBER-CM (compare Center-of-Mass System).

Where the first coefficient ($i=0$) is either unity or another constant, it need not be coded in the data table.

Where the first coefficient is identical to the cross section, it should be coded as a separate subentry. Each subentry should have a cross-reference under STATUS to the other subentry, using the code COREL.

Example: STATUS (COREL,10234002) ZEROOTH ORDER COEFFICIENT = 4PI GIVEN AS ELASTIC SCATTERING CROSS SECTION

Note: If the directly measured differential cross sections are also coded in EXFOR, the fitting coefficients need not be compiled. If compiled, the coefficients should be marked as dependent data under STATUS, with a cross-reference to the subentry number of the cross section from which they were derived.

Reference:

1. M.Abramowitz and I.A.Stegun, *Handbook of Mathematical Functions*, Dover Publications, 1970.

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FITTING COEFFICIENTS

Expansions to be coded into EXFOR

The following pages contain examples of data to be coded in EXFOR. For a complete list of fitting coefficient codes, see Dictionary 36.

Cosine Coefficients

Definition: Coefficients obtained by fitting a differential cross section using an equation containing a sum in powers of cosine.

REACTION Coding: COS in SF8 plus a code indicating the representation used.

Representations:

DA,,COS = a_i (unit type DA, e.g., B/SR) where:

$$\frac{d\sigma}{d\Omega}(E,\theta) = a_0 + \sum_{i=1}^n a_i(E) \cos^i \theta$$

DA,,COS/RS = a_i (units NO-DIM) where:

$$\frac{d\sigma}{d\Omega}(E,\theta) = \frac{\sigma}{4\pi} \left[1 + \sum_{i=1}^n a_i(E) \cos^i \theta \right]$$

DA,,COS/RS0 = a_i (units NO-DIM) where:

$$\frac{d\sigma}{d\Omega}(E,\theta) = \frac{d\sigma}{d\Omega}(E,\theta^0) \sum_{i=0}^n a_i(E) \cos^i \theta$$

DA,,COS/1K2 = a_i (units NO-DIM) where:

$$\frac{d\sigma}{d\Omega}(E,\theta) = \frac{1}{k^2} \sum_{i=0}^n a_i(E) \cos^i \theta \quad k = \text{wave number}$$

FITTING COEFFICIENTS

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Legendre Coefficients

Definition: Coefficients obtained by fitting a differential cross section using an equation containing a sum of Legendre polynomials.

REACTION Coding: LEG in SF8 plus a code indicating the exact representation used.

Representations:

DA,,LEG = a_i (unit type DA, e.g., B/SR) where:

$$\frac{d\sigma}{d\Omega}(E,\theta) = a_0 + \sum_{i=1}^n a_i(E) P_i(\cos\theta)$$

DA,,LEG/RS = w_i (units NO-DIM) where:

$$\frac{d\sigma}{d\Omega}(E,\theta) = \frac{\sigma}{4\pi} \left[1 + \sum_{i=1}^n w_i(E) P_i(\cos\theta) \right]$$

DA,,LEG/RSL = B_i (units NO-DIM) where:

$$\frac{d\sigma}{d\Omega}(E,\theta) = \frac{\sigma}{4\pi} \left[1 + \sum_{i=1}^n (2i+1) B_i P_i(\cos\theta) \right]$$

DA,,LEG/2L2 = a_i (unit type DA, e.g., B/SR) where:

$$\frac{d\sigma}{d\Omega}(E,\theta) = 1/2 + \sum_{i=0}^n (2i+1) a_i(E) P_i(\cos\theta)$$

DA,,LEG/L4P = a_i (unit type DA, e.g., B/SR) where:

$$\frac{d\sigma}{d\Omega}(E,\theta) = \frac{1}{4\pi} \sum_{i=0}^n (2i+1) a_i(E) P_i(\cos\theta)$$

DA,,LEG/1K2 = a_i (units NO-DIM) where:

$$\frac{d\sigma}{d\Omega}(E,\theta) = \frac{1}{k^2} + \sum_{i=1}^n a_i(E) P_i(\cos\theta) \quad k = \text{wave number}$$

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FITTING COEFFICIENTS

Associated Legendre Polynomials of the First Kind

Definition: Coefficients obtained by fitting

- a differential cross section
- or the product of a differential polarization and a differential cross section
- or the product of a differential polarization and the square of a differential cross section

using an equation containing a sum of associated Legendre polynomials of the first kind (see, for example, Chapter 8 of Reference 1 for the relationship between Legendre functions). See also Polarization.

REACTION Coding: AL1 in SF8.

Examples:

FM/DA,,AL1 = a_i (unit type DA, e.g., B/SR) where:

$$P(E,\theta) \times \frac{d\sigma}{d\Omega}(E,\theta) = \sum_{i=0}^n a_i(E) P_i^1(\cos\theta)$$

FM2/DA,,AL1 = a_i (unit type DA, e.g., MB/SR) where:

$$P(E,\theta) \times \frac{d\sigma^2}{d\Omega}(E,\theta) = \sum_{i=0}^n a_i(E) P_i^1(\cos\theta)$$

Sine-Squared Coefficients

Definition: Coefficients obtained by fitting

- a differential cross section
- or the product of a differential polarization and a differential cross section
- or the product of a differential polarization and the square of a differential cross section

by an equation containing a sum in powers of sine θ . See also Polarization.

REACTION Coding: SN2 in SF8.

Examples:

FM/DA,,SN2 = a_i (unit type DA, e.g., B/SR) where:

$$P(E,\theta) \times \frac{d\sigma}{d\Omega}(E,\theta) = \sum_{i=0}^n a_i(E) \sin^{2i}\theta$$

FM2/DA,,SN2 = a_i (unit type DA, e.g., MB/SR) where:

$$P(E,\theta) \times \frac{d\sigma^2}{d\Omega}(E,\theta) = \sum_{i=0}^n a_i(E) \sin^{2i}\theta$$

Flags

Flags are used to link information in the BIB section to specific lines in the DATA section. There are, currently, three types of flags in use in EXFOR.

Data-Heading Keyword FLAG

To link free-text comments in the BIB section with one or more lines in the data table, fixed point numbers (compare EXFOR 5.3) are coded under the data-heading keyword FLAG with units NO-DIM. There may be more than one field with the heading FLAG (see EXFOR 5.5)

The meaning of the flags is given under the Information-Identifier Keyword FLAG, where the actual flags are given in parenthesis, each on a separate line, starting in column 12, followed by a free text comment. (See EXFOR, page 8.F.1.)

Note: FLAG should not, in general, be used for entire subworks or for one-line data tables. An exception would be where the BIB-information is given in the common subentry (SAN=1) and, for some, but not all, of the following subentries, a flag would be used in a one line data table. (All flags given in the common subentry must be used in all data subentries.) FLAG may not be used in the COMMON section.

Data-Heading Keyword DECAY-FLAG

To link coded information on decay data in the BIB section with one or more lines in the data table, fixed point numbers (compare EXFOR 5.3) are coded under the data-heading keyword DECAY-FLAG with units NO-DIM.

The data lines are linked to the appropriate coded information by giving the actual flags, enclosed in parenthesis, as the first field in the coding string.

Example: DECAY-DATA ((1.)60-ND-138,5.04HR,DG,328.,0.065)

Usage is presently limited to the information-identifier keywords DECAY-DATA and RAD-DET. See EXFOR 8.D.1 for DECAY-DATA and 8.R.1 for RAD-DET. See also Decay Data.

Data-Heading Keyword LEVEL-FLAG

To link coded information on level properties in the BIB section with one or more lines in the data table, fixed point numbers (compare EXFOR 5.3) are coded under the data-heading keyword LEVEL-FLAG with units NO-DIM.

The data lines are linked to the appropriate coded information by giving the actual flags, enclosed in parenthesis, as the first field in the coding string.

Example: LEVEL-DATA ((1.)82-PB-206,E-LVL=0.,SPIN=0.,PARITY=+1.)

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FREE TEXT

Free Text

Be short and precise!

The free text in EXFOR should be clear enough so that users who are not familiar with the system, can easily understand it. No abbreviations should be used that are not self-explanatory. No codes from dictionaries are allowed in the free text. For general rules see EXFOR 4.3.

Some examples:

- Write NUCL.PHYS., and not NP
- Write Z, and not PC
- Separate a number and its unit by a blank for clarity.
- Element symbols and their A values may be written as, e.g., 235-U. The Z value can be omitted. For natural elements only the symbol should be used, e.g., FE.

Free text information should be entered under the keyword to which it pertains. In particular, comments which refer to any of the REACTION subfield codes or which are necessary to understand a special coding or reaction type, should be given in the free text under REACTION rather than under COMMENT.

Standard values, parameters and other numerical values should, if suitable, be entered in the DATA or COMMON section, although they maybe also given in free text.

When writing formulae in free text, the compiler should attempt to use the FORTRAN conventions when they apply with liberal use of parentheses for clarity.

Blank lines should be used with discretion. Free text following codes can start right after the closing parenthesis; however, for clarity, it may be indented. Continuation lines may start in column 12. See EXFOR page 4.3 for the structure of free text lines.

Parentheses ')' can be used in the free text except in column 12 where the opening parenthesis marks a code. Beginning continuation lines after column 12 is good coding practice, as it eliminates the accidental coding of a parenthesis in this column.

The language of the free text is English. However, names of journals or other names should not be translated into English. Write "Yadernaya Fizika", and not "Nuclear Physics" which applies to another journal.

Free text comments not originating with the author must be clearly labelled, e.g., '(COMMENT BY THE COMPILER)', and unambiguously separated from authors comments, e.g., by including it between quotation marks or by inserting a blank line between authors and compilers comments. See also Comments.

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GAMMA SPECTRA

Gamma Spectra

Data to be compiled in EXFOR

Neutron capture γ -ray spectra are not given high priority. Whether they are coded in EXFOR is left to the discretion of the individual data centers.

1. Intensities of γ lines

REACTION code: (.....(N,G).....,SPC)

Unit type: SPC (e.g., GAM/100N)

The γ -ray energies are discrete values coded under the data heading 'E'.

Relative measurements require the addition of the modifier 'REL' and units 'ARB-UNITS'.

2. Continuous spectra of unresolved γ 's

REACTION code: (.....(N,G).....,DE)

Unit type: DE (e.g., MB/MEV)

The γ -ray energy is a continuous variable coded under the data headings 'E-MIN' and 'E-MAX'.

3. Partial radiation widths

REACTION code: (.....(N,G),PAR,WID)

Unit type: E (e.g., EV)

The independent variable is:

- either the γ -ray energy, coded under the data heading 'E'
- or the final level energy, coded under the data heading 'E-LVL-FIN'.

General Quantity Modifiers

The list of general quantity modifiers is given at the beginning of Dictionary 34. They can be added to any quantity without requiring an entry in Dictionary 36. Some of them require clarification:

1. The RAW modifier is used for raw or uncorrected data such as transmission data, reaction yields, raw gamma spectra, etc. See Raw Data.
2. The FCT modifier is used when the data has been multiplied by a defined factor not containing another quantity (e.g., a mathematical factor or a branching ratio). Explanatory free text is compulsory. If the factor contains another quantity, the appropriate reaction combination is to be used, except in the case of a ratio of the same quantities (see REL modifier). The modifier FCT must not be used for factors (such as isotopic abundance) for which specific codes have been introduced; see Products.
3. The REL modifier is used in the case of shape normalized data, that is, data proportional to the quantity given. There are two cases:
 - a.) The normalization factor is unknown. The data-unit keyword ARB-UNITS (arbitrary units) should then be used.
 - b.) The cross section is divided by a cross section at a certain energy or angle. In this case the units are left to the discretion of the compiler. An exception to this is the ratio relative to the cross section at 90 degrees, in which case the RSD modifier must be used with units NO-DIM.

Note: NDS will always use ARB-UNITS if the REL modifier is used.

The REL modifier always needs explanation in free text.

An explicit ratio defined under the REACTION keyword does not require the modifier REL and will usually have the units NO-DIM.

4. The MSC modifier is used for unusual data types, indicating that the exact definition of the quantity is given in free text following the REACTION code. This modifier should be used with discretion because the data will not be fully machine retrievable.

Currently used only for photonuclear data.

See Spectrum Average for details on FIS, MXW and SPA.

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HALF-LIVES

Half-lives

Half-life values in EXFOR entries serve a dual purpose: they may define a isomeric state, or they may be basic parameters for deducing the data value from the experiment.

Consequently, the half-life should be coded in computer-intelligible form:

- whenever a code indicating a metastable state occurs in a target nucleus, quantity or residual nucleus;
- when a target nucleus or residual nucleus is not stable and its half-life is an essential parameter in the analysis of the experimental data.

● Half-lives may be coded in one of the following ways:

1. In the BIB section using the keyword DECAY-DATA, see DECAY-DATA.
2. In the COMMON or DATA section using data headings from Dictionary 24 with the family code 6, e.g., HL, HL1. These are linked to the BIB keyword HALF-LIFE (see below).

Numerical uncertainties may be entered using data headings from Dictionary 24 with the family code 7, e.g., HL-ERR, with a free text explanation under ERR-ANALYS, see EXFOR 8.E.2.

Furthermore, for certain data types, the half-life functions as an independent variable to be coded under the data heading HL; no explanation is needed under the keyword HALF-LIFE. Compare Delayed Fission Neutron Data.

Information-identifier keyword HALF-LIFE: used to explain to which nucleus a half-life value given in the COMMON or DATA section refers. The coded information contains the data-heading keyword used and the relevant nucleus.

● Example:

```
BIB
REACTION ((Z-S-A-M1(N,G)Z-S-A'-M,SIG)/
           (Z-S-A-M1(N,G)Z-S-A'-G,,SIG))
HALF-LIFE (HL1,Z-S-A-M1)
           (HL2,Z-S-A'-M)
           (HL3,Z-S-A'-G)
ENDBIB
COMMON
HL1      HL1-ERR    HL2        HL2-ERR    HL3        HL3-ERR
MIN      MIN        YR         YR        HR         HR
...
ENDCOMMON
```

LEXFOR H.1

HALF-LIVES

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If more than one half-life is given, the relevant nuclei must be coded under this keyword. If only one half-life value is given under the data heading HL with no explanation, then it refers to the half-life of the residual nucleus.

The free text must include the source of the half-life value.

See EXFOR 5.4 for the repetition of the data heading HL in coding half lives in different units.

July 1988

HISTORY

HISTORY

The information-identifier keyword HISTORY is used to document the chronological handling of the work within a data center. The coded information consists of a date and a one-character code, and is followed by free text. (See EXFOR 8.H.1 for coding details).

In particular, important corrections or revisions to an entry or subentry must be documented under HISTORY. Such important alterations are flagged with the code 'A' following the date. The purpose of this flag is to automate, as far as possible, follow-up actions resulting from the alteration, such as updating an index, or informing data users who have received an earlier version.

The following items are considered sufficiently important to be flagged with 'A':

- any change in the numbers given under COMMON or DATA
- any change in the meaning of these numbers (e.g., due to change of reaction, units, the reaction under MONITOR, etc.)
- any other change which the compiler considers important enough that earlier recipients of the entry should be informed.

Less important changes which the compiler wishes to document may be referenced flagged by the code 'U'.

Note: Compilers are urged to document all changes under HISTORY.

Examples of possible entries under the HISTORY keyword

- (671119R) Data received from author on tape
- (680220L) Data entered into library
- (690411C)
- (691015R) Data on tape ND 1234 from Ribon.
- (691223) Proof copy sent to author
- (701003T) Data converted from SCISRS-I, and checked for agreement with table 3 in Phys. Rev. 58, p. 78
- (721130A) Some mispunches in data table corrected
- (721130U) Spelling error in BIB corrected

Notes: For data converted from SCISRS-I or NEUDATA compare also under STATUS.

The origin of the numerical data may be given in free text under this keyword (see use of code R in the above examples) or under the keyword STATUS.

The rules concerning BIB information apply to HISTORY, i.e., an entry under HISTORY in subentry 1 applies to all other subentries and should not be repeated.

July 1988

INCIDENT-PROJECTILE

Incident-Projectile Energy

The energy of the incident projectile is entered in the COMMON or DATA section under the appropriate data-heading keyword (i.e., a data-heading keyword from Dictionary 24 having an A in column 88).

Compare: Secondary Particles, Secondary Energy.

The wave-length of an incident neutron corresponds to the neutron energy:

$E(\text{eV}) = \frac{81.8}{(\lambda/\text{\AA})^2}$	<u>λ (Angstrom)</u>	<u>$E(\text{eV})$</u>
	1.	81.8
	1.8	25.3
	2.	20.5
	4.	5.1
	6.	2.3
	10.	0.8

The wave-length of the incident neutron is entered under the data-heading keyword EN with units ANGSTROM.

Note: If, for whatever reason, the compiler converts the wave-length to neutron energy, this should be noted in the BIB section.

For data are averaged over an incident-neutron spectrum, see under Spectrum Average for energy specification.

Information on the characteristics of the resolution and the spectrum of the incident-projectile beam is entered in free text under the keyword INC-SPECT. See EXFOR 8.I.1.

Nuclear Quantities

No incident energy is entered for nuclear quantities, i.e., data specified by REACTION SF2 (incident projectile) = 0 (zero).

For nuclear properties such as the Nuclear Temperature, for which the incident-projectile energy is not quite irrelevant, the incident-projectile energy may be given in free text but should not be coded under EN.

Inelastic Scattering

See also Scattering

Definition: Two-body interaction in which the incident projectile re-emerges with an energy less than its' initial energy by the amount of energy deposited in the target nucleus. The residual nucleus is left in an excited state which then decays, primarily, by γ -ray emission.

Note: The term "inelastic scattering", as used here, covers only inelastic nuclear scattering. Slow-neutron inelastic scattering, where molecular and/or crystalline forces are involved, is called "thermal scattering", see Thermal Neutron Scattering.

Method of Measurement

Inelastic scattering may be measured by detecting the inelastically scattered particle or by detecting the de-excitation γ radiation. Due to γ -ray cascades, the production of a specific γ -ray may differ from the excitation of its state of origin. They will be equal, however, if γ -ray cascades to and from the level can be excluded.

REACTION Coding: INL in SF3 (Process).

For inelastic γ emission, 'G' is coded in SF7 (Particle considered).

For partial reactions due to the excitation of a discrete level or the production of a specific γ ray, the code 'PAR' is entered into SF5 (Branch).

For the excitation of a discrete level or group of levels, the level energy or excitation energy must be given under the data-heading keyword E-LVL or E-EXC.

For the production of a discrete inelastic scattering cascade γ or range of γ 's, the γ -ray energy must be given under the data-heading keyword E.

See EXFOR 5.4 for the coding of two or more unresolved levels.

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INELASTIC

Examples:

- | | |
|--------------------------------|---|
| (....(...,INL).....,SIG) | total inelastic-scattering cross section |
| (....(...,INL).....,SIG,G) | total inelastic γ -emission cross section
(\geq inelastic-scattering cross section) |
| (....(...,INL).....,PAR,SIG) | partial inelastic-scattering cross section for
the excitation of a discrete level or range of levels |
| (....(...,INL).....,PAR,SIG,G) | partial cross section for the production of a
discrete inelastic γ or range of γ 's |
| (....(...,INL).....,DA) | angular distribution of inelastically scattered
particles |
| (....(...,INL).....,DA,G) | angular distribution of inelastic γ 's |
| (....(...,INL).....,DE) | energy distribution of inelastically scattered
particles |
| (....(...,INL).....,DE,G) | energy spectrum of inelastic γ 's |
| (....(...,INL).....,DA/DE) | double differential inelastic-scattering cross
section |
| (....(...,INL+F).....,SIG) | inelastic-scattering cross section to a
fission isomer |

LEXFOR 1.3

INSTITUTE

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Institute

The laboratory, institute or university at which the experiment was performed, or with which the author is affiliated, is entered in coded form under the information-identifier keyword INSTITUTE. More than one institution may be entered for a given work. (See EXFOR 8.I.1 for coding details).

The institution to be entered first is, in general, the one containing the facility. Exceptions are:

- a. If an itinerant group uses the facility of another institution, the institution of the itinerant group should be given first;
- b. In an ambiguous case, that institution from which one is most likely to obtain further information on the experiment should be entered.

Compiling Responsibility

For neutron data, the first digit of the institute code determines the center responsible for compiling the data. If two institutions of different service areas are involved, the institute to be coded first according to above rules, shall determine the center responsible.

If a publication reports the results of different experiments, done at different laboratories, or, of data measured at one laboratory and, subsequently, analyzed at another laboratory, and the laboratories are in different service areas, the results should be compiled in separate entries by the center responsible for each institute. The entries may be linked using the STATUS code 'COREL', see STATUS.

The centers involved must inform each other of their intentions to code the work in order to avoid duplication.

July 1988

INTERDEPENDENT DATA

Interdependent data

Data that have been measured by the same technique, have certain systematic error sources in common and are, therefore, interdependent; their errors are correlated.

Examples:

1. $\bar{\nu}$ for ^{233}U and ^{236}U , both measured in the same manganese bath.
2. Absorption, $\bar{\nu}$ and α all obtained simultaneously in the same experiment (Cabell, AERE-R-5874,68).

Error correlations must be considered carefully by evaluators. Therefore, the compiler may enter all required information on common error sources and cross-references between interdependent data sets or subentries. This is particularly worthwhile in the case of private communications; in other cases, evaluators would rather use published references.

Different results for the same quantity obtained in the same experiment by two different methods of analysis may be coded in the same subentry, see EXFOR 6.4.

Such data may also be entered in separate subentries, in which case, the subentries should be linked to each other using STATUS code 'COREL'. (See EXFOR 8.S.I for coding details).

Isomeric States

Definition: An isomeric state is defined as a long-lived energy state, where long-lived is, generally, accepted as having a measurable half-life (i.e., greater than $\sim 10^{-5}$ sec).

For practical applications, a Metastable state is defined in EXFOR as an energy state having a half-life of the order of 0.1 milliseconds or longer.

The term isomeric states refers to the ground and known metastable states.

Coding: Where a nucleus has a known metastable state, the isomeric states are indicated by an isomer code following the isotope code, e.g., 95-AM-242-M1. (See EXFOR 8.3 for a complete list of isomer codes.)

Note: The isomer code 'G' is not used in SF1 of the REACTION string. The nucleus in the ground state is coded without an isomer code.

The assignment of isomeric states for a given nucleus may vary in the literature according to the growing knowledge of a particular nucleus. In order to define an isomeric state uniquely, at least the half-life for the isomer must be coded (see Decay Data and Half Lives). Any other information about its decay properties, if given by the author, should be included under the keyword DECAY-DATA.

Partial reactions leading to isomeric states

Partial reactions leading to isomeric states are coded by entering the isomer code in REACTION SF4. Sums and ratios are given algebraically (see EXFOR 8.R.6).

Examples: (.....(.....)Z-S-A-M1,,SIG)
(.....(.....)Z-S-A-M/G,,SIG/RAT)
(.....(.....)Z-S-A-M1+M2,,SIG)

Note: Isomer extensions are used in SF4 only for partial reactions; they must not be used when the total reaction cross section is measured. Consequently, the extension 'G+M' should never be used.

When nuclei are coded within a data table under the data headings ELEMENT and MASS, using the variable nucleus formalism, the isomer is coded using the data heading ISOMER and numerical isomer codes as defined on EXFOR 8.6, Variable Nucleus and 8.R.7. These are linked to the decay information by the use of decay flags (see Flags).

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ISOMERIC STATES

Uncertain Isomeric Contributions

Sometimes experimental data cannot be accurately assigned to specific isomeric states. If the cross section for the isomeric state specified was measured, and partial feeding from a metastable state via isomeric transition may be included, either because the isomeric state decays only partially by isomeric transition, or because its half-life is long in comparison with the lower isomeric state measured, one of the branch codes following (REACTION SF5) should be used.

M+ - Including formation via partial isomeric transition

M- - Excluding formation via partial isomeric transition

(M) - Uncertain whether formation via partial isomeric transition is included

Note: These codes are used only for partial feeding from a higher isomeric state. Where 100% of the isomeric decay is included, the sum reaction should be coded.

See also Cross Sections.

July 1988

LIGHT-NUCLEI

Light-Nuclei Reactions ($Z \leq 6$)

The light-nuclei reactions require special care, because many different notations exist. For example, the notations



may all describe the identical reaction, $\text{Li}(n,nd)\alpha$.

In EXFOR, data retrievals for light-nuclei reactions would be rather difficult if the notations for these reactions were not standardized. This is easily solved using the following rule: the heaviest of the reaction products is defined as the residual nucleus, and the remaining reaction products are sorted as given on EXFOR 8.R.3 - 8.R.5.

In angular or energy distributions the particle considered must be given in REACTION SF7 when not self-evident. See Particles.

Example: In the reaction $^6\text{Li}(n,2np)^4\text{He}$, the angular distribution:

of the neutrons:	(3-LI-6(N,2N+P)2-HE-4,,DA,,N)
of the protons:	(3-LI-6(N,2N+P)2-HE-4,,DA,,P)
of the alphas:	(3-LI-6(N,2N+P)2-HE-4,,DA,,A)

To aid the compiler, the following table lists all possible light-nuclei reactions, together with their thresholds and REACTION codes. The threshold energies were taken from reference 1. Note that the table gives only the end products and that in some cases competing reactions exist that lead to the same end products.

No REACTION codes other than those listed on the following pages should be used in EXFOR for the light-nuclei reactions. In addition to the processes listed, only scattering processes as well as sum cross sections, such as absorption, nonelastic, charged-particles emission, etc., are defined for these nuclei.

Reference

R. J. Howerton, et al., *Thresholds of Nuclear Reactions*, UCRL-14000, (1964)

REACTION	Threshold (MeV)	REACTION	Comments
H(n, γ)D	0	1-H-1(N,G)1-H-2	
D(n, γ)T	0	1-H-2(N,G)1-H-3	
D(n,2np)	3.34	1-H-2(N,2N)1-H-1	
T(n,2nd)	8.35	1-H-3(N,2N)1-H-2	
T(n,3np)	11.31	1-H-3(N,3N)1-H-1	
³ He(n, γ) ⁴ He	0	2-HE-3(N,G)2-HE-4	
³ He(n,pt)	0	2-HE-3(N,P)1-H-3	
³ He(n,2d)	4.35	2-HE-3(N,D)1-H-2	
³ He(n,npd)	7.32	2-HE-3(N,N+P)1-H-2	
³ He(n,2n2p)	\leq 14.	2-HE-3(N,2N+P)1-H-1	
⁴ He(n,dt)	21.97	2-HE-4(N,D)1-H-3	
⁴ He(n,npt)	24.76	2-HE-4(N,N+P)1-H-3	
⁴ He(n,2n) ³ He	25.72	2-HE-4(N,2N)2-HE-3	
⁴ He(n,n2d)	29.80	2-HE-4(N,N+D)1-H-2	
⁶ Li(n, γ) ⁷ Li	0	3-LI-6(N,G)3-LI-7	
⁶ Li(n,t α)	0	3-LI-6(N,T)2-HE-4	
⁶ Li(n,nd α)	1.71	3-LI-6(N,N+D)2-HE-4	
⁶ Li(n,p) ⁶ He	3.19	3-LI-6(N,P)2-HE-6	
⁶ Li(n,2np α)	5.43	3-LI-6(N,2N+P)2-HE-4	
⁶ Li(n,nt) ³ He	18.42	3-LI-6(N,N+T)2-HE-3	

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LIGHT-NUCLEI

REACTION	Threshold (MeV)	REACTION	Comments
$^7\text{Li}(\text{n},\gamma)^8\text{Li}$	0	3-LI-7(N,G)3-LI-8	,
$^7\text{Li}(\text{n},\text{n}+\alpha)$	2.81	$3\text{-LI-7(N,N+T)2-HE-4}$	via ^3He , ^7Li , ^4H or three-particles break-up (NP/A, 98, 305, 67)
$^7\text{Li}(\text{n},2\text{n})^6\text{Li}$	8.29	$3\text{-LI-7(N,2N)3-LI-6}$	
$^7\text{Li}(\text{n},\text{d})^6\text{He}$	8.87	3-LI-7(N,D)2-HE-6	
$^7\text{Li}(\text{n},2\text{n}\alpha)$	11.06	$3\text{-LI-7(N,2N+D)2-HE-4}$	
$^7\text{Li}(\text{n},\text{np})^6\text{He}$	11.41	$3\text{-LI-7(N,N+P)2-HE-6}$	
$^7\text{Li}(\text{n},3\text{n}\alpha)$	14.76	$3\text{-LI-7(N,3N+P)2-HE-4}$	including search for bound trineutron
$^9\text{Be}(\text{n},\gamma)^{10}\text{Be}$	0	$4\text{-BE-9(N,G)4-BE-10}$	
$^9\text{Be}(\text{n},\alpha)^6\text{He}$	0.67	4-BE-9(N,A)2-HE-6	
$^9\text{Be}(\text{n},2\text{n}2\alpha)$	1.85	$4\text{-BE-9(N,2N+A)2-HE-4}$	
$^9\text{Be}(\text{n},\text{t})^7\text{Li}$	11.59	4-BE-9(N,T)3-LI-7	
$^9\text{Be}(\text{n},\text{p})^6\text{Li}$	14.74	4-BE-9(N,P)3-LI-9	
$^9\text{Be}(\text{n},\text{d})^8\text{Li}$	16.28	4-BE-9(N,D)3-LI-8	
$^9\text{Be}(\text{n},\text{n d})^7\text{Li}$	18.54	$4\text{-BE-9(N,N+D)3-LI-7}$	
$^9\text{Be}(\text{n},\text{np})^6\text{Li}$	18.76	$4\text{-BE-9(N,N+P)3-LI-8}$	
$^9\text{Be}(\text{n},\text{n t})^8\text{Li}$	19.66	$4\text{-BE-9(N,N+T)3-LI-6}$	
$^9\text{Be}(\text{n},3\text{n})^7\text{Be}$	22.85	$4\text{-BE-9(N,3..,-BE-7)}$	
$^9\text{Be}(\text{n},\text{n }^3\text{He})^6\text{He}$	23.54	$4\text{-BE-9(N,N+HE3)2-HE-6}$	

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LIGHT-NUCLEI

REACTION	Threshold (MeV)	REACTION	Comments
$^{10}\text{B}(\text{n},\gamma)^{11}\text{B}$	0	5-B-10(N,G)5-B-11	
$^{10}\text{B}(\text{n},\text{p})^{10}\text{Be}$	0	5-B-10(N,P)4-BE-10	
$^{10}\text{B}(\text{n},\text{t}\,2\alpha)$	0	5-B-10(N,T+A)2-HE-4	via $^6\text{Be},^7\text{Li}$ (2nd exc.st) three-particle break-up
$^{10}\text{B}(\text{n},\alpha)^7\text{Li}$	0	5-B-10(N,A)3-LI-7	to ground state and 1st exc. state; (2nd exc. state decays to t+α)
$^{10}\text{B}(\text{n},\text{d})^9\text{Be}$	4.79	5-B-10(N,D)4-BE-9	
$^{10}\text{B}(\text{n},\text{n}\alpha)^6\text{Li}$	4.90	5-B-10(N,N+A)3-LI-8	
$^{10}\text{B}(\text{n},\text{n}\,\text{d}\,2\alpha)$	6.62	5-B-10(N,N+D+A)2-HE-4	
$^{10}\text{B}(\text{n},\text{n}\,\text{p})^6\text{Be}$	7.24	5-B-10(N,N+P)4-BE-9	
$^{10}\text{B}(\text{n},\text{n}\,\text{p}\,2\alpha)$	9.28	5-B-10(N,2N+P+A)2-HE-4	
$^{10}\text{B}(\text{n},^3\text{He})^8\text{Li}$	17.32	5-B-10(N,HE3)3-LI-8	
$^{10}\text{B}(\text{n},\text{n}^3\text{He})^7\text{Li}$	19.56	5-B-10(N,N+HE3)3-LI-7	
$^{10}\text{B}(\text{n},\text{n}\,\text{t})^7\text{Be}$	20.54	5-B-10(N,N+T)4-BE-7	
$^{10}\text{B}(\text{n},3\text{n})^8\text{B}$	29.72	5-B-10(N,3N)5-B-8	
$^{11}\text{B}(\text{n},\alpha)^6\text{Li}$	7.23	5-B-11(N,A)3-LI-8	
$^{11}\text{B}(\text{n},\text{n}\alpha)^7\text{Li}$	9.44	5-B-11(N,N+A)3-LI-7	
$^{11}\text{B}(\text{n},\text{d})^{10}\text{Be}$	9.82	5-B-11(N,D)4-BE-10	
$^{11}\text{B}(\text{n},\text{t})^9\text{Be}$	10.42	5-B-11(N,T)4-BE-9	
$^{11}\text{B}(\text{n},\text{p})^{11}\text{Be}$	11.70	5-B-11(N,P)4-BE-11	
$^{11}\text{B}(\text{n},\text{n}\,\text{p})^{10}\text{Be}$	12.25	5-B-11(N,N+P)4-BE-10	
$^{11}\text{B}(\text{n},\text{n}\,\text{t}\,2\alpha)$	12.25	5-B-11(N,N+T+A)2-HE-4	

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LIGHT-NUCLEI

Reaction	Threshold (MeV)	REACTION	Comments
$^{11}\text{B}(\text{n},2\text{n})^{10}\text{B}$	12.50	5-B-11(N,2N)5-B-10	
$^{11}\text{B}(\text{n},\text{nd})^9\text{Be}$	17.25	5-B-11(N,N+D)4-BE-9	
$^{11}\text{B}(\text{n},3\text{n}\text{p}2\alpha)$	21.70	5-B-11(N,3N+P+A)2-HE-4	
$^{11}\text{B}(\text{n},^3\text{He})^9\text{Li}$	25.73	5-B-11(N,HE3)3-LI-9	
$^{11}\text{B}(\text{n},\text{n}^3\text{He})^8\text{Li}$	29.68	5-B-11(N,N+HE3)3-LI-8	
$^{12}\text{C}(\text{n},\gamma)^{13}\text{C}$	0	6-C-12(N,G)6-C-13	
$^{12}\text{C}(\text{n},\alpha)^9\text{Be}$	6.17	6-C-12(N,A)4-BE-9	
$^{12}\text{C}(\text{n},\text{n}3\alpha)$	7.98	6-C-12(N,N+2A)2-HE-4	
$^{12}\text{C}(\text{n},\text{p})^{12}\text{B}$	13.63	6-C-12(N,P)5-B-12	
$^{12}\text{C}(\text{n},\text{d})^{11}\text{B}$	14.87	6-C-12(N,D)5-B-11	
$^{12}\text{C}(\text{n},\text{np})^{11}\text{B}$	17.29	6-C-12(N,N+P)5-B-11	
$^{12}\text{C}(\text{n},\text{t})^{10}\text{B}$	20.50	6-C-12(N,T)5-B-10	
$^{12}\text{C}(\text{n},2\text{n})^{11}\text{C}$	20.28	6-C-12(N,2N)6-C-11	
$^{12}\text{C}(\text{n},^3\text{He})^{10}\text{Be}$	21.09	6-C-12(N,HE3)4-BE-10	
$^{12}\text{C}(\text{n},\text{n}^3\text{He})^9\text{Be}$	28.47	6-C-12(N,N+HE3)4-BE-9	
$^{12}\text{C}(\text{n},\text{nd})^{10}\text{B}$	27.28	6-C-12(N,N+D)5-B-10	
$^{12}\text{C}(\text{n},\text{npt}2\alpha)$	29.65	6-C-12(N,N+P+T+A)2-HE-4	
$^{12}\text{C}(\text{n},3\text{n})^{10}\text{C}$	34.47	6-C-12(N,3N)6-C-10	

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MEASUREMENT

Measurement Techniques

Physics information on experimental measurement techniques is entered under several keywords (see EXFOR Chapter 8 for coding rules).

*METHOD: describes the experimental technique(s) employed in the experiment, e.g., activation.

Information which can be entered under one of the more specific keywords, below, should not be entered under METHOD.

*FACILITY: used to identify the main apparatus or machine used in the experiment, e.g., reactor or cyclotron.

When there is more than one institute code for an entry, the code for the institute at which the facility is located should be entered following the facility code, if known.

INC-SOURCE: used to enter the source of the incident-projectile beam used in the experiment.

This keyword is used exclusively for the nuclear reaction used as an incident-projectile source. The apparatus in which this reaction took place is entered under FACILITY, and the quality of the resulting particle beam is entered under INC-SPECT (see Incident-Projectile Energy). (For certain cases, e.g., reactor neutrons used as source, the use of the keywords INC-SOURCE and FACILITY is somewhat overlapping.)

*SAMPLE: used to identify information on sample material characteristics.

*DETECTOR: used to enter information on detectors used in the measurement

Detectors used as monitors are also entered under this keyword.

For particles detected and the keyword PART-DET see Particles; for their energies and the keyword EN-SEC, see Secondary Energy.

*Note: One of the following keywords must be present: FACILITY, DETECTOR, ANALYSIS, or METHOD. It is advisable that all four of these keywords be given, except when not relevant. For example, FACILITY is not relevant with respect to spontaneous fission.

MISCELLANEOUS

July 1988

Miscellaneous

A data field with supplementary information for which no data-heading keyword has been defined, is given using the data heading MISC (or MISC1, MISC2, etc., if more than one is given). Such data are usually entered in the DATA section, but may also be entered in the COMMON section, although the latter is not recommended.

The meaning of these data headings is explained in the BIB section under the keyword MISC-COL. In order to link explanations when more than one miscellaneous data field is given, the data heading is given as a code under MISC-COL, followed by the free text explanation. This formalism is the same as for error fields. See EXFOR 8.M.1 for coding example.

If the information under the data heading MISC is given in units for which no data-unit keyword exists, the data unit SEE TEXT is entered and the explanation is given in free text under the keyword MISC-COL. (This is to avoid introducing data-unit keywords which are unlikely to occur often.) The data unit SEE TEXT must not be used for an independent variable or for a DATA field.

For REACTION modifier 'MSC', see General Quantity Modifiers.

Multilevel Resonance Parameters

See also Single-Level Resonance Parameters, Quantum Numbers.

In analyzing resonance structure for fissile nuclides, it is necessary to use a multilevel formalism to account for interference effects from neighboring resonances and also those due to distant resonances.

Three different multilevel formalisms are generally used: Vogt, Reich-Moore and Adler-Adler. All three are derived from the R-matrix theory of Wigner and Eisenbud.

Reich-Moore and Vogt Resonance Parameters

In Vogt and Reich-Moore formalisms, cross sections are expressed in terms of R-matrix level parameters. Cross sections due to resonance levels of the same spin and parity are related to the elements U_{nn} of the collision matrix by relations of the form:

$$\text{Total cross section: } \sigma_{nT} = 2\pi\lambda_n^2 g \operatorname{Re}(1-U_{nn})$$

$$\text{Other cross sections: } \sigma_{nr} = \pi\lambda_n^2 g |\delta_{nr} - U_{nr}|^2$$

where: λ_n = neutron wave length in the center-of-mass system

g = statistical weight factor

δ_{nr} = Kronecker delta

and Re stands for the real part of the expression in parentheses.

The collision matrix U is related to the nuclear level properties by means of the derivative matrix R , in the following form:

$$R = \sum_{\lambda} \frac{\vec{\gamma}_{\lambda} \times \vec{\gamma}_{\lambda}}{E_{\gamma} - E}$$

where: $\vec{\gamma}_{\lambda} \times \vec{\gamma}_{\lambda}$ is the direct product of the vectors γ_{λ} ; λ refers to levels.
The diagonal elements of γ_{λ} are reduced width parameters.

The collision matrix U can be related to the derivative matrix R through the matrix:

$$(1-RL^0)^{-1}R$$

where: $L^0 = L-B$; B is a constant diagonal matrix; L is a complex matrix with elements being a function of momentum l .

Both the Vogt and the Reich-Moore formulas require that off-diagonal matrix elements describing interference in the radiative capture channels must vanish.

The Reich-Moore formula involves summation over levels and a matrix inversion with respect to channels.

The matrix $(I - RL)$ is partitioned into a 2×2 matrix, each element of which leads to a definition on the matrix

$$K_{cc'} = \frac{1}{2} \sum_{\lambda} \frac{\Gamma_{\lambda c}^{1/2} \Gamma_{\lambda c'}^{1/2}}{E_{\lambda} - E - \frac{1}{2} \Gamma_{\lambda} \gamma}$$

The fission cross section can be expressed by:

$$\sigma_{nf} = \sum_{c=2}^{l+1} 4\pi \lambda_n^2 g |(1-K)_{nc}^{-1}|^2$$

where l = number of fission channels

Similar expressions are obtained for other partial cross sections.

Reich-Moore Resonance Parameters are entered under the quantity codes:

(N,0),EN	E_{λ}	Resonance energy; units of energy (e.g., eV)
(N,TOT),WID,,RM	Γ_{λ}	Total width; units of energy
(N,G),WID,,RM	$\Gamma_{\lambda\gamma}$	Capture width; units of energy (including all primary gamma decays not followed by a neutron or charged-particle emission).
(N,F),1,WID,,RM	$\Gamma_{\lambda r_1}$	Fission width for channel 1; units of energy
(N,F),2,WID,,RM	$\Gamma_{\lambda r_2}$	Fission width for channel 2; units of energy
(N,F),WID,,RM	$\Gamma_{\lambda f}$	Total fission width = $ \Gamma_{\lambda r_1} + \Gamma_{\lambda r_2} $
(N,EL),WID,,RM	$\Gamma_{\lambda n}$	Neutron width; units of energy
(N,EL),WID/RED,,RM	$\Gamma_{\lambda n}^*$	Reduced neutron width; units of energy where $*$ = orbital angular momentum

* The relative phases of $\Gamma_{\lambda r_1}$ and $\Gamma_{\lambda r_2}$ are either 0 or 180 degrees; therefore, the parameter values are given with either a positive or negative sign.

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MULTILEVEL

The Vogt Formula involves summation of channels and matrix inversion with respect to levels, and requires that level interference in the neutron channel be equal to zero.

The inversion of the channel matrix ($I - RL^0$) leads to the definition of the level matrix A, which is given by:

$$(A^{-1})_{\lambda\lambda'} = (E_\lambda - E) \delta_{\lambda\lambda'} - \frac{1}{2} \sum_c (\Gamma_{\lambda c})^4 (\Gamma_{\lambda' c})^4$$

where c is the channel number.

A reduced neutron width for an s-wave resonance is defined as:

$$\Gamma_{\lambda n}^0 = 2g\Gamma_{\lambda n} E^{-4}$$

Vogt Resonance Parameters are entered under the quantity codes:

(N,0),EN,,VGT	E_λ	Resonance energy; units of energy (e.g., eV)
(N,TOT),WID,,VGT	Γ_λ	Total width; units of energy
(N,G),WID,,VGT	$\Gamma_{\lambda\gamma}$	Capture width; units of energy (including all primary gamma decays not followed by neutron or charged-particle emission)
(N,F),1,WID,,VGT	$\Gamma_{\lambda f_1}$	Fission width for channel 1; units of energy
(N,F),2,WID,,VGT	$\Gamma_{\lambda f_2}$	Fission width for channel 2; units of energy
(N,EL),WID,,VGT	$\Gamma_{\lambda n}$	Neutron width; units of energy
(N,EL),WID/RED	$\Gamma_{\lambda n}^t$	Reduced neutron width; units of energy * sqrt of energy, where t = orbital angular momentum
(N,0),PHS,,VGT	$\theta_{\lambda_i \lambda_j}$	Relative phase of channel λ_i and λ_j ; units of angle

Adler-Adler Resonance Parameters

The Adler-Adler formalism is a generalized Kapur-Peterls formalism in which cross sections are given in terms of Kapur-Peterls poles μ and ν , and residues G and H.

The resonance part of the reaction cross section (without Doppler Broadening) in the Adler-Adler formalism is given by:

$$\sigma\lambda(E) = \frac{1}{\sqrt{E}} \sum_k \frac{G_{rk} \nu_k + H_{rk}(\mu_k - E)}{(\mu_k - E)^2 + \nu_k^2}$$

where: G, H, μ and ν are treated as constants, since they have only a weak energy dependence.

Adler-Adler coefficients are entered under the quantity codes:

(N,0),EN,,AA	μ_k	Resonance energy; units of energy (e.g., eV)
(N,TOT),WID,,AA	ν_k	Corresponding to half the total width; units of energy
(N,F),AG,,AA	$G_{\lambda f}$	Fission symmetry coefficient; in B^*EV^*RT-EV
(N,F),AH,,AA	$H_{\lambda f}$	Fission asymmetry coefficient; in B^*EV^*RT-EV
(N,G),AG,,AA	$G_{\lambda \gamma}$	Capture symmetry coefficient; in B^*EV^*RT-EV
(N,G),AH,,AA	$H_{\lambda \gamma}$	Capture asymmetry coefficient; in B^*EV^*RT-EV
(N,TOT),AG,,AA	G_λ	Total symmetry coefficient; in B^*EV^*RT-EV
(N,TOT),AH,,AA	H_λ	Total asymmetry coefficient; in B^*EV^*RT-EV

The parameters are functions of μ which corresponds to the resonance energy. Since this representation of the energy causes difficulty in a data retrieval by energy, the energy limits of the Adler-Adler fit must be entered explicitly in the COMMON section under the data-heading keywords EN-MIN and EN-MAX.

July 1988

MULTILEVEL

R-Matrix Resonance Parameters

The R-Matrix reduced width is given by:

$$\Gamma = 2 \gamma^2 P$$

where: P = penetrability

These may be entered under the Reaction keyword using the modifier code 'RMT' in SF8.

For further details see:

M.S.Moore, IN-1222, p. 199 (1969)

D.B.Adler, F.T.Adler, ANL-6792, p. 695 (1963)

E.Vogt, *Phys.Rev.* 112, 203 (1958)

C.W.Reich, M.Moore, *Phys.Rev.* 111, 929 (1958)

LEXFOR M.7

MULTIPLE REACTION

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Multiple Reaction Formalism

At present, the following classes of data may be coded using *Multiple Reaction Formalism* (compare EXFOR 8.R.10).

1. Resonance parameters of the same isotope;

Example: REACTION 1(.....(N,O),,EN)
2(.....(N,EL),,WID)

2. Multiple representations of the same data;

When one of the reactions given has been deduced from the other (e.g., if absolute $^{236}\text{U}\sigma_{n,f}$ data were deduced from relative data using standard reference data from another author), the appropriate status code is entered with the relevant pointer.

Example: REACTION 1((92-U-235(N,F),,SIG)/(94-PU-239(N,F),,SIG))
2(92-U-235(N,F),,SIG)
STATUS 2(DEP,12345008) free text.

Explanation in free text may be given following the status code and/or following the reaction code.

3. Partial cross sections of the sum reaction (i.e., for the REACTION keyword, all subfields except SF5 (Branch) are equal).

- a) isomer data (branches, ratios, etc.) of the same reactions.
- b) compound nucleus and direct interaction parts for the same reactions.
- c) high-energy fission and spallation parts for the same reactions.
- d) binary and ternary parts for fission measured.
- e) light and heavy fragment parts for a given fission yield.

Example: REACTION M(39-Y-89(N,INL)39-Y-89-M,,SIG)
G(39-Y-89(N,INL)39-Y-89-G,,SIG)

4. Data measured simultaneously for the production of specific particles or nuclides where the author has assigned values to given reactions based on systematics or theoretical considerations.

- Examples:*
- 1.) (p,2n)
(p,3n)
(p,4n)
 - 2.) (n,a)
(n,na)

Note: Where only the product nucleus is variable for a given reaction (i.e., for the REACTION keyword, SF1, SF2 and SF3 are constant) the *Variable Nucleus Formalism* is used (see EXFOR 8.0).

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MULTIPLE REACTION

5. Data for the same reaction obtained by different types of analysis on the same experimental data; in this case the code must be repeated for each analysis.

Example: REACTION 1(79-AU-197(N,G)79-AU-198,,SIG)
 2(79-AU-197(N,G)79-AU-198,,SIG)
DETECTOR 1(NAICR)
 2(GELI)

MULTIPLICITY

July 1988

Multiplicity

Definition: Particle yield per event.

REACTION Coding: MLT in REACTION SF6.

Examples:

(.....(P,A).....,MLT,G) γ yield from (p, α) reaction

(.....(N,X)0-G-0.,MLT) γ yield from all neutron-induced reactions

Partial Multiplicity

In many cases the experimental arrangement will be such that not all of the particles produced will be detected. In such cases the branch code PAR must be used in REACTION SF5.

The most common experimental occurrence of this will be limits on the energies of the particle detected.

Authors will also often deduce the multiplicities as a function of spin or momentum transfer; these deduced results should not be coded.

Neutron Multiplicity

The neutron multiplicity should be coded as given above only for those reactions for which special codes do not exist. For neutron multiplicity from neutron-induced reactions or from spontaneous fission, see Neutron Yield.

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NEUTRON YIELD

Neutron Yield

The following special terms are defined for neutron yields from neutron-induced reactions or from spontaneous fission. For other neutron yields, see Multiplicity.

Nu-bar ($\bar{\nu}$)

Definition: Average number of fission neutrons emitted per fission event.

REACTION Coding:

(.....(N,F),,NU)	neutron-induced fission $\bar{\nu}$
(.....(0,F),PR,NU)	spontaneous fission prompt $\bar{\nu}$
(.....(N,F),DL,NU)	neutron-induced fission delayed $\bar{\nu}$
(.....(N,F+XN),,NU)	*probability for the emission of x neutrons from neutron-induced fission

Sum rule: total $\bar{\nu}$ = prompt plus delayed $\bar{\nu}$.

See also Delayed Fission Neutrons

Eta (η)

Definition: The average neutron yield per nonelastic event.

For the thermally fissile isotopes, where fission and capture are, up to a certain threshold, the only nonelastic processes, μ is defined as average neutron yield per absorption.

REACTION Coding:

in general:	(N,NON),,ETA
for thermally fissile nuclei:	(N,ABS),,ETA
μ at resonance:	(N,ABS),,ETA,,RES

In the case of thermal neutron fission, μ is related to $\bar{\nu}$ by:

$$\mu = \nu \frac{\sigma_f}{\sigma_a}$$

For further related quantity codes see Dictionary 36.

*See EXFOR 6.8 for use of variable number of emitted nucleons.

NODATA

July 1988

NODATA

In the following cases NODATA EXFOR entries may be transmitted which do not contain numerical data in the DATA section:

1. Unobtainable data: In the case where a center is aware that data exist, but the center is unable to obtain the data, a NODATA entry should be made in EXFOR to inform the other centers (and their users) of the status of the data. This will eliminate many repeated requests for the same data and needless bookkeeping concerning data which will be entered into the system with extensive delays or not at all. The code 'UNOBT' is entered after the keyword STATUS, followed by free text giving, if known, the approximate date when the data may be released, or the reason the data cannot be obtained.
2. Raw data: Voluminous files of "raw" data may be stored on special archival tapes. A NODATA EXFOR entry is then transmitted, using the keyword STATUS to give a cross-reference to the special archival tape, the approximate number of "raw" data records, and information on how to request the data. A warning may be given in free text that the raw data should be used only after consultation with the author. See Raw Data.

The BIB section of the NODATA entry should be prepared as usual, containing at least the obligatory keywords (see EXFOR 8.4).

The COMMON section should contain minimum and maximum of the incident-projectile energy, if known.

The DATA section is replaced by the system identifier NODATA (see EXFOR 3.9). The system identifier NODATA cannot be used in subentry 001. Thus, an entry always has a minimum of two subentries.

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NONELASTIC

Nonelastic

Definition: The sum of all energetically possible interactions with $Q \leq 0$.
Effectively, the sum of all interactions (total), except elastic scattering.

REACTION Coding: Process code 'NON' in SF3

Example: (....(N,NON),,SIG)

Sum-rules: Nonelastic = Total minus Elastic
= Absorption plus Inelastic.

Note: The nonelastic cross section is a sum cross section and should only
be used when two or more of the relevant interactions are possible.

For average neutron yield per nonelastic process, see Neutron Yield, Eta.

Nuclear Quantities

When a quantity to be coded does not refer to a target nucleus, it is referred to as a nuclear quantity.

These are coded by entering the nucleus to which the data are pertinent in the target nucleus field of the information-identifier keyword REACTION; a zero is entered in SF2 (incident projectile field).

At present, the following nuclear quantities are coded in EXFOR.

Spontaneous fission, see Fission.

Level-Density Parameter: proportional to single-particle level spacing at top of Fermi-sea in the Fermi-gas model of the nucleus, in specified formalism.

REACTION Coding: LDP in SF6 (Parameter).

Example: (....(0,0),,LDP)

Note: For nuclei around A=208, neutron emission spectra can only be interpreted by assuming a variable level-density parameter, i.e., increasing density with increasing excitation energy. Therefore, the incident projectile must be specified in REACTION SF2 and its energy must be coded.

Example: (Z-S-A(N,INL)Z-S-A,,LDP) where, Z-S-A is the target nucleus
The incident-neutron energy is coded, as usual, under the data heading EN.

Nuclear Temperature - from Fermi-gas model of the nucleus.

REACTION Coding: TEM in SF6 (Parameter).

Example: (....(0,0),,TEM)

Spin-cut-off factor

REACTION Coding: SCO in SF6 (Parameter).

Example: (....(0,0),,SCO)

Subentries with nuclear quantities should, if applicable, contain the STATUS code "DEP" with cross reference to the subentry containing the reaction data from which the nuclear quantity was derived.

Example: STATUS (DEP,30343003)

LEXFOR N.4

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PARTIAL REACTIONS

Partial Reactions

Reaction coding: PAR in SF5 (Branch).

There are two types of reaction data which are specified as partial in EXFOR:

1. A partial reaction leaving the residual nuclis (reaction product) in an excited state, excluding isomeric states.

The excited state is defined by specifying one, several or a range of:

- level energies
- excitation energies
- reaction Q-values
- energy gain (primary to secondary particle)
- energy degradation (primary to secondary particle)

The excitation energies are coded in the data table using data headings from Dictionary 24 with the family code E.

When the data is a function of the secondary energy of more than one secondary particle, the particle(s) must be defined under the information-identifier keyword EN-SEC (see EXFOR 8.E.2).

2. Reactions which lead by the same particle sequence to the same reaction products, but through different reaction-decay mechanisms are also considered partial reactions in EXFOR.

Example: (1) $^{12}_{\text{C}}(\text{n},\text{n}')^{12}_{\text{C}} \rightarrow \alpha + ^{8}_{\text{Be}} \rightarrow 2\alpha$
(2) $^{12}_{\text{C}}(\text{n},\text{n}')^{12}_{\text{C}} \rightarrow 3\alpha$

The intermediate states should be specified in the data table and explained under the information-identifier keyword EN-SEC as clearly as possible.

Example: REACTION 1(6-C-12(N,N+2A)2-HE-4,PAR,SIG)
2(6-C-12(N,N+2A)2-HE-4,PAR,SIG)
EN-SEC 1(E-LVL,4-BE-8)
2(E-LVL,6-C-12)

If ratios of partial reactions are given, it is possible that both units of the ratio may have identical codes, both using the code PAR. The explanation should be given in free text.

For other partial reactions due to competing reaction mechanisms, see Reaction Mechanisms.

For partial reactions specified by the sequence of outgoing particles, see Sequence of Outgoing Particles.

For partial reactions to isomeric states, see Isomeric States.

Excitation Function

Definition: The energy dependence of a partial reaction cross section leading to the excitation of a discrete level or to the production of a particular radiation or particle group.

REACTION Coding: PAR in SF5 (Branch)

Example: (....(N,INL)....,PAR,SIG)

The energy must be given in the COMMON or DATA section under a secondary-energy data-heading keyword (Family E).

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PARTICLES

Particles

See also Secondary Particles

Particles participating in a reaction

The incident projectile is coded in REACTION SF2. Particles resulting from the REACTION to be defined are given in SF3 and SF4. See EXFOR 8.R.3-8.R.5 and Sequence of Outgoing Particles/Processes for coding rules.

Particle Considered

The particle considered is assumed to be the particle given in REACTION SF3. If more than one particle is given in REACTION SF3, or if the particle considered is not given in REACTION SF3, and the quantity given is dependent on a specific particle, the particle considered must be entered in REACTION SF7. See EXFOR 8.R.8 for coding rules.

Examples:

(.....(P,P+A).....,PAR,SIG,A) partial cross section for a specific α group.
(.....(N,P)2-HE-4,,DA,A) angular distribution of α particles.

If the code given in REACTION SF3 is a process code, and the reaction refers to a specific particle, the particle considered is determined as follows:

INL: The particle considered is assumed to be the same as the incident projectile. If γ -rays are considered, the code 'G' must be entered in REACTION SF7.

(.....(N,INL).....,DA,G) angular distribution of γ -rays from inelastic neutron scattering.

F: The particle considered is ambiguous and should be entered in REACTION SF7.
(.....(N,F),,DA,,FF) angular distribution of fission fragments.

X: The particle considered is assumed to be the particle for which the production is measured. See Production Cross Sections.

PARTICLES

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Particles/Radiations Detected

Particles actually detected in the experiment may be identified using the keyword PART-DET (see EXFOR 8.P.1 for coding rules). This keyword should be used only in those cases where the particle detected is not obvious from the quantity given (see preceding).

If the particle detected may be attributed to the decay of a specific nucleus, it may be coded using the keyword RAD-DET (see EXFOR 8.R.1 for coding rules.) However, the keyword RAD-DET should not be used to duplicate information also coded under the keyword DECAY-DATA.

The particles detected in a monitor reaction should not be included under the keywords PART-DET or RAD-DET.

See Dictionary 13 for a list of permissible codes.

Distinguish the different codes:

- decay γ -rays	DG
- other γ -rays	G
- decay electrons (β^-)	B-
- decay positrons (β^+)	B+
- internal conversion electrons	ICE
- other electrons	E

Variable number of emitted nucleons

When a mass or element distribution of product nuclei is given and their Z and/or A values act as independent variables, a variable sum of outgoing nucleons may be indicated in REACTION SF3 using the process codes XN, YP or XN+YP. The numerical values of the multiplicity factors X and Y are entered in the DATA table under the data-heading keywords N-OUT and P-OUT, respectively. See EXFOR page 6.8.

This formulation is only permitted if all REACTION subfields except SF3 and SF4 remain unchanged.

This formulation should not be used for frequently occurring reactions such as (n,2n), otherwise, retrievals for such important reactions would become difficult. If data for only a few reactions are given, e.g., (n,2n), (n,3n), etc., the *Multiple Reaction Formalism* should be used instead (see EXFOR 8.R.10 and *Multiple Reaction Formalism*).

The code 'XN' must not be confused with 'neutron emission' (compare Production Cross Sections).

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PARTICLES

Undefined/Defined Reaction Channels

Note: For the present, this formalism is used only for charged particle data.

In some cases a given residual nucleus may be produced by more than one reaction channel, e.g., (P,A) and (P,2N+2P), but only the residual nucleus has been investigated. If it is clear that more than one channel contributes, e.g., for energies well above the threshold for (P,2N+2P), the branch code UND (undefined reaction channel) should be given in REACTION SF5. In this case, the particles coded in SF3 denote only the sum of emitted nucleons, implying that the product nucleus coded in SF4 has been formed via different reaction channels. The reaction is coded as given by the author or by giving only the emitted nucleons.

Example: (....(P,2N+2P)....,UND,SIG)

Where it is not clear whether the reaction channel is undefined or defined, the reaction is coded as specified by the author with the code '(DEF)' in SF5.

Examples: (....(P,A)....,(DEF),SIG)
(....(P,2N+2P)....,(DEF),SIG)

Where the reaction channel is unambiguously defined either by measuring the outgoing particles, or, due to theoretical considerations, the reaction is written as specified by the author and no special code is given in SF5; the codes 'UND' and '(DEF)' are not used.

Free text comments should explain any reasons not explicitly given in the publication, by which the reaction is proven to be defined.

Absence of the codes 'UND' or '(DEF)' gives a positive definition of the reaction coded, stating it to be defined with respect to the reaction channel and the outgoing particles coded in SF3.

Note: The 'undefined' processes X and F are not combined with the branch code 'UND'. In cases where an explicit specification of the number of outgoing nucleons is meaningless (e.g., too many outgoing nucleons, spallation, etc.), the coding:

(....(P,X)...., ,SIG) should be used
rather than (....(P,XN+YP)....,UND,SIG).

Pointers

A pointer is a numeric or alphabetic character used to link pieces of EXFOR information. (See EXFOR 6.1 for details.)

Where feasible, the compiler may choose as pointers meaningful digits or characters. For example, when the pointers refer to an isomeric ratio and the partial isomeric cross sections leading to ground state and metastable states, the characters R, G and M, respectively, may be chosen as pointers. Or, when the pointers refer to the Legendre coefficient numbers 0., 2. and 4., the digits 0, 2 and 4 may be chosen.

Caution to Compilers: Since a pointer links the information given only to other information with the same pointer, or to information with no pointer, only one set of pointers may be used for each data set.

The following is an example of an illegal use of pointers.

```
BIB
REACTION M(79-AU-197(N,G)79-AU-198-M,,SIG)
          G(79-AU-197(N,G)79-AU-198-G,,SIG)
MONITOR 1(29-CU-63(N,2N)29-CU-62,,SIG)
          2(29-CU-65(N,2N)29-CU-64,,SIG)
MONIT-REF 1(LISKIEN+,J,JNE,19,73,65)
          2(POLLEHN,J,ZN/A,16,227,61)
ENDBIB
```

(The monitor data is not linked to either reaction because the pointers are different.)

Pointers should be used carefully and only for those cases specified in EXFOR 6.1 to 6.4.

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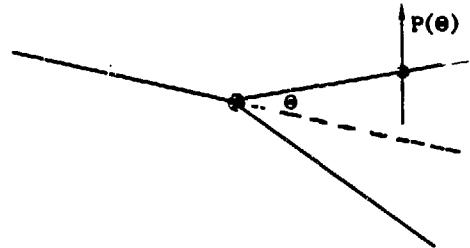
POLARIZATION

Polarization

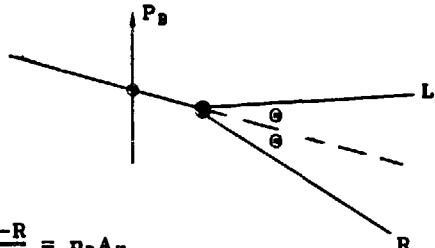
Definitions

The following definitions and coding rules are given for spin- $\frac{1}{2}$ particles. Cartesian notation is used. Definitions will be added for spin-1 particles as the need arises.

Under the influence of a spin-orbit force, an unpolarized beam of particles becomes at least partially polarized (i.e., the particles acquire a preferred spin).



The inverse of this situation is the asymmetric scattering of a polarized beam of particles. The degree of polarization of such a beam may be determined by measuring the left-right asymmetry upon scattering from a target nucleus which plays the role of an Analyzer.



$$e = \frac{L-R}{L+R} = p_B A_Y R$$

where e = asymmetry

p_B = polarization of incident particle beam

A_Y = analyzing power

L, R = intensity of particles scattered right and left in the same plane under the same angle

The principle of Polarization-Asymmetry Equality states that, for time-reversal invariant reactions, the polarization induced in a previously completely unpolarized beam by elastic scattering from spin-zero nuclei is identically equal to the asymmetry ensuing from the scattering of a perfectly polarized beam under the same conditions.

Jul

Basel (sign) Convention for spin-½ Particles

Dep

In nuclear interactions the positive polarization of particles with spin-½ is taken in the direction of the vector product $k_i \cdot k_o$, where k_i and k_o are circular wave vectors of the incoming and outgoing particles respectively.

Rot

See Reference 1 for more detail.

Dif

Madison Convention

Sp

The state of spin orientation of an assembly of particles, referred to as polarization, should be denoted by the symbols t_{kq} (spherical) or $p_i, p_{i'}$ (Cartesian).

Cn

These quantities should be referred to a right-handed coordinate system in which the positive z-axis is along the direction of momentum of the particles, and the positive y-axis is along $k_i \cdot k_o$ for the nuclear reaction which the polarized particles initiate, or from which they emerge.

Terms used to describe the effect of initial polarization of a scatterer on the differential cross section for a nuclear reaction (referred to as analyzing power) should include the modifiers analyzing or efficiency. These quantities should be referred to a right-handed coordinate system in which the positive z-axis is along the beam direction of the incident particles and the y-axis is along $k_i \cdot k_o$ for the reaction in question.

A

In the expression for a nuclear reaction $A(b,c)D$, an arrow placed over the symbol denotes a particle which is initially in a polarized state or whose state of polarization is measured.

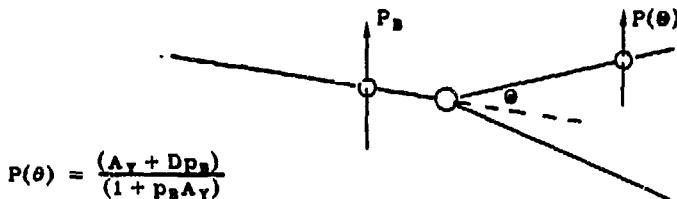
Example: $\overrightarrow{A}(b,\vec{c})D$ polarization is measured for a particle c emerging from a reaction between unpolarized particles A and b.

See Reference 2 for more details.

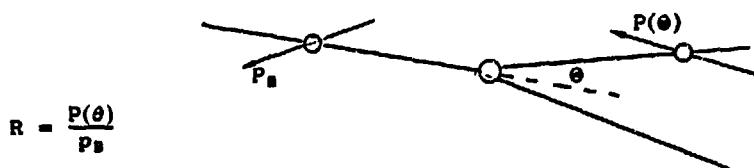
July 1988

POLARIZATION

Depolarization Parameter (D): change in polarization due to scattering.



Rotation Parameter: measure of rotation of spin of scattered beam.



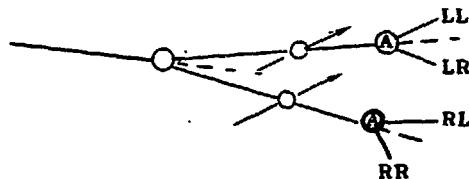
Differential polarization:

$$I_p = I_0 P(\theta)$$

where I_0 = differential cross section for an unpolarized beam

Spin-Correlation Parameters:

C_{NN} : unpolarized beam; unpolarized target; outgoing particle spins normal to scattering plane; outgoing particles scattered right and left analyzed.



$$C_{NN} = \frac{1}{A_Y^2} \frac{(LL)(RL) + (LR)(RR) - (LL)(RR) - (LR)(RL)}{(LL)(RL) + (LR)(RR) + (LL)(RR) - (LR)(RL)}$$

A_{YY} : polarized beam; polarized target; outgoing particle spins normal to scattering plane; asymmetry is measured.

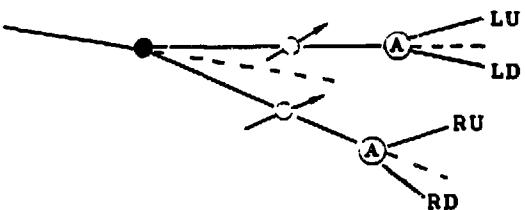
$$\epsilon = |p_B| |p_t| A_{YY}$$

If time reversal holds: $C_{NN} = A_{YY}$

POLARIZATION

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C_{kp} : unpolarized beam; polarized target; outgoing particle spins in scattering plane.



$$C_{kp} = \frac{1}{\Lambda^2} \frac{(LU)(RU) + (LD)(RD) - (LU)(RD) - (LD)(RU)}{(LU)(RU) + (LD)(RD) + (LU)(RD) - (LD)(RU)}$$

References

1. *Proceedings of the International Symposium on Polarization Phenomena of Nucleons*, P.Huber and K.P.Meyer, eds., *Helvetica Phys.Acta*, Suppl. VI (1961)
2. *Polarization Phenomena in Nuclear Reactions*, page xxv, H.H.Barschall and W.Haeberli, eds., The University of Wisconsin Press, Madison (1971)
3. *Polarization Phenomena in Nuclear Physics - 1980*, G.G.Ohlsen, R.E.Brown, N.Jarmie, W.W.McNaughton, G.M.Hale, eds., American Institute of Physics (1981).
4. W.Larkin, *Phys. Rev.* 98, 139 (1955)
5. L.J.B.Goldfarb, *Nuclear Phys.* 7, 622 (1958)
6. A.Simon, *Phys. Rev.* 92, 1050 (1953)
7. *Physics of Nuclei and Particles*, Vol. II, Ch. 13, P.Marmier and E.Sheldon, Academic Press, 1970.
8. *Polarization of Fast Neutrons*, L.Wolfenstein, *Annual Review of Nuclear Science* 6, 43 (1956)
9. *Nucleon-Nucleon Experiments*, J.C.Hopkins, LA-DC-10061 (1968).

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POLARIZATION

Coding

The sign should follow the "Basel" or "Madison" Convention.

The following quantities are coded in EXFOR:

- Spin-polarization probability, integrated over all pertinent angles, is coded with 'POL' in REACTION SF6.
- Differential spin-polarization probability with respect to angle of emission is coded with 'POL/DA' in REACTION SF6.
- Asymmetry is coded with 'POL/DA' in REACTION SF6 and 'ASY' in SF8.
- Analyzing power is coded with 'POL/DA' in REACTION SF6 and 'ANA' in SF8.
- Spin-correlation parameter (A_{YY}), is coded with 'POL/DA' in REACTION SF6 and 'AYY' in SF8.

Data units should be coded as 'NO-DIM'.

Data are assumed to be in Cartesian Coordinates. (Coding rules for data in spherical coordinates should be proposed as the need arises.)

Polarized incident-projectile source

Entries should be made under the information-identifier keyword INC-SOURCE for the following cases:

- A polarized neutron source is entered using the code 'POLNS'.
- A polarized target is entered using the code 'POLTR'.
- An atomic beam source is entered using the code 'ATOMIC'.
- A Lamb-shift source is entered using the code 'LAMB'.

The incident-projectile source should be coded in sufficient detail to describe the reaction. The polarization of the beam and target should be given in the data table, if known, using the data headings POL-BM and POL-TR, respectively. Numerical uncertainties for these quantities can be entered using the data headings POL-BM-ERR and POL-TR-ERR, with an explanation in free text under ERR-ANALYS (see EXFOR 8.E.2).

Example:

INC-SOURCE (POLTR,LAMB) Polarized target and Lamb-shift ion source

Production Cross Sections

Definition: The production cross section for a particle Y is defined as the sum of all energetically possible reactions resulting in the production of at least one particle Y in the exit channels, each reaction weighted by the multiplicity of particle Y. The interactions involved and their multiplicity need not be known.

The term emission cross section is defined as a special case and excludes elastic scattering. Where the incident projectile is not equal to Y, the production and emission cross sections are equal.

Note: These quantities are sum cross sections, which should be used only when two or more reactions producing particle Y are energetically possible.

Sum rules:

$$\begin{aligned}\text{neutron production} &= \text{neutron emission} + \text{elastic} \\ \text{neutron emission} &= (n,n') + 2(n,2n) + 3(n,3n) + (n,np) + (n,f) + \dots\end{aligned}$$

REACTION Coding: The code X is entered in SF3 (Process). The product measured is coded either in REACTION SF4 or as a variable in the data table (see Variable Nucleus, EXFOR page 6.6).

For emission cross sections, the code EM is entered in SF5 (Branch). This is coded only when the incident projectile is not equal to the particle Y.

For inelastic gamma emission, see Inelastic Scattering.

Examples:

(.....(P,X)0-G-0,,SIG) proton-induced gamma-production cross section
(.....(N,X)0-NN-1,EM,SIG) neutron-induced neutron emission cross section
(.....(N,X)ELEM/MASS,,SIG) neutron-induced isotope production cross section

For isotope production on a natural target, the REACTION is coded:

(Z-S-0(-,X)Z'-S'-A',,SIG)
or (Z-S-A(-,X)Z'-S'-A',,SIG,,A) if only one REACTION is possible.

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PRODUCTS

Products

Products of 2 or more reactions can be expressed as a reaction combination using the separator '=' (see EXFOR 8.4.10.)

Example:

REACTION ((42-MO-98(N,TOT),,WID)=(42-MO-98(N,EL),,WID))

Products implicit in the quantity codes

For certain products which can be measured directly, or are frequently used, special quantities have been introduced.

The following factors are coded using special codes in REACTION SP8 (modifier):

$$\sigma_0 = S0$$

$$g.ag.2g.2ag = G,AG,2G,2AG$$

$a = A$ (abundance), or (A) , if unclear whether corrected for natural isotopic abundance

$$\sqrt{E} = RTE$$

$$4\pi = 4PI$$

$$(- - -)^2 = SQ$$

$$\frac{4\pi}{\sigma_{el}} = RS$$

See also Fitting Coefficients.

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QUANTUM NUMBERS

Quantum Numbers

For resonance levels in compound nuclei

Momentum l - the orbital angular momentum of neutrons exciting a compound-nucleus resonance

Resonance Spin J - the total spin value of the compound-nucleus resonance

Parity π - the parity of a compound-nucleus resonance

Statistical weight g - the statistical weight of a compound-nucleus resonance

These quantum numbers can be entered in two different ways:

1. Frequently such quantum numbers are assumed as parameters of strength functions, reduced neutron width, or other quantities. Then they are entered as parameters in an additional field of the data table, either in the COMMON or in the DATA section, under the data-heading keywords.

```
MOMENTUM L  
SPIN J  
PARITY  
STAT-W G
```

Example:

```
DATA  
MOMENTUM L SPIN J PARITY STAT-W G DATA  
NO-DIM NO-DIM NO-DIM NO-DIM MILLI-EV  
1.0 0.5 -1.0 1.5  
ENDDATA
```

2. If the quantum number is the result of the resonance parameter analysis, one of the following REACTION codes is used:

```
(....(N,0),,L)  
(....(N,0),,J)  
(....(N,0),,PTY)  
(....(N,0),,SWG)
```

In this case the data are entered into the data table under the data-heading keyword DATA, and the data-unit keyword NO-DIM.

The quantum numbers, themselves, should be entered with the decimal point (in the case of parity as 1. or -1.).

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QUANTUM NUMBERS

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The statistical weight factor may also be used as modifier in the quantity code (see Products).

Note: In RENDA spin, parity and energy of levels are grouped together in one category 'LQN' (level quantum numbers).

For excited states in product nuclei

Spin J - the spin value of a level in a product nucleus

Parity π - the parity of a level in a product nucleus

These quantum numbers may be entered in the BIB section under the keyword LEVEL-PROP to define the level for which the data are measured. See EXFOR page 8.L.1.

Example:

```
LEVEL-PROP (26-FE-56,LVL-NUMB=1.,SPIN=2.,PARITY=+1.)
```

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RATIOS

Ratios

Ratios of 2 or more reactions can be expressed as a reaction combination using the separator '/' (see EXFOR 8.R.9).

Example: ((3-LI-6(N,T)2-HE-4,,SIG)/(92-U-235(N,F),,SIG))

In the case where the numerator and denominator of the reaction refer to different values for one or more of the independent variables, the separator '//' is used. The independent variables which differ are coded in the data table using data headings with the extension -NM and -DN for the numerator and denominator, respectively. See EXFOR page 6.8 and LEXFOR F.13 for examples.

Ratios implicit in the quantity codes.

For certain frequently used ratios, special quantity codes have been introduced.

ALF (SF6) = capture-to-fission ratio (see Alpha)

ETA (SF6) = average neutron yield/nonelastic event (see Neutron Yield)

RS (SF8) = $4\pi/\text{elastic scattering cross section}$

Isomeric Ratios are coded using the separator '/' in the isomer field of the reaction product (SF4), and with the modifier 'RAT' in SF6. (See Isomeric States.)

REACTION Parameter Code RAT

The code 'RAT' in REACTION SF6 is given when, and only when,

either: the separator '/' appears in the isomer extension of the reaction product (see above).

or: when SF5 contains the codes 'TER/BIN' or 'BIN/TER'

RAW DATA

July 1988

Raw Data.

"Raw" data are experimental data which are not yet reduced to the final form but still contain, for example, contributions from detector efficiency, instrumental resolution, or sample thickness.

Although such data are of little use to usual data center customers, it has been recognized that "raw" data should be stored by the data centers. Such data would then be available:

- for re-analysis when improvements in analysis techniques are made
- for realistic assessments of data errors as they become increasingly important to evaluators.

(See recommendation by the NEANDC/NEACRP meeting on neutron data for structural materials, Geel, December, 1977.)

The following types of "raw" data have been encountered to date:

1. transmissions: $\langle e^{-n\sigma_T} \rangle = 1 - n\langle\bar{\sigma}_T\rangle + \frac{1}{2}n^2\langle\bar{\sigma}_T^2\rangle + \dots$

2. reaction yields: $\langle y_r \rangle = \langle (1 - e^{-n\bar{\sigma}_T}) \bar{\sigma}_r / \bar{\sigma}_T + \sum_{i=1}^{\infty} y_{r,i} \rangle$

where: $\langle \dots \rangle$ denotes resolution broadening
 n is the sample thickness in nuclei/barn
 σ_T and σ_r are the Doppler-broadened, abundance-weighted total and partial reaction cross sections, respectively
 $y_{r,i}$ is the reaction yield from neutrons scattered i times before inducing the reaction of type r , e.g., fission, scattering or radiative capture.

Note that for thin samples ($n\bar{\sigma}_T \ll 1$) the following simple relationship with the (broadened) cross section exists:

$$-\frac{1}{n} \ln \langle e^{-n\sigma_T} \rangle \approx \langle \bar{\sigma}_T \rangle, \quad \frac{1}{n} \langle y_r \rangle \approx \langle \bar{\sigma}_r \rangle$$

Data may be given as "counts" or as uncorrected cross sections in "barns".

Additional data types may be added as they are encountered.

The data may be transmitted in EXFOR using the modifier RAW in REACTION SP8. The RAW modifier should always be explained in free text.

A center is free to transmit or not to transmit such data, but if it decides not to do so, a NODATA entry should be made (see NODATA).

LEXFOR R.2

Reaction Mechanisms

Partial Cross Sections due to different reaction mechanisms

An author may assign fractions of a measured cross section to different reaction mechanisms.

The following reaction mechanisms are defined, based on currently accepted nuclear models, and may be entered into EXFOR in the manner described on the following pages.

Definitions

Compound-Nucleus Interaction: A reaction in which the incident projectile is absorbed by the target nucleus and its initial energy is assumed to be shared by all other nucleons, such that the mode of disintegration of the 'compound nucleus' is independent of the way in which it was produced.

Direct Interaction: A reaction in which there is direct interaction between the incident projectile and single nucleons or clusters of nucleons in the target.

Spallation: A reaction where several particles are ejected from the target nucleus by direct interaction leaving behind a nucleus in an excited state which then evaporates nucleons or clusters of nucleons.

High-energy Fission (Energies > about 50 MeV): proceeds in essentially the same manner as spallation except that the excited nucleus divides into roughly two fragments.

See Fission for fission process at lower energies.

Data Specification

1. Compound-Nucleus Interaction and Direct Interaction

Some reactions may proceed by either mode, in which case the total reaction is equal to the sum of the compound-nucleus interaction and direct interaction portions. In this case, the partial cross sections for the compound-nucleus interaction and direct interaction portions of a reaction may be coded with the modifiers 'CN' and 'DI', respectively, in SF5 (branch) for the keyword REACTION.

REACTION MECHANISMS

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Examples:

(.....(N,P),CN,SIG) Compound nucleus portion of (n,p) cross section
(.....(N,P),DI,SIG) Direct interaction portion of (n,p) cross section

These partial cross sections cannot be measured directly but are deduced from theoretical considerations. Therefore, careful explanation in free text is required whenever these modifiers are used.

Note: If the author measures the total (n,p) cross section and states that this reaction is totally a direct interaction, then the modifier 'DI' must not be given, because 'DI' and 'CN' designate partial cross sections.

2. Spallation and High-energy Fission

The breakup of a nucleus at high energies may, in some cases, proceed by either mode. In this case, the partial quantity for fission or spallation may be coded under the keyword REACTION using the modifiers 'SPL' and 'FIS', respectively, in SF5 (branch).

Examples:

(8-C-12(P,X),SPL,SIG) Spallation cross section
(8-C-12(P,X),FIS,SIG) High-energy fission cross section

Note: If the author measures the total break-up or production of a given product and states that this reaction is totally due to spallation or fission, then the codes SPL or FIS must not be given, because these designate partial cross sections.

For the production of specified product nuclei see Product Yields.

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REACTION PRODUCT

Reaction Product

Definition: In general, the heaviest of all identifiable products of the reaction specified is defined as the Reaction Product (also called the residual nucleus) and is entered into SF4 of the REACTION keyword. See EXFOR 8.R.5-8.R.7 for a complete discussion of the use of the Reaction Product Subfield.

In the case of product yield data for which the reaction specified may lead to the production of more than one reaction product, the *Variable Nucleus Formalism* may be used (see EXFOR 8.6).

A description of the decay information about the reaction product may be given using the information-identifier keyword DECAY-DATA (see Decay Data). This information should always be given, where known, for an activation measurement.

LEXFOR R.5

Reaction Rate

Definition: The thermonuclear reaction rate is defined as cross section times ion velocity averaged over the Maxwellian ion velocity distribution of the temperature kT:

$$\langle \sigma \cdot v \rangle = \frac{\int_0^{\infty} (\sigma \cdot v) \exp(-mv^2/2kT) v^2 dv}{\int_0^{\infty} \exp(-mv^2/2kT) v^2 dv}$$

The ion with the mass m_2 has the velocity v relative to the target ion of mass m_1 . The reduced mass m of the ion pair is $m = m_1 m_2 / (m_1 + m_2)$.

REACTION Coding: (.....,SGV,,MXW)

Data Units: data are usually given in units of cm^3/sec and coded with the data-unit keyword CM3/SEC.

Energy Coding: Data are given as function of the Maxwellian temperature (kT) which is coded under the data heading KT with units of energy.

See Spectrum Average for definition of incident spectrum.

References:

1. D. D. Clayton, *Principles of Stellar Evolution and Nucleosynthesis*, McGraw-Hill, N. Y. (1968)
2. W. A. Fowler, et al, *Thermonuclear Reaction Rates*, Ann. Rev. Astron. Ap. 5, 525 (1967)
3. T. A. Trombello, *Conf. on Nuclear Cross Sections and Technology*, Washington, D. C., 3-7 March 1975, p. 659.
4. J. M. Davidson, et al, *Low Energy Cross-Sections for B-11(p,3α)*, Nuclear Phys. A 315, 253 (1979).

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REFERENCE

Reference

Information-Identifier Keyword REFERENCE

All bibliographic references which contain information of importance directly relating to the data compiled in EXFOR, i.e., not only the reference from which the data were taken, but also other important references, such as journal articles, conference papers, and laboratory reports may be coded under the keyword REFERENCE. Progress reports and abstracts should, in general, be excluded, if they contain no additional useful information.

Other related references must not be coded under this keyword, but may be coded under the keywords REL-REF or MONIT-REF (see following page).

For the coding rules see EXFOR 8.R.11 to 8.R.16.

The purpose of the bibliography is

to help compilers:

- avoid duplicate entry of data in EXFOR
- identify a data set when data are requested by reference

to help users of EXFOR:

- get easy access to any additional information available in the published references
- check whether a given reference has been considered by the compiler

Therefore, the free text should indicate to users of EXFOR:

- the main reference.
- the kind of information contained in each reference given, e.g., "instrumentation only", "graphs only", "no data", "theoretical analysis", etc.

When translations of references exist, these should be included also, for the convenience of users of EXFOR.

Important references which are published after the first compilation of the EXFOR entry, should be added subsequently and the entry retransmitted as specified on EXFOR 9.1. Usually such a new reference will provide additional information on the experiment or the numerical data, which should be added and retransmitted simultaneously.

If the coding of the references in EXFOR is coordinated with the blocking of the same references in CINDA, both systems will benefit.

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When referencing a document which has more than one document code, the primary code (i.e., the document code assigned by the originating laboratory) should be given first, in most cases. The main exceptions are reports issued by advisory committees where the agency-assigned number is the primary report number.

Private Communications

If data are received via a private communication, the correspondent and the date of the private communication may be entered as a reference (see EXFOR 8.R.15) or under the information-identifier keyword STATUS (see point of disagreement, below).

Point of disagreement:

NDS feels that a private communication should be entered under REFERENCE only if there is no other reference.

NNDC considers private communications as valid references, and, if they contain information not given in published articles, prefers to code them under REFERENCE so they can be accessed by computer. They do agree that where there is no additional information in a private communication, it should not be entered.

Conferences

If conference proceedings are issued within a report series, so that they can be identified with a report number, then the report number must be used, not the conference code.

Example: The proceedings of the standards panel 67BRUSSELS were issued as report IAEA-107. In this case, the code 67BRUSSELS is not used.

Paper Number

If two or more papers start on the same page of a given reference, they should be differentiated in the paper number field. If no paper number is given, the papers should be numbered sequentially.

Example:

(J,PR,104,482(1),5612) first paper on page 482 of Phys. Rev., 104
(J,PR,104,482(2),5612) second paper on page 482 of Phys. Rev., 104

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REFERENCE

Information-Identifier Keyword REL-REF

A reference relating to, but not directly pertaining to the data given, may be entered under REL-REF. Examples are: critical remarks or corrections applied by another author, e.g., within a data review or evaluation. (See EXFOR 8.R.17 for coding rules.)

Information-Identifier Keyword MONIT-REF

References from which the standard (or monitor) data used in the experiment were taken are coded under MONIT-REF. (See EXFOR 8.M.4 for coding rules.)

RESOLUTION

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Resolution

The word resolution can describe:

either the energy spread or channel width (or a combination) of the incident projectile
or the angular or energy spread of the outgoing particle(s).

Incident-particle Energy Resolution

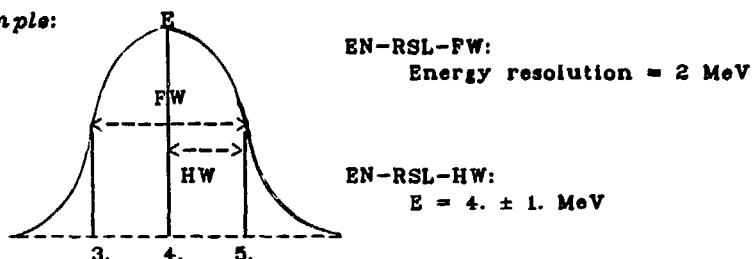
The energy resolution describes the distribution curve of the energy spread. It is usually defined as full-width at half-maximum (FWHM), but may be given in other representations. The shape and definition of the resolution function should be given in free text under INC-SPECT, if known.

Resolution is coded using the following data headings:

EN-RSL-FW Incident-particle energy resolution (FWHM)
EN-RSL-HW Incident-particle energy resolution (\pm FWHM)
EN-RSL Incident-particle energy resolution (unspecified)

The energy resolution can be given in energy units, in percent, or in units of a reciprocal velocity (e.g., nsec/m).

Example:



Note: The terms resolution and error are often misused in the literature.
Distinguish between them, where possible. See Errors.

Secondary-energy resolution: see Secondary Particles.

Angular resolution: see Angle

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RESONANCE INTEGRAL

Resonance Integral

Definition: Index of epithermal reaction by a material in a reactor flux.

REACTION coding: RI in SF8 (Parameter)

Example:(N,ABS),,RI)

The energy limits are specified under the data-heading keywords EN-MIN and EN-MAX.

Infinitely dilute resonance integrals for a 1/E spectrum are defined as:

$$I_r = \int_{E_c}^{\infty} \sigma_r(E) \frac{dE}{E}$$

where E = cutoff energy near the lower limit of the epithermal region.

These are usually measured as cadmium ratios where E is the cadmium cutoff energy which is dependent on the thickness of the cadmium cover.

In some cases, an upper limit is given for the energy (e.g., 10 MeV) and should be coded. When an upper limit is not given, EN-MAX may be omitted.

Resonance integrals over smaller energy ranges, where the sum over the partial energy ranges given from the cutoff energy to the maximum energy is equal to the total resonance integral, should be coded with the quantity modifier LIM.

Reduced resonance integrals, where the 1/v part has been subtracted, should be coded with the quantity modifier RNV in REACTION SF8.

Resonance integrals calculated from resonance parameters should be entered using the code 'DERIV' in REACTION SF9 (data type). See also Data Type.

For further details, see:

N. P. Baumann, DP-817 (1963)

J. J. Scoville and J. W. Rogers, IN-1195 (1968)

Effective Resonance Energies

The 'ideal' resonance integral is defined for an epithermal flux as being proportional to $1/E$. This is an approximation which may be sufficiently accurate only in certain cases. Directly measured resonance integrals and those computed from cross-section curves assuming a $1/E$ flux are often discrepant due to the fact that realistic epithermal fluxes deviate from the $1/E$ shape.

Ryves has developed a better approximation, which is sufficiently accurate for most applications, in which the epithermal part of the reactor neutron spectrum is proportional to $1/E^{1+\alpha}$. Accordingly, the realistic resonance integral is defined as:

$$I(\alpha) = \int_{E_c}^{\infty} \frac{\sigma(E)dE/eV}{(E/eV)^{1+\alpha}}$$

where α = a constant close to zero (either positive or negative) which can be determined for each reactor spectrum

E_c = cutoff energy near the lower limit of the epithermal

For $\alpha = 0$ this formula goes to the ideal infinite dilute resonance integral.

The realistic resonance integral and the 'ideal' resonance integral are related by:

$$I(\alpha) = \frac{I_0 0.429 \sigma_e}{(E_r/eV)^\alpha} + \frac{0.429 \sigma_e}{(2\alpha+1)(E_c/eV)^\alpha}$$

where σ_e = 2200 m/sec cross section

E_r = effective resonance energy

The effective resonance energy is a microscopic nuclear constant representing a kind of average over the major resonances. It is tabulated in the literature and can be determined by experiment and evaluation.

Note: For (n,γ) activation analysis, the effective resonance energy is needed as a correction factor of similar importance to the resonance integral. Its value need not be known with high accuracy; a 50% uncertainty in the effective resonance energy may lead to a 1% uncertainty in activation analysis measurements; whereas, ignoring the parameter α may lead to a 25% error in the measurements.

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RESONANCE INTEGRAL

Conclusion for EXFOR Compilation

When directly measured resonance-integral data are compiled in EXFOR, it is essential

- to give all available information on the epithermal neutron spectrum and to quote the α parameter if given
- to state whether the resonance integral given is for the realistic epithermal neutron spectrum, or whether appropriate corrections have been applied so that the value given is for the ideal epithermal $1/E$ spectrum.

References

T.B.Ryves, *Metrologia*, 5, 119 (1969)

A.Simonits, F.deCorte, L.Moens, J.Hoste, *J.Radioanal.Chem.* 72, 209 (1982);
see page 215

S.Jovanovic, F.deCorte, L.Moens, A.Simonits, J.Hoste, *J.Radioanal.Chem.* 82/2,
379 (1984)

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SCATTERING

Scattering

See also Thermal-Neutron Scattering, Differential Data, Inelastic Scattering.

Definition: Two-body interaction with only one particle, which is the same as the incident particle, in the exit channel.

The following scattering processes are defined:

1. Total Scattering. The sum of all scattering interactions.

Sum Rule: Total scattering = elastic scattering plus inelastic scattering
= total minus absorption

REACTION Coding: SCT in SF3 (Process).

Example: (.....(P,SCT).....,SIG)

alternately; (.....(P,P).....,SIG) for use only when the scattering type need not be distinguished.

Note: In some experiments (e.g., Lane, et al., *Phys. Rev.* 107, 1077 (1957)), the data may be called scattering even though they extend above a threshold where other reactions producing the scattered particle are also possible. It should be specified whether such data have to be corrected for the effects of such threshold reactions. If not, the quantity should be coded as neutron production.

2. Elastic Scattering. Scattering without excitation of the scattering nucleus ($Q = 0$).

REACTION Coding: EL in SF3 (Process).

Example: (.....(N,EL).....,DA)

3. Inelastic Scattering. Scattering with excitation of the scattering nucleus ($Q \neq 0$). De-excitation of the residual nucleus, usually, by electromagnetic radiation. See Inelastic Scattering.

4. Potential Scattering. Elastic scattering which proceeds without the formation of an intermediate nucleus. (Elastic scattering is a mixture of potential and resonance scattering.)

REACTION Coding: POT in SF5 (Branch).

Example: (.....(N,EL).....,POT,SIG)

5. Thermal Scattering. Low energy scattering processes for which molecular and crystalline forces are involved. See Thermal-Neutron Scattering.

Scattering Amplitude

Definition: $\frac{d\sigma}{d\Omega} = |f(\theta)|^2$

where the scattering amplitude (f) is a function of the wavelength of the incident projectile and of the relative orientation of the incident-projectile spin and target spin.

For neutrons, for which only s-wave scattering is possible (and for which the scattering is, therefore, isotropic) and for zero energy: $f = -a$, where a is the Fermi scattering length.

REACTION Coding: AMP in SF6 (Parameter)

Example: (.....(N,THS).....,COH,AMP)

LEXFOR S.2

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Secondary Particles

See also Angle, Particles.

Secondary Energy

Information on the energy state of a nucleus after reaction, or on the energy values of detected particles, or on any other energies related to the secondary particles, is entered as follows:

1. Numerical values are entered in the COMMON or DATA section using data headings from Dictionary 24 with the family code E, e.g., E-LVL.

In the case of two or more unresolved energy levels, the data heading may be repeated (see EXFOR 5.4).

If it is not evident to which reaction product the secondary energy refers, this must be specified under the keyword EN-SEC, see below.

The secondary-energy uncertainty or resolution may be entered using a data heading from Dictionary 24 with the family code F, e.g., E-RSL, E-LVL-ERR. Further information can be given under the keyword ERR-ANALYS (see EXFOR 8.E.2). See also Errors, Resolution.

2. The information-identifier keyword EN-SEC may be used:

- to specify to which reaction product the secondary energy given in the COMMON or DATA section refers. (See EXFOR 8.E.2).
- to give free text information about the secondary energy.

This keyword must always be coded when the data headings E1, E2, etc., are used.

A secondary-energy data heading which is not defined under the keyword EN-SEC must be defined by the REACTION code.

3. Energy Correlation of Secondary Particles

REACTION Coding: 'ECO' in SF6 (parameter)

Example: (.....(G,N+P).....,ECO) neutron-proton energy correlation

Secondary Effective Mass

Information about the effective squared mass of detected particles or particle systems may be entered as follows:

1. Numerical values are entered in the COMMON or DATA section using data headings from Dictionary 24 with the family code 'S', e.g., EMS.
2. The information-identifier keyword EMS-SEC may be used:
 - to specify to which reaction product the effective squared mass refers
 - to give free text information about secondary mass.

The keyword is always coded when more than one effective secondary squared mass is given in the COMMON or DATA section using the headings EMS1, EMS2, etc.

3. Mass Correlation of Secondary Particles

REACTION Coding: 'EMC' in SF6 (parameter)

Example: (.....(G,N+P).....,EMC) neutron-proton mass correlation

Secondary Linear Momentum

Information about the linear momentum of a secondary particle may be entered as follows:

1. Numerical values are entered in the COMMON or DATA section using data headings from Dictionary 24 with the family code 'L', e.g., MOM-SEC.
2. The information-identifier keyword MOM-SEC may be used:
 - to specify to which of several particles the secondary linear momentum given in the COMMON or DATA section refers.
 - to give free text information about secondary linear momentum.

The keyword is always coded when more than one secondary linear momentum is given in the COMMON or DATA section using the headings MOM-SEC1, MOM-SEC2, etc.

3. Linear Momentum Correlation of Secondary Particles

REACTION Coding: 'MCO' in SF6 (parameter)

Example: (.....(G,N+P).....,MCO) neutron-proton linear momentum correlation

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SEQUENCE

Sequence of process/particle codes

For general rules on the coding of sequence of process/particle codes in REACTION SF3 and SF4 see EXFOR S.R.3-S.R.5.

Sometimes, data are given for partial reactions where the sequence of outgoing processes/particles is defined, for example:

$$\text{total (n,np)} = \text{partial (n,np)} + \text{partial (n,pn)}$$

(1) (2) (3)

The corresponding REACTION codes are:

- (1) (.....(N,N+P).....,SIG)
- (2) (.....(N,N+P).....,SEQ,SIG)
- (3) (.....(N,P+N).....,SEQ,SIG)

Note that the code SEQ should be given within the REACTION code only when it is a partial reaction. If the author states that the reaction proceeds, e.g., totally in the sequence (n,pn) without any contribution in the sequence (n,np), then the reaction is coded primarily as (1), above. A comment stating that the reaction proceeds entirely in the sequence (n,pn) may be added in free text (if this occurs at all) or, alternatively, both codes may be given in the form of a tautology:

REACTION ((.....N,N+P).....,SIG)=(.....(N,P+N).....,SEQ,SIG))

For the following partial reactions the specified sequence of process and particle codes is always indicated by the code SEQ.

Excitation of excited level(s) which decay by fission:

- (n,n'f) cross section: (N,N+F),SEQ,SIG
- (n,γf) cross section: (N,G+F),SEQ,SIG

Emission of a primary gamma ray followed by unidentified decays:

- (n,γx) cross section: (N,G+X),SEQ,SIG

This formalism can occur only for the process codes F and X.

Compare also under Partial Reactions.

SINGLE-LEVEL

July 1988

Single-Level Resonance Parameters

See also Average Resonance Parameters, Quantum Numbers, Multilevel Resonance Parameters

Resonance cross sections as a function of energy may be described using a Breit-Wigner single-level formalism.

For s-wave scattering the formula is:

$$\sigma_{ss}(E) = 4\pi\kappa_0^2 g \left| \frac{\Gamma_n}{(E-E_0) + i\Gamma/2} + \frac{R'}{\lambda_0} \right|^2 + 4\pi R'^2(1-g)$$

where: $4\pi R'^2 = \sigma_{pot}$

For reactions (capture, fission, etc.):

$$\sigma_r(E) = \pi\kappa_0^2 g \left(\frac{E_0}{E} \right)^2 \frac{\Gamma_n \Gamma_r}{(E-E_0)^2 + (\Gamma/2)^2}$$

For further detail see:

A.M.Lane and R.A.Thomas, *Rev. Mod. Phys.* 30, 257 (1958)

Experimental Neutron Resonance Spectroscopy, J.A.Harvey, ed., Academic Press, (1970).

Definitions and codes for data to be compiled in EXFOR.

(See Dictionary 36 (REACTION) for a complete list of codes.)

Resonance Energy (E_0) is coded in EXFOR in one of two ways.

- 1.) When the resonance energy is determined by the author, it is assigned a REACTION code and entered into the data table under the corresponding DATA field.

REACTION Coding: '0' (zero) in SF3 (process); 'EN' in SF6 (parameter)

Example: (....(N,0),,EN)

- 2.) When the resonance energy is not determined by the author, but is taken from other sources, it should be entered into the data table as an independent variable under the data-heading keyword EN-RES. In this case, it should only be entered for those resonances for which the author has presented other resonance parameters.

Negative energy resonances, in many cases, will influence very low energy cross sections. These bound levels should be coded with the negative energy, as given.

LEXFOR S.6

July 1988

SINGLE-LEVEL

Resonance widths ($\Gamma_{(r)}$)

REACTION Coding: WID in SF6 (parameter) and the code for the reaction described in SF3

Examples:

REACTION (.....(N,TOT),,WID) = total width (Γ)
(.....(N,EL),,WID) = neutron width (Γ_n)
(.....(N,G),,WID) = capture width, or radiation width (Γ_γ),
including all preliminary γ decays not
followed by a neutron or charged-particle
emission.

The units are that of energy, e.g., eV or millieV.

For partial radiation width, see Gamma Spectra.

Reduced neutron widths are defined at 1 eV as follows:

$$\Gamma_n' = \frac{\Gamma_n}{\nu_i \sqrt{E_0/1 \text{ eV}}}$$

where: E_0 is the resonance energy in eV.
 ν_i is the penetration factor of the nucleus.

Or, more specifically:

for s-wave resonances ($\nu_s=1$):

$$\Gamma_n^0 = \frac{\Gamma_n}{\sqrt{E_0/1 \text{ eV}}} \quad (1)$$

for p-wave resonances:

$$\Gamma_n^1 = \frac{\Gamma_n}{\sqrt{E_0/1 \text{ eV}}} \left(1 + \frac{1}{k_o^2 R^2} \right) \quad (2)$$

where: k_o = wave number
 R = nuclear radius

REACTION coding: (.....(N,EL),,WID/RED)

The angular momentum should be specified under the data-heading keyword MOMENTUM L. (See Quantum Numbers for coding of angular momentum).

The units are that of energy, e.g., eV or milli-eV.

SINGLE-LEVEL

July 1988

Note: Some authors give the reduced neutron width (for s-wave neutrons) as:

$$\Gamma_n^{(o)} = \frac{\Gamma_n}{\sqrt{E_0}} \quad (3)$$

which has the dimension of the square-root of an energy. (Compare: Hennies, 1966 Paris Conf., Vol. 2, page 333). For consistency, only definition (1) with the dimension of an energy should be used in EXFOR, the numerical values of definitions (3), and (1) being anyway identical except for the dimensions.

Peak cross section is defined as a cross section at the peak of the resonance, assuming the line shape in a Breit-Wigner formalism, corrected (where important) for instrumental and temperature effects. The peak cross section for s-wave neutrons can be expressed by:

$$\text{total: } \sigma_o = 4\pi\kappa_0^2 g \frac{\Gamma_p}{\Gamma}$$

$$\text{partials: } \sigma_{or} = \sigma_o \frac{\Gamma_p}{\Gamma}$$

These are coded with the modifier code RES in combination with the code for the reaction described.

Example:

REACTION (.....(N,TOT),,PCS) Total peak cross section

Note: Eta or Alpha at resonance are coded as:

(.....(N,ABS),,ETA,,RES)
(.....(N,ABS),,ALF,,RES)

September 1989

SINGLE-LEVEL

Resonance area is defined:

$$\text{for scattering: } A_{sc} = 2\pi^2 \lambda_0^2 g \frac{\Gamma_n^2}{\Gamma}$$

$$\text{for other reactions: } A_r = 2\pi^2 \lambda_0^2 g \frac{\Gamma_n \Gamma_r}{\Gamma}$$

These are coded with the parameter code ARE in combination with the relevant reaction code.

Example: (.....(N,EL),,ARE) Scattering area

The units are cross section times energy, e.g., b·eV.

The quantity: $g \frac{\Gamma_n \Gamma_r}{\Gamma}$

is often presented as a result of the resonance analysis and is proportional to the capture area. It is coded the REACTION combination followed by the keyword RESULT, using the code 'CAPTA'.

Example:

```
REACTION (((....(N,EL),,WID,,G)*(....(N,G),,WID))/  
          ....(N,TOT),,WID))/  
RESULT    (CAPTA)
```

The units are energy, e.g., eV.

Special representations are coded as follows:

$\sigma_0 \Gamma_r$ (.....(N,F),,WID,,SO)

$\sigma_0 \Gamma^2$ (.....(N,TOT),,WID,,SQ/SO)

$g \Gamma_n$ (.....(N,EL),,WID,,G)

$2g \Gamma_n$ (.....(N,EL),,WID,,2G)

$a g \Gamma_n$ (.....(N,EL),,WID,,AG) where a = isotopic abundance

$2a g \Gamma_n$ (.....(N,EL),,WID,,2AG)

SPECTRUM AVERAGE

July 1988

Spectrum Average

Cross sections averaged over a broad incident-projectile energy spectrum may be entered into EXFOR using the proper modifier to REACTION SF8. The type of spectrum and its characteristic should be entered in free text under the information-identifier keyword INC-SPECT.

Three spectrum types are defined:

1. Maxwellian Average: Modifier MXW

The spectrum temperature should be given, if known. For thermal Maxwellian spectrum averaged data, see Thermal Neutron Energies.

2. Fission-Neutron Spectrum Average: Modifier FIS

For details, see Fission-Neutron Spectra.

3. Spectrum Average: Modifier SPA

Used for all other spectra, e.g., thermal reactor spectra. Care should be taken to compile only those data which would be of value to the user of EXFOR.

For pile or reactor spectrum, see Thermal Neutron Energies.

The spectrum energy should be entered into the data table using one of the following data headings:

KT - spectrum temperature

EN-MEAN - mean energy

EN-DUMMY - dummy energy (characteristic of spectrum)

0.0253 eV	thermal Maxwellian and thermal reactor spectra
1.5 MeV	fission-neutron spectra
4.5 MeV	α -Be neutron sources

July 1988

STANDARDS

Standards

See also Dosimetry Reaction Data.

Standard and/or monitor information should be entered into an EXFOR data set using the information-identifier keyword MONITOR (see EXFOR 8.M.2 for coding rules). Only that standard data to which the data given are proportional should be coded. Other information should be entered under the information-identifier keyword ASSUMED (see Assumed Values).

Note: Data which are measured as consistency checks should not be coded under MONITOR. They should, however, be coded as a separate data table if the data are given.

Standard information should be coded except when it is not relevant, as for quantities which are usually obtained without a standard, that is:

- total cross sections
- nuclear quantities (see Nuclear Quantities)
- ratios
- quantities defined using the modifiers RS, RSL, RSD, REL
- scattering radius, strength function, average level spacing
- resonance parameters; however, for resonance areas, peak cross sections and similar quantities, either the standard should be given or a cross-reference to the data from which the resonance parameters were deduced.

For all other quantities which can be measured either with a standard or absolutely, the positive statement in free text that the data are measured absolutely is pertinent information and, therefore, should be included.

It should be noted, however, that so-called "absolute" data often depend on the assumption of certain numerical values (e.g., for calibrations or corrections); it is desirable to give such values in free text. The compiler should restrict the use of the term absolute to those cases in which it is known that there are no "hidden" standards.

For complicated descriptions of standards or normalization procedures, a cross-reference to published literature may be sufficient.

The reference pertinent to the standard(s) used is coded using the information-identifier keyword MONIT-REF (see EXFOR 8.M.4 for coding rules).

Decay data for the standard(s) used is coded using the information-identifier keyword DECRY-MON (see EXFOR 8.D.4 for coding rules).

Entry of standard values into DATA or COMMON

See examples on following page.

1. If standard values are given at several points (i.e., energies, angles), these values are given in the data table as an additional field under the data heading MONIT. See example (1) on following page.
2. If the data is normalized to a standard at one point (i.e., energy, angle), there are two possibilities:
 - the standard is entered as in case (1), above; the field headed by MONIT is blank for all but one line.
 - the standard is entered in the COMMON section under the data heading MONIT. The incident energy, secondary energy, angle, etc., at which the normalization was done are entered under the data headings EN-NRM, E-NRM, ANG-NRM, respectively. These are omitted if the data table includes only one data point for which the independent variables are the same as those for the normalization value. See example (2) on following page.
3. If the originally measured ratio (data/standard) is also given, see example (3) on following page.
4. If the data are normalized at two or more energies in an unspecified way, this should be noted in free text in an appropriate place.

Note: Every data line must have a dependent variable entry, therefore, standards may not be entered on a separate line in the data table.

5. If two or more standard reactions are given for the same data set, see EXFOR 8.M.2 for coding rules.

Numerical values for the uncertainty are entered using the data heading MONIT-ERR. Further information can be entered under the keyword ERR-ANALYS, see EXFOR 8.E.2.

List of commonly accepted standards

1-H-1(N,EL)1-H-1	SIG and DA	1 keV to 20 MeV
2-HE-3(N,P)1-H-3	SIG	≤50 keV
3-LI-6(N,A)2-HE-4	SIG	≤100 keV
5-B-10(N,A)3-LI-7	SIG	to gnd, 1st exc.st. ≤100 keV
6-C-12(N,EL)8-C-12	SIG and DA	≤ 2 MeV
25-MN-55(N,G)25-MN-56	SIG	thermal
27-CO-59(N,G)27-CO-60	SIG	thermal
79-AU-197(N,G)79-AU-198	SIG	thermal, 200 - 3500 keV
92-U-235(N,F)	SIG	100 keV - 20 MeV
98-CF-252(O,F)	NU and DE	----

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STANDARDS

Examples:

(1) BIB

```
MONITOR      (MONIT1,.....)
              (MONIT2,.....)

ENDBIB
NOCOMMON
DATA
EN          DATA      MONIT1      MONIT2
MEV         B          B          B
1.          —          —          —
2.          —          —          —
3.          —          —          —
ENDDATA
```

(2) COMMON

```
EN-NRM      E-LVL-NRM    MONIT
MEV         MEV         MB
ENDDATA
```

(3) BIB

```
REACTION 1((3-LI-8(N,T)2-HE-4,,SIG)/(92-U-235(N,F),,SIG)
           2(3-LI-8(N,T)2-HE-4,,SIG)
MONITOR 2(92-U-235(N,F),,SIG)
```

```
ENDBIB
NOCOMMON
DATA
EN          DATA      1DATA      2MONIT      2
MEV         NO-DIM    B          B
ENDDATA
```

STATUS

July 1988

STATUS

Various types of information are combined under the information-identifier keyword STATUS. See EXFOR 8.S.1 for coding rules and Dictionary 16 for a complete list of codes and their use. Some general items should be kept in mind:

Preliminary - Superseded - Final Data

If the STATUS codes PRELM and SPSDD are absent, the data are understood to be final.

The frequent case in which a preliminary data set is replaced by its final version can be handled in one of two ways:

- 1.) the final set replaces the preliminary set in the same subentry so that the preliminary set is deleted from the file.
- 2.) the final set is entered into a new subentry (preferably in the same entry). The earlier set is labeled as superseded with a cross-reference to the data set which supersedes it. If the earlier set has the status code PRELM, it is removed. (The codes PRELM and SPSDD exclude each other.)

Example: STATUS (SPSDD,10048009)

The superseding subentry should have a free text cross-reference to the superseded subentry.

This is the preferred method if the earlier data has already been published.

The code SPSDD can also be used when a data set is withdrawn by the author without replacement. Explanation is required in free text.

Dependent Data - see Dependent Data.

Author Approval

After the proof copy of a data set has been approved by the author, the code APRVD is entered under STATUS. The absence of the code APRVD means that no reply on the proof copy has been received from the author.

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STATUS

Source of the data

The actual source from which the numerical values given in the data set were taken may be entered in free text under STATUS.

When the author's original numerical values have been lost or are not obtainable, data read from graphs, if available, should be entered into EXFOR for completeness. Data of this type should be labeled with the status code CURVE.

Note: Older entries may have been labeled only under the keyword COMMENT or HISTORY.

Normalization

If the codes OUTDT and RNORM are absent, the data are compiled as resulting from the author's corrections and normalizations.

Only in exceptional cases should renormalizations or reassessments of the data as given by an evaluator be compiled. However, some "renormalizations" are not trivial multiplication by a factor; for instance, when a detector-efficiency curve or the geometry of the experiment is involved. For such cases, see Corrections.

A data set which is renormalized by an evaluator is labeled with the status code RNORM. The older data set which is superseded by the later renormalization or reassessment is labeled with the status code OUTDT. Both must give a cross reference to the other data set as follows:

STATUS (OUTDT,10231002)

STATUS (RNORM,10231003)

Renormalization should not be done by the compiler except on the advice of the author.

Data translated from older libraries

Data which are converted from older data libraries are given a status code to indicate the library from which they were converted. Such data may not have all the required BIB information.

Unobtainable Data - see NODATA.

Correlated Data - see Interdependent Data.

SUMS

July 1988

Sums

Sums of 2 or more reactions can be expresses as a reaction combination using the separator '+' (see EXFOR S.R.9).

Examples:

- 1.) Single target nucleus; sum of reactions

REACTION ((28-NI-58(N,N+P)27-CO-57,,SIG)+
(28-NI-58(N,D)27-CO-57,,SIG))

- 2.) More than one target nucleus; more than one reaction

REACTION ((28-NI-58(N,P)27-CO-58,,SIG)+
(28-NI-60(N,T)27-CO-58,,SIG))

For mathematical correctness, certain REACTION combinations require that isotopic abundances be coded in SF8:

Example: REACTION ((28-NI-58(N,P)27-CO-58,,SIG,,A)+
(28-NI-60(N,T)27-CO-58,,SIG,,A))

Sum reactions such as absorption or nuclide production, where the individual competing reactions may not be known, cannot be coded using the form above.

Sums of reactions to isomeric states are coded using the separator '+' in the isomer field of the reaction product; see Isomeric States.

July 1988

TARGET

Target Nucleus

The target nucleus to be coded is the one to which the data refer; this is not necessarily the same as the actual material which was irradiated in the experiment.

If an isotopic mixture or a chemical compound was used as the experimental target, the data may, nevertheless, be given for one isotope, and that isotope should be coded.

If a reaction can occur, by energetic reasons, for only one of the isotopes in the irradiated target, that isotope should be coded as the target nucleus.

In these cases, compilers must take care that, if corrections for isotopic abundance have not been applied, one of the following modifiers is given with the quantity code:

A - for a natural isotopic mixture

(A) - for a natural isotopic mixture, where it is not clear whether the data were corrected for abundance

FCT - for an enriched target. (In this case free text explanation is necessary.)

In these cases the target description must be entered under the keyword SAMPLE.

The neutron as target nucleus, (e.g., for neutron-neutron interactions) is coded as 0-NN-1.

Codes valid for target nuclei are flagged in column 13 of Dictionary 27 (see EXFOR 7.16).

For elemental targets, see also Elements.

For compounds as targets, see also Compounds.

For coding rules see EXFOR 8.3 and 8.R.3.

Tautologies

Tautologies can be expressed as a reaction combination using the separator '=' (see coding rules EXFOR 8.R.9). Its use is optional, i.e., at the discretion of the compiler.

It may be used when a data set can be equally well described by two or more reactions which are identical in the energy range considered. If it is used, the sequence of the reactions should be such that the one with the narrowest definition (as outlined below) is given first.

Two types of tautologies are considered:

1. Below thresholds. For example, total scattering equals elastic scattering below the inelastic threshold.
2. Emission cross sections, for certain secondary energies. For example, γ emission cross section equals inelastic γ cross section for some γ -ray energies.

Broader definitions should, in general, only be used when two or more competing reactions are present. This rule seems to avoid any real cases of a tautology. However, where the author uses the broader definition to define the reaction, it may be useful to code both for purposes of identification.

The tautology formalism should not be used in the following cases:

1. When a data set extends beyond a known threshold, the broader definition, and only the broader definition, should be used. See also Thresholds.
2. Where a compiler has doubts about which quantity is actually given in a data set, the compiler must decide in favor of one of the possible codes.
3. In old papers obsolete designations such as "inelastic collision cross section" for nonelastic or "absorption" for (n,γ) may have been used. In these cases, the presently valid definition should be used. The author's designation may be given in free text.

See also Compounds.

July 1988

THERMAL NEUTRON ENERGIES

Thermal Neutron Energies

Thermal energy is defined as 2200 m/sec or 0.0253 eV or 20.43°C.

Cross sections given for a thermal reactor spectrum must be coded with:

- SPA - if the spectrum has a non-negligible epithermal part.
- MXW - if the result has been corrected for the epithermal part of the spectrum, or if the epithermal part is negligible.

In the Westcott formalism, a cross section averaged over a thermal reactor spectrum (effective cross section) is described as:

$$\hat{\sigma} = \sigma_0 (g + rs)$$

where σ_0 = cross section at 2200 m/sec.

g = ratio of Maxwellian to 2200 m/sec cross section

r = epithermal index: measure of the proportion of epithermal neutrons in the spectrum ($r=0$ for Maxwellian spectrum)

s = temperature dependent quantity given by:

$$s = \frac{2\sqrt{T}}{\pi T_0} - \frac{RI'}{\sigma_0}$$

where RI' = resonance integral minus the integral of the Maxwellian averaged cross section

If the cross section varies as $1/v$, $g = 1$ or:

$$\sigma_0 = \sigma_{MXW}$$

See also Spectrum Average.

Reference

C.W.Westcott, AECL-1101 (1960)

Thermal-Neutron Scattering

Theory: The scattering of slow neutrons (energies less than 0.1 eV), with matter depends on the atomic structure of the material (because the wavelength of slow neutrons is of the order of inter-atomic distances) and on the atomic dynamics in the scattering medium (because the energy of slow neutrons is of the same order as the chemical bonding energy and the energy of thermal motion of atoms in crystals and solids). At these energies, two types of scattering must be considered; nuclear scattering and magnetic scattering due to the interaction between the magnetic moment of the neutron and the magnetic moment of the electrons of the target.

Coding: For all scattering processes where molecular and crystalline forces are involved the code THS is used in REACTION SF3.

The sample temperature should be given using the data heading TEMP.

The crystal structure of the sample is given using the information-identifier keyword SAMPLE.

The following special processes are defined:

1. **Free-Atom Scattering.** Scattering by a free nucleus, originally at rest.

REACTION coding: FA in SF5 (Branch)

2. **Bound-Atom Scattering.** Scattering by a nucleus bound in a crystal lattice.

REACTION coding: BA in SF5 (Branch)

3. **Coherent Scattering.** Collective scattering by a regular arrangement of scattering centers with common physical properties which will ensure a constant phase relationship between waves scattered by different centers. That is, a single wave is produced with a resultant amplitude due to scattering by a set of particles as a whole.

REACTION coding: COH in SF5 (Branch)

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THERMAL-NEUTRON SCATTERING

4. Incoherent Scattering. Scattering by a non-regular arrangement of scattering centers which will lead to random phase differences by the scattered waves. That is, the incoherent scattering cross section is the sum of the section for the individual centers.

Isotopic Incoherence: due to a random distribution of different isotopes in the scattering target. If there is only one isotope in the target, there will be no isotopic incoherence.

Spin Incoherence: due to orientation of the neutron and nuclear spins. Spin incoherence may be eliminated by using polarized neutrons and polarized targets.

REACTION coding: INC in SF5 (Branch)

See also Scattering, Scattering Amplitude

References

I. I. Gurevich and L. V. Tarasov, *Low-Energy Neutron Physics*, North Holland Publishing Co., Amsterdam (1968)

W. Marshall and S. W. Lovesey, *Theory of Thermal Neutron Scattering*, Oxford University Press, London (1971)

THRESHOLD

July 1988

Threshold

A data set may extend beyond a threshold. For example, a data table resulting from a neutron-detecting experiment may actually give in a single data set:

1. elastic scattering below the inelastic threshold energy, and total scattering above the inelastic threshold energy;
2. total scattering below the ($n,2n$) threshold energy, and neutron production above the ($n,2n$) threshold energy.

In these cases the wider definition should be used, that is: in the first case, the table should be entered as total scattering; in the second case, as neutron production.

The compiler is not allowed to split the data set in two parts below and above the threshold.

When retrieving, for example, elastic scattering data, one should realize that it may also be worthwhile to retrieve total scattering, with $E_n \leq$ threshold energy.

If, however, as in (1.), above, the data table has been corrected for inelastic neutrons, or if the portion of inelastic neutrons measured is negligible, the data set may be given as elastic scattering.

See also Tautologies.

LEXFOR T.6

July 1988

TITLE

Title

Full title of work, document or experiment is given in free text. If the original title is not in English, only a literal English translation is given. Computer-compatible substitutes should be used where necessary (e.g., ALPHA for the Greek letter α).

Where no title is given, e.g., private communications, a title which describes the experiment may be provided by the compiler.

See EXFOR 8.T.1 for coding rules.

TOTAL

July 1988

Total

Total cross section

Definition: the sum of all energetically possible interactions.

REACTION Coding: TOT in SF3

Examples: (.....(N,TOT),,SIG
(.....(N,TOT),,WID

Sum-rules: Total = elastic plus nonelastic
= scattering plus absorption.

Note: At thermal energies, where a large portion of the total cross section may be due to crystal effects (thermal scattering), the sample structure should be given using the keyword SAMPLE, if provided by the author.

Total as distinct from partial: no code is given under REACTION for "total", except when it refers to the total cross section, see above. Instead, codes are given in the branch field for "partial" reactions.

Examples: (N,F),,NU = total $\bar{\nu}$
(N,F),PR,NU = prompt $\bar{\nu}$
(N,INL),,SIG = total inelastic scattering cross section
(N,INL),PAR,SIG = partial inelastic scattering cross section

Units

A datum or value is always a combination of a number and a unit. For example, 500 mb and .5 b is the same value. mb and b are units of the same dimension (or units group). Units of the same dimension can be converted into each other by multiplication with a numerical (dimensionless) factor.

Example: Angstrom and cm are units of the same dimension.

A quantity can have only one dimension, i.e.,

a quantity (REACTION code) can be combined with only one group of units. Or, data with different dimensions cannot have the same quantity code.

In general, in order to avoid errors in conversion, data are coded in the units given by the author. However, since the proliferation of non-standard unit codes is not desirable, for exotic unit codes, the compiler may choose to convert the data to standard units. This should be accompanied by a comment in the BIB section giving the relationship used for the conversion.

In Dictionary 36 (REACTION), each quantity code given is followed by a code indicating the dimension of the quantity. For example, 'E' means energy units (milli-eV, eV, keV, MeV, etc.), 'NO' means dimensionless (i.e., unit 'one').

The same dimension codes are also given in Dictionary 25 (Units), so that it is possible to check by computer whether a given quantity code is combined with a unit code which has the correct dimension. For example, the REACTION quantity code 'SIG' has the dimension 'B' and can only be given in units B, MB, etc., which also have the dimension code 'B'.

In Dictionary 25, a conversion factor is given for each unit code, which allows computerized conversion between different units of the same dimension.

See EXFOR, Chapter 5, for use of unit codes.

Special cases:

1. An angle given in degrees and minutes must be entered in two separate fields with the data heading 'ANG' repeated (see EXFOR 5.4).
2. If data are given in arbitrary units (ARB-UNITS), the quantity code is marked as "relative" by entering the modifier 'REL' in REACTION SF8. See Relative.
3. Errors must have the same dimension (not necessarily the same units) as the quantity to which they refer, or must be in percent.

UNITS

July 1988

4. PER-CENT is used only for errors and must not be used under the data-heading keyword DATA. If data were given using 'PER-CENT', the meaning of 'PER-CENT' in the error field would be ambiguous. Data given by the author in percent should be converted to NO-DIM by dividing the results by 100. If the DATA error is given in percent, this always means a percentage of the relevant DATA.
5. The unit SEE TEXT may be used in a MISC data field when no code from Dictionary 25 applies. It is explained in free text under MISC-COL. It must not be used with any other data heading.

See Miscellaneous.

Note: The compiler should avoid any carelessness in the use of units. This would jeopardize any automatic data processing. It is forbidden to set the light velocity $c=1$ or Planck's constant $h=1$ as is usually done in high-energy physics.

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