Partial Reaction and Isomer Production

(N. Otsuka, 2013-04-15, CP-D/781 Rev.)

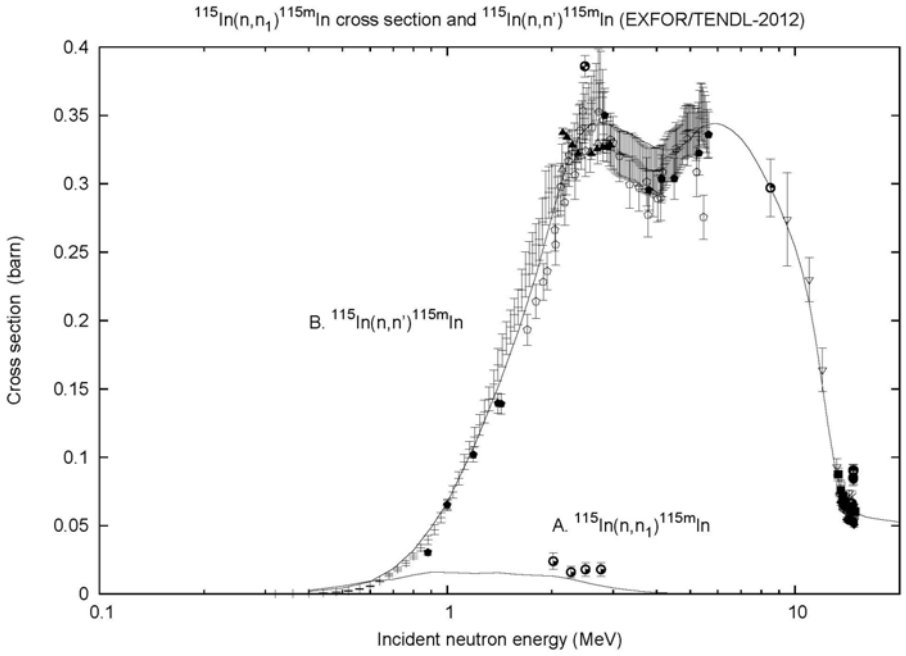
The partial reaction and isomer production must be properly distinguished.

Example: ^{115}In(n,n')^{115m}In (E_x = 336 keV, $T_{1/2}$ = 4.5 hrs) cross section for

A. direct population of ^{115m}In by inelastically scattered neutrons resulting to this excitation level;
B. "A" plus feeding from higher excitation levels to ^{115m}In.

Experimentally "A" can be determined by detection of the outgoing neutrons, while "B" can be determined by detection of gamma-ray transition from ^{115m}In to ^{115g}In .

The next figure shows experimental and evaluated cross sections for both cases. We observe significant difference above the threshold energy of the 2nd level excitation (~ 600 keV).



I believe that the cross sections for A and B should be coded as:

A. `(49-IN-115(N,INL)49-IN-115,PAR,SIG)`, E-LVL=336 keV
B. `(49-IN-115(N,INL)49-IN-115-M,,SIG)`, $T_{1/2}$=4.5 hrs under `DECAY-DATA`.

However the underlined phrase of the following statement in LEXFOR "**Partial Reactions**" does not allow us to treat the direct population of an isomeric state (*e.g.*, the quantity "A") as a partial reaction:

> **Definition**
> A partial reaction, as defined for EXFOR, is a reaction leading to or proceeding through a specific level or emitting a specific gamma or particle group, and excludes isomeric states.

In order to differentiate two cases appropriately, the following change (*italicized part*) in LEXFOR is proposed:

Definition
A partial reaction, as defined for EXFOR, is a reaction leading to or proceeding through a specific level or emitting a specific gamma or particle group, and excludes *production of an isomeric state fed from higher levels to the isomeric state.*

Differences between these two cases are summarized below:

	A. ^{115}In(n,n$_1$)^{115m}In	**B. ^{115}In(n,n')^{115m}In**
Experiment		
Detected particle	outgoing neutrons	IT transition gammas
EXFOR		
REACTION (SF4-SF6)	`IN-115,PAR,SIG`	`IN-115-M,SIG`
E-LVL	`336 KEV`	(not given)
DECAY-DATA	(not given)	`4.5 HOUR`
ENDF-6		
MF	3 (cross section)	10 (production cross sections for radionuclides)
MT	51 (Production of a neutron, with residual in the 1st excited state)	4 (Production of one neutron in the exit channel)

The following changes (*italicized part*) in LEXFOR "**Reaction Product**" and "**Isomeric State**" are also proposed:

1. LEXFOR "Reaction Product"

Definition
…
If no isomer code is given *without* `PAR` *in SF5*, then the reaction is to a nucleus in the ground state and ~~*includes decays from*~~ *all* isomeric states (i.e., *all excitation levels)*. If an isomer code is given, a ~~*partial*~~ reaction for the formation of that isomeric state is given, and, in general, ~~*decays from higher*~~ *the other* isomeric states are not included. (See **Isomeric States**).

Examples:
`(63-EU-151(N,G)63-EU-152,,SIG)`
Sum of production cross sections for ^{152g}Eu (13.5 years), ^{152m1}Eu (9.3 hours), and ^{152m2}Eu (96 min)

`(63-EU-151(N,G)63-EU-152-M1,,SIG)`
Production cross sections for ^{152m1}Eu (9.3 hours).

2. LEXFOR "Isomeric State"

…
Coding
Where a nucleus has a known metastable state, *(1) the target nucleus in an isomeric state, and (2) an isomeric state populated by direct production as well as by transition of higher levels to the isomeric state* are indicated by an isomer code following the isotope code, *e.g.*, `95-AM-242-M1`. (See EXFOR Exchange Formats Manual Chapter 6: Coding of nuclides and compounds)

~~Partial reactions leading to~~ Isomeric states are coded by entering the isomer code in `REACTION` SF4. Sums and ratios are given algebraically.

Examples:
```
(…(…,…)Z-S-A-M1,,SIG)
(…(…,…)Z-S-A-M/G,,SIG/RAT)
(…(…,…)Z-S-A-M1+M2,,SIG)
```

Isomer codes ~~*are used in SF4 only for partial reactions. They*~~ must not be used when the total cross section (including isomeric decay) is measured, *i.e.*, the extension `G+M` is never used.
…

In this opportunity, data sets coded with `G+M` or `M+G` in `REACTION` SF4 were extracted (Appendix B). These are illegal and must be deleted.

Appendix A. Definition of isomeric state and metastable state (LEXFOR)

An **isomeric state** is defined as a long-lived energy state, where long-lived is, generally, accepted as having a measurable half-life greater than ~0.1 sec.

A **metastable state** is an excited state having a half-life of the order of 0.1 seconds or longer. The term 'isomeric states' refers to the ground and all known metastable states.

Appendix B. Data sets with illegal combination of isomeric flags in SF4

Subentry	REACTION
20658.009	`27-CO-59(N,G)27-CO-60-G+M,,RI/SUM,,RNV`
20658.023	`55-CS-133(N,G)55-CS-134-G+M,,RI/SUM,,RNV`
21008.003	`(92-U-235(N,F)41-NB-97-G+M,IND,FY/SUM,,MXW)/` `(92-U-235(N,F)MASS,CHN,FY,,MXW)`
22132.004	`27-CO-59(N,2N)27-CO-58-M+G,,SIG`
31481.008	`40-ZR-90(N,A)38-SR-87-M+G,,SIG`
41240.013	`27-CO-59(N,2N)27-CO-58-M+G,,SIG`
A0304.004.S	`46-PD-104(P,N)47-AG-104-G+M,,SIG`
A0304.011.S	`46-PD-106(P,N)47-AG-106-G+M,,SIG`
A0335.009	`47-AG-109(HE3,N)49-IN-111-M+G,,SIG,,A,EXP`
O0243.002.4	`26-FE-58(P,N)27-CO-58-G+M,,SIG`
O0243.003.4	`26-FE-58(P,N)27-CO-58-G+M,,SIG`

O0560.002.T	94-PU-239(P,F)55-CS-134-M+G,,SIG
O0562.002	92-U-0(P,F)50-SN-113-M+G,IND,SIG
O0573.003	92-U-0(P,F)51-SB-120-M+G,IND,SIG
O0573.006	92-U-0(P,F)51-SB-124-M+G,,SIG
O0573.010	92-U-0(P,F)51-SB-126-M+G,IND,SIG
O0578.018	(92-U-0(P,F)61-PM-148-M+G,IND,SIG)/ (92-U-0(P,F)MASS,,SIG,,,EVAL)
O0594.003	92-U-235(P,F)39-Y-90-M+G,IND,SIG
O0594.005	92-U-235(P,F)39-Y-91-M+G,IND,SIG
O0594.011	92-U-238(P,F)39-Y-90-M+G,IND,SIG
O0594.013	92-U-238(P,F)39-Y-91-M+G,IND,SIG
O0708.007	93-NP-237(P,F)55-CS-134-G+M,IND,SIG
O0721.003	92-U-235(P,F)55-CS-134-M+G,IND,SIG
O0721.006	92-U-233(P,F)55-CS-134-M+G,IND,SIG
O0768.204	82-PB-0(P,X)82-PB-195-M+G,IND,SIG

Additional comments to the list

1. O0573.003, 010, O0578.018, O0708.007, O0721.003, 006
   SF5: Delete IND. No precursor exists.

2. O0573.003, 006, 010
   They are measured production cross sections for longer lived isomers multiplied by isomeric ratios reported by E.Hagebo (1967). Delete these data, or at least add DERIV in SF9 with an appropriate explanation under the keyword ANALYSIS.

Remarks on Partial Reactions vs. Isomer Production

(O. Schwerer, 2013-04-18, CP-C/417)

I propose to include the following issues in the discussion of the proposal of CP-D/781Rev.:

1) How are we going to code those cases where the partial cross section is equivalent to the isomer production? E.g. in the example of the above memo, the reaction ^{115}In(n,n')^{115m}In below the threshold energy of the 2nd level excitation?

We should avoid using two different "spellings" for the same data. Neither should the way of coding depend on the measurement method, if the result is the same quantity.

2) Do we have a similar rule for the excitation of levels which are not metastable, or should we have one?

3) Proposed new wording in LEXFOR "Isomeric States": CP-D/781Rev says

"….. Where a nucleus has a known metastable state, *(1).... , and (2) an isomeric state populated by direct production as well as by transition of higher levels to the isomeric state* are indicated by an isomer code following the isotope code...."

I think we should be more explicit to avoid misunderstandings. If the intention is to say that the isomer code can be used only when the state is actually produced both directly and by decay of higher states, a sentence should be added like
"If the isomeric state is produced only directly, without transition from higher levels, the isomer code must not be used. Instead, the reaction is to be coded with SF5=PAR."

Another exception may have to be added here if we decide e.g. to use the isomer code when both reactions are equivalent (see item 1 above).