Memo CP-D/180

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To: Distribution

From: O. Schwerer

Subject: Coding of IND and CUM in REACTION SF5

Reference: Memo CP-A/57, item 3.
Memo CP-D/175, page 2, first paragraph

We feel that there is a major difference in interpretation of the meaning of the codes CUM and IND between CAJaD and NDS and would like to clarify this at the forthcoming data centres' meeting. A consistent usage of these codes is important, e.g. for applications like plotting of comparable Exfor data from different entries. Apart from charged particle cross sections, the other main data area where these codes are used is fission product yields; in our understanding CUM and IND should mean the same thing in both fields of application.

In our opinion, the following "rules" should be borne in mind generally to achieve consistent coding of REACTION:

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If the same quantity is measured by 2 different experimental methods, this difference should be reflected under the keywords METHOD, DETECTOR etc., but the REACTION code must be the same. This principle is basic to the REACTION coding in Exfor.

If an (A,2N) cross section is measured (example in CP-A/57) not by activation but by neutron counting, the same quantity is measured. Consequently, N must not be given in SF7 and IND must not be given in SF5. The difference of measurement methods (activation vs. neutron counting) must show up only under the appropriate keywords (in this case probably METHOD, PART-DET, DETECTOR).

SF7 is used only to point to one of several outgoing particles if it must be specified to which one a differential cross section refers to, e.g. (A,N+P),,DA,N = differential c.s. with respect to neutrons; (A,N+P),,DA,P = differential c.s. with respect to protons; but (A,2N),,DA without SF7 because there is only one kind of outgoing particles (=neutrons). SF7 is the particle considered, i.e. to which the code DA refers: it is given only when necessary to define the quantity given. The particle detected is given separately under the BIB keyword PART-DET.

If, besides (A,2N), the reaction (A,N+P) is energetically possible, too (case 2 in CP-A/57), this case must not be compiled (A,2N),CUM,SIG because (A,N+P) is a different reaction: (A,N+P) cannot be compiled as (A,2N).

Let us consider this (α,2n) example in more detail.

Given the reaction

[Z,A](A,2N)[Z+2,A+2] followed by β^+-decay to [Z+1,A+2].

(Most of the following is, of course, only applicable for suitable decay schemes and half-lives.)

1) Activation method:

a) Measuring the radioactivity of the nucleus [Z+2,A+2]: in our case (β^+-activity of [Z+2,A+2]), the (α,2n) reaction will be the only channel to produce the nuclide [Z+2,A+2] when bombarding [Z,A] with α particles. Therefore this measurement yields the "clean" (α,2n) cross section to be coded

[Z,A](A,2N)[Z+2,A+2],,SIG without any code in SF5.

b) Measuring the activity of the daughter nuclide [Z+1,A+2].
This is produced

(1) through β^+-decay of the reaction product of the (α,2n) reaction

(2) directly through the reaction
[Z,A](A,X)[Z+1,A+2]
with (A,X) meaning the sum of all energetically possible channels leading to [Z+1,A+2], in this case (α,np) + (α,pn) + (α,d).

If the measurement, by some means depending on the decay scheme and the experimental arrangement, excludes the production through β-decay (1) above, this is coded

[Z,A](A,X)[Z+1,A+2],IND,SIG. *)

If the measurement includes both (1) and (2), it is coded

[Z,A](A,X)[Z+1,A+2],CUM,SIG.

It cannot be coded

[Z,A](A,2N)[Z+2,A+2],CUM,SIG

because the (A,N+P) reaction is not a contribution to the (A,2N) process.

2) Neutron counting:
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a) If it is made sure, by the experimental technique, that only events with 2 outgoing neutrons are counted (and reactions with 3 or more outgoing particles are excluded energetically), the measured quantity is the same as in 1a) above and must be coded the same way:

[Z,A](A,2N)[Z+2,A+2],,SIG.

b) Neutron production: neutron counting including all reactions with at least 1 neutron in the exit channel. If the energy is high enough to permit more reactions than just (α,n), this is coded

[Z,A](A,X)0-NN-1,,SIG

with (A,X) = sum of (α,n), (α,np), (α,2n), etc.

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*) If there is actually no contribution from (α,d), this should be coded [Z,A](A,N+P)[Z+1,A+2],,SIG without IND, because the "explicit" reaction (A,N+P) automatically excludes production through (A,2N) and following β-decay.

Conclusion
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Following these rules, the usage of CUM for explicit reactions like (A,2N), (P,G) etc. makes no sense; and for a reaction (SF1-SF4) where CUM cannot be used, IND must not be used either. (See CP-D/175, top of page 2).

There are plenty of correct examples in recent entries from CAJaD where the difference between IND and CUM is essential, e.g. in subentry A0344.017:

13-AL-27(P,X)10-NE-22,IND,SIG,,EXP and
13-AL-27(P,X)10-NE-22,CUM,SIG,,EXP.

In general, CUM and IND should be used only if there are several reaction channels possible - which all fit under the process coded in SF3 - to produce the product nuclide coded in SF5.

Strictly speaking, this is fulfilled only for SF3 = 'F' or = 'X'; for a sum of various particles like '3N+4P', there is no room left to include production through β-decay because the number of outgoing protons and neutrons are fixed individually.

Unfortunately, the 2 codes

13-AL-27(P,X)10-NE-22,IND,SIG and

13-AL-27(P,2N+4P)10-NE-22,UND,SIG

describe the same reaction, and both codes are legitimate. This has developed historically although it violates the basic rule that each quantity should have a unique REACTION code.

This somewhat unfortunate situation sometimes gives rise to the mistake to include IND also in the second version of coding where it is redundant, e.g.:

13-AL-27(P,2N+4P)10-NE-22,IND/UND,SIG (not correct).

We checked also the usage of IND and CUM in existing charged particle entries from all compiling centres. Although in most cases there is 'F' or 'X' in SF3, there is still an appreciable number of subentries (particularly in B-entries) with explicit channels in SF3. There may be several explanations for this in addition to the one discussed above; one possibility is that in a publication a table may be headed "all cross sections are independent" and the compiler enters them all with 'IND' in SF5. In Exfor, however, IND may be entered only in those cases where there is, at least in principle, a cumulative cross section for the same reaction (SF1 - SF4) to be distinguished. (This is similar to the case

where a table of activation cross sections is headed "in all cases the production of the ground state was measured" and the compiler would enter them all with -G in SF4. This coding is, of course, correct only for those cases where there actually is a metastable state; the compiler may have to check this in every case by himself.) In other cases, I suspect that CUM actually was used in place of M+, perhaps because the author used the expression 'cumulative'.

In the long run, we would like to clean up also old charged particle entries in this respect in order to achieve consistency, to make Exfor more suitable for plotting and other automatic applications. Befor doing this, we would like to discuss the matter in detail with the other centres.