Nuclear Data Section
International Atomic Energy Agency
P.O.Box 100, A-1400 Vienna, Austria

Memo CP-D/647

Date: 10 June 2010
To: Distribution
From: N. Otsuka, V. McLane, O. Schwerer, S. Dunaeva
Subject: **1. Reaction Coding SF3-SF4**
2. Proposed renaming of LEXFOR Secondary Particles
3. Proposed revision and renaming of LEXFOR Particles
Reference: Memo CP-D/607, 622, 644

1. Proposed revision of the EXFOR Formats Manual Chapter 6. Reaction Specification

Following is update of the EXFOR Formats Manual section on Reaction SF3 and SF4 and to two LEXFOR entries **Particles** and **Secondary Particles**. The entry has been rearranged for clarity, for example notes have been moved to the appropriate section. Other than that, the main changes are:

- Deletion of the explanation about the branch code (DEF);
- Addition of explanation for unstable product nuclei (e.g., 4-BE-8) in SF4;
- Clarification of SF4 coding rule when a process code is coded in SF3.

2. Proposed renaming of LEXFOR Secondary Particles.

We propose to rename this entry to **Secondary Energy.**

3. Proposed revision of LEXFOR Particles (to be renamed to Outgoing Particles).

Also following is the proposed write-up for **LEXFOR Outgoing Particles**, which has been moved from **LEXFOR Particles**. The explanation of the use of the code (DEF) has been removed.

(Note that description about incident particles will be moved to another LEXFOR entry “Incident Particles”. See Memo CP-D/622.)

EXFOR Manual Chapter 6: Reaction field (proposed update for SF3 and SF4)

SF3. Process. In general, this field contains a process code or the particle(s) produced in the reaction with the exception of the reaction product (which is given in SF4), or a combination of the two (see Coding rules, following).

Coding: This subfield contains one of the following:

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

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

b) A particle code from Dictionary 33 with an "allowed SF3 flag" (3) of 2, which may be preceded by a multiplicity factor with a value of 2→99.[1]

Examples: A
4A

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 6.5.

(Explanation of (DEF) removed.)

c) For particles heavier than α, a nuclide code in the form *Z-S-A-X* (see page 6.2, but the mass number may not have the value zero). No multiplicity factor is allowed; instead the nuclide code is repeated, if necessary.

Examples: `8-O-16`
`8-O-16+8-O-16`

d) Combinations of a), b) and c), with the codes connected by '+'. Outgoing particles are ordered starting with the *lightest*[2] at the left of the subfield, 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, Outgoing Particles**).

Examples: `HE3+8-0-16`
`X+N`

[1] In the few cases where the multiplicity factor may exceed 99, the ***Variable Number of Emitted Nucleons Formalism*** may be used, see page 6.9.
[2] Lowest Z, then lowest A.

SF4. Reaction Product**.** 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 the branch code SEQ is given in SF5, 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 product of the last process (*e.g.*, break-up).

***Examples*:**

`(.…(…,D+N)2-HE-4,SEQ,…)`	Emission of deuteron followed by break-up of ^{5}He
`(.…(…,D+X),SEQ,…)`	Emission of deuteron followed by unspecified process
`(.…(…,D+F),SEQ,…)`	Emission of deuteron followed by fission.

The branch code SEQ may not be used when there are only two products in SF3 and SF4.

b) For a product nuclide that is unstable and breaks up with the emission of a particle (e.g., 8Be → 2α), if the reaction is dependent on the nuclide before break-up, the pre-breakup particle may be coded in SF4. See **LEXFOR Light-Nuclei Reactions (Z<6)** for a complete discussion.

c) There is no reaction product if a nuclear quantity is given (*i.e.*, SF2 contains the code 0).

d) There is no reaction product if the reaction specifies a resonance parameter (defined in Dictionary 236 by using the resonance flag '.').

e) There is no reaction product if the reaction is measured for a target of natural isotopic composition, excluding scattering.
Examples: `(40-ZR-0(N,G),,SIG)`

f) If a process code is required for SF3, then there are special rules for what is given in SF4.

1. For total (TOT), absorption (ABS), nonelastic (NON), and total charge change (TCC) cross sections, SF4 is blank. See LEXFOR, **Total**, **Absorption**, **Nonelastic, Reaction Mechanisms**, and **Cross Sections**, respectively, for more information.
2. For fission (F) and fusion (FUS), SF4 is blank or contains nuclide code, a variable product (ELEM, MASS, ELEM/MASS) or variable number of particles (NPART).
3. For the scattering processes, total scattering (SCT), elastic scattering (EL), inelastic scattering (INL), and thermal scattering (THS), the nuclide code in SF1 is also coded in SF4 except for the isomer code, which can be different for (de-)excitation of the isomeric state (see LEXFOR, **Scattering**).
4. Likewise for pair production (PAI), the nuclide code in SF1 is also coded in SF4.

5. For production quantities where SF3 contains only the code X, SF4 gives the particle/nuclide considered:
   - either a nuclide code or a variable product (ELEM, MASS, ELEM/MASS),
   - or a variable number of particles (NPART).

   See LEXFOR, **Production and Emission Cross Sections**.

Coding: This subfield:

a.) either is blank, the following comma is always present.

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

b.) or contains a code in the form *Z-S-A-X*, as described on page エラー! ブックマークが定義されていません。.

If light particles or gammas are defined as the reaction product, these are coded using the *Z-S-A* formalism *(i.e.*, the particle codes N, G, P, *etc*., are not used in SF4).

Examples: (82-PB-0(P,X)0-NN-1,,DA/DE) double differential neutron production cross section
`(28-NI-0(N,X)0-G-0,,SIG)` γ production cross section

For scattering on a target nucleus which is a natural isotopic mixture (A=0) (see **LEXFOR, Scattering**), A=0 is given for the product nucleus; otherwise, A=0 is not used in 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, without parenthesis, *e.g.*, M1+M2/G. The code T is used in an isomeric ratio to denote the sum over all isomers (see page エラー! ブックマークが定義されていません。). (See **LEXFOR, Isomeric States**).

Examples: `(92-U-235(N,F)54-XE-124,CUM,FY)`
`(51-SB-123(N,G)51-SB-124-M1+M2/T,,SIG/RAT)`

c.) or, if the reaction product is entered into the data table using the data headings ELEMENT, MASS, and/or ISOMER (see page エラー! ブックマークが定義されていません。, Variable Nucleus), it contains one of the following codes:

ELEM if only the data heading ELEMENT is used in the data table,
MASS if only the data heading MASS is used in the data table,
ELEM/MASS if the data headings ELEMENT and MASS are used in the data table.

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

Use of this formalism is restricted to those cases given on page エラー! ブックマークが定義されていません。.

d.) or, if the number of particles emitted is entered into the data table using the data heading PART-OUT, it contains the code NPART.

Example: `(79-AU-197(92-U-238,X)NPART,NUM,SIG,HF)` Cross section for a given number on heavy fragments emitted; the number of fragments is given in the DATA or COMMON section under the heading PART-OUT.

Note on SF3 and SF4

For reaction codes allowed in the coding of neutron-induced reactions for light targets, see **LEXFOR Light-Nuclei Reactions (Z<6)**.

LEXFOR Manual Proposed new entry: Outgoing Particles.

Outgoing Particles

(See also **Secondary Energy**).

Outgoing particles participating in a reaction

Particles resulting from the REACTION to be defined are given in SF3 and SF4.

Sometimes, data are given for **partial reactions where the sequence of outgoing processes/ particles is defined**, for example:

total (n,np) = partial (n,np) + 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:

Example:
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.

1. Excitation of excited level(s) that decay by fission:
   (n,n'f) cross section: (N,N+F),SEQ,SIG
   (n,γf) cross section: (N,G+F),SEQ,SIG
2. 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.

For general rules on the coding of sequence of process/particle codes in REACTION SF3 and SF4 see EXFOR Exchange Formats Manual Chapter 6.

For correlation data on secondary particles, see **Differential Data**.

Particle Considered

Definition: The particle considered is the particle to which a given function refers, *e.g.*, an angular or energy distribution, or a reaction to a specific particle group. In a reaction where only one outgoing particle is specified in SF3, the particle considered is assumed to be that particle, unless there is an entry in SF7 (Particle Considered).

Outgoing Particles (continued)

When the quantity given refers to a specific secondary particle (*e.g.*, angular distributions), the particle considered must be entered in reaction SF7 if:

- more than one particle is given in reaction SF3,
- the particle considered is not given in reaction SF3,
- the quantity is a function of more than one secondary particle.

See EXFOR Exchange Formats Manual Chapter 6 for coding rules.

Examples:

a)	`(...(P,P+A)...,PAR,SIG,A)`	partial cross section for a specific group.
b)	`(...(N,P)2-HE-4,,DA,A)`	angular distribution of α particles.
c)	`(...(P,N+P)...,,DA/DA,N/P)`	double differential cross section, $d^2\sigma/d\Omega_n/d\Omega_p$.

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 (or nuclide) for which the production is measured (SF4). See **Production Cross Sections**.

Particles/Radiations Detected

Particles actually detected in the experiment may be identified using the keyword PART-DET (see EXFOR Exchange Formats Manual Chapter: 7 PART-DET 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 Chapter 7: RAD-DET 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 33 for a list of permissible codes.

Outgoing Particles (continued)

Distinguish the different codes:

`DG` - decay γ-rays
`G` - other γ-rays
`B-` - decay electrons (β^-)
`B+` - decay positrons (β^+)
`ICE` - internal conversion electrons
`E` - other electrons

Particle pairs

If the angle given is the angle between a secondary particle pair or a secondary energy is given as the center-of-mass energy of the relative motion of a particle pair emitted in the reaction, the particles are specified in SF7.

Example: `REACTION (…(…,…)…,,DA,N+P)` angular distribution of n-p pair.

`(…(…,…)…,,DE,P+A)` energy spectrum on p-α pair.

Variable number of emitted particles.

If the data table contains yields or production cross sections as a function of the number of secondary particles, and the number of particles is entered as a variable in the data table, SF4 of the reaction keyword contains the code `NPART` and SF5 contains the code `NUM`:

See also Exfor Exchange Formats Manual Chapter 6.

Example:

```
BIB
REACTION   (…(…,X)NPART,NUM,…)
…
ENDBIB
NOCOMMON
DATA
EN         PART-OUT   DATA
MEV        NO-DIM     B
…           2.         …
…           3.         …
…           …          …
ENDDATA
```

Residual Nucleus Production

In some cases, a given residual nucleus may be produced by more than one reaction channel, *e.g.*, (p,α) and (p,2n2p), 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,2n2p)), the process code `X` is entered in SF3 of the `REACTION` string. See **Production Cross Sections**.

(Explanation of (DEF) removed.)

Distribution:

blokhin@ippe.ru
chiba@earth.sgu.ac.jp
claes.nordborg@oecd.org
emmeric.dupont@oecd.org
ganesan@barc.gov.in
gezg@ciae.ac.cn
hongwei@ciae.ac.cn
jhchang@kaeri.re.kr
j.roberts@iaea.org
kaltchenko@kinr.kiev.ua
katakura.junichi@jaea.go.jp
kato@nucl.sci.hokudai.ac.jp
kiralyb@atomki.hu
l.vrapcenjak@iaea.org
manuel.bossant@oecd.org
manokhin@ippe.ru
mmarina@ippe.ru
mwherman@bnl.gov
nicolas.soppera@oecd.org
nklimova@kinr.kiev.ua
n.otsuka@iaea.org
nrdc@jcprg.org
oblozinsky@bnl.gov
ogritzay@kinr.kiev.ua
otto.schwerer@aon.at
pronyaev@ippe.ru
r.forrest@iaea.org
samaev@obninsk.ru
s.babykina@polyn.kiae.su
scyang@kaeri.re.kr
s.dunaeva@iaea.org
stakacs@atomki.hu
stanislav.hlavac@savba.sk
taova@expd.vniief.ru
tarkanyi@atomki.hu
varlamov@depni.sinp.msu.ru
vlasov@kinr.kiev.ua
vmclane@optonline.net
v.zerkin@iaea.org
yolee@kaeri.re.kr