Memo issued on behalf of
National Nuclear Data Center
Brookhaven National Laboratory
USA

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To: Distribution
From: O. Schwerer

Subject: **Usage of RAD-DET and its relation to DECAY-DATA and PART-DET**

Recently the question was raised how the keyword RAD-DET should be used, and for what situations it is needed.

We checked the relevant descriptions in the Exfor Manual and in LEXFOR, including those for the related keywords DECAY-DATA and PART-DET. Most entries dealing with measurements of radiation use one or more of these keywords (except some which measure only one type of radiation which can unambiguously be recognized from the REACTION code). As these three keywords are related, we have to consider their usage together.

Then we checked the actual usage of RAD-DET in the various service areas (=compilation centres) and found extreme differences in how often RAD-DET is used. Most of these differences cannot be explained by differences in the typical data types compiled (which do exist) but only by a different interpretation of the prescriptions of the manual and of LEXFOR. This finding confirms the need for clarification.

Our result can be summarized as follows (see below for details):

- There are certain types of experiments where RAD-DET must be used to give the necessary information in a clear way in coded form. They are, however, not very frequent.

- There are, on the other hand, many entries in the master file where RAD-DET is used but gives only redundant information, i.e. duplicating information which is already given in DECAY-DATA, in spite of the fact that such redundant usage is actually discouraged in the present wording in LEXFOR.

- Presently, our rule is that, whenever RAD-DET is used, DECAY-DATA must be given also.
We propose to allow exceptions to this rule in well-defined cases (namely, when no numerical decay data information at all is given).

- Presently, the radiation type field must not be omitted in RAD-DET. We propose to allow its omission. Furthermore, we propose a clarification on when both, the half life field and the radiation field in DECAY-DATA may be omitted (namely, only when decay data information in free text is following).

See further below for details and explanations.

1. Difference between RAD-DET, PART-DET and DECAY-DATA

DECAY-DATA is used to specify half-live, radiation type, energy and abundance (or some of these) of the radiation(s) measured and used by the authors to determine the quantity specified under REACTION. Only values actually used and specified by the authors may be given in coded form. In most activation measurements, all relevant data can be given under this keyword. In general it is not necessary to specify separately what radiation was measured, because DECAY-DATA (in spite of this name) is **not** used to give general decay information taken by the compiler from other sources and independent of the present measurement.

PART-DET is used mainly to specify prompt particles measured which are not products of radioactive decay, when it is not obvious from the REACTION code. However, the code DG (decay gammas) can also occur here, e.g. when the decaying nuclide is not specified, or when the compiler wants to stress that both prompt and decay gamms were measured:
PART-DET (G,DG)

RAD-DET is used to specify the radiation detected when it is not obvious from REACTION and/or DECAY-DATA. Typical examples are: not the reaction product (from REACTION SF4) was measured but its decay product; or a fission product (not specified in SF4 nor under ELEMENT/MASS) was measured to determine a fission quantity.
However, when e.g. decay gammas coming from the product given in SF4 are measured, and the data of these gammas are given anyway under DECAY-DATA, coding of RAD-DET is redundant and should be avoided. Once these data are given in DECAY-DATA, it is understood that these gammas were measured and used to determine the cross section.
Real examples for both "good" and "redundant" use of RAD-DET are given further below.

2. Actual usage of RAD-DET in the various Exfor areas

Area	**# of entries using RAD-DET**	**Total # of entries in area**	**Comments**
1	5	out of 4220	All justified
2	14	out of 3031	3 of them justified
3	2	out of 1414	1 redundant, 1 justified (DECAY-DATA possibly incomplete)
4	0	out of 1526	
A	171	out of 1253	Probably most of them redundant [*])
B	132	out of 180	Probably most of them redundant [*])
C	4	out of 1705	All justified
D0 (NDS)	5	out of 601	3 justified, 2 redundant
D4 (ATOMKI)	54	out of 222	Probably most of them redundant [*])
D5 (UkrNDC)	0	out of 73	
D6 (India)	2	out of 94	1 of them justified
E	11	out of 813	6 of them justified

F	2	out of 1006	Both redundant
G, J, K, L, M	0	out of 1056	
O	171	out of 1733	Probably most of them redundant [*])
P	2	out of 144	Both justified
R	24	out of 52	Probably most of them redundant [*])
S	0	out of 55	
T	2	out of 280	Both justified

[*]) Some (randomly selected) entries were checked, in all these cases RAD-DET is redundant.

3. Relevant paragraphs in the Exfor Manual and LEXFOR

(Direct quotations from Manual and LEXFOR are in *italics*. ***Bold*** characters as in original.
Passages stressed for the purpose of this memo are in *blue*. Proposed additions are in ***red.***)

[3.1] Manual, DECAY-DATA

DECAY-DATA. *Gives 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***.

1. If the keyword RAD-DET is used, an entry should also be made for DECAY-DATA
except if neither half-life nor radiation energy nor intensity are given, neither in coded form nor in free text.
Also, if decay flags appear in the data section, they must be linked to an entry under DECAY-DATA, see below. Otherwise, its presence is optional, and free text or coded information, with or without free text, may be given.
If the keyword DECAY-DATA is present, the keyword HALF-LIFE may not be used. See also ***LEXFOR, Half-Lives***.

2. 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).

.....

Half-life field. Contains the actual half-life of the nuclide specified, coded as a number,.....
This field may be omitted, ...
.....

Radiation field. Consists of three subfields. This field may be omitted,
.....

Note that both the half-life and the radiation fields may be omitted, therefore a DECAY-DATA entry giving only the nuclide is legal. This is meaningful only when decay data information is given in free text, e.g. when it is not given by the authors but it was only assumed by the compiler.

Therefore the following addition is proposed:

Omission of both, half-life field and radiation field, is permitted only if decay data information in free text is following. Otherwise RAD-DET should be used instead. The same applies if only nuclide and radiation type are given but neither half-life nor radiation energy nor intensity.

[3.2] LEXFOR, Decay Data

.....

Decay data are entered:
in order to define an isomeric state, or
when used as basic parameters for deducing the data given in the DATA section.

.....

Only the values used by the author to obtain the data *should be entered in coded form.*
Values assumed by the compiler may be entered in free text only.

[3.3] Manual, PART-DET

PART-DET. Gives information about the particles detected directly in the experiment. *Particles detected in a standard/monitor reaction are not coded under this keyword. See also* ***LEXFOR, Particles****.*

1. Presence is optional, but, if the particle is not evident from the REACTION code, it must be given, either under this keyword, or under RAD-DET or DECAY-DATA. If the keyword is present, coded information is obligatory.

.....

[3.4] LEXFOR, Outgoing Particles, sub-section "Particles/Radiations Detected"

Particles actually detected in the experiment may be identified using the keyword PART-DET (see EXFOR 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.....

If the particle detected may be attributed to the decay of a specific nucleus, it may be coded using the keyword RAD-DET. . . However, the keyword RAD-DET should not be used to duplicate information also coded under the keyword DECAY-DATA.

[3.5] Manual, RAD-DET

RAD-DET*. Gives information about the decay radiation (or particles) and nuclides observed in the reaction measured. See also* ***LEXFOR, Particles****.*

1. ***If the decay radiation detected is not evident from the DECAY-DATA code****, it must be specified either under this keyword, otherwise presence of this keyword is optional. If the keyword is present, it must have coded information, with or without free text.*
If this keyword is present the keyword DECAY-DATA must also be present, ***unless no actual decay data information at all can be given (half-life and/or radiation energy and/or radiation intensity, in coded form or in free text).***

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

*Flag Field: a code of the form (n.), where n has the numerical value which appears in the data section under the data heading DECAY-FLAG. This field may be omitted, in which case its' parentheses are also omitted. See also **LEXFOR, Flags**.*

Nuclide field. A code of the form Z-S-A-X, see page 6.2.

Radiation field: One or more codes from Dictionary 33 with a D in the 1 position of the allowed subfields flags, each separated by a comma.
Proposed addition: ***This field may be omitted, in which case the closing parenthesis immediately follows the nuclide.***
.....

Consequently, an additional example should be added:

g.) RAD-DET (12-MG-29)

Note that, presently, neither the nuclide nor the radiation field may be omitted. (If the nuclide is not given, the keyword PART-DET should be used.) However, there are cases where only the nuclide whose radiation is measured is specified but not the radiation type. For such cases, specifying the nuclide alone should be allowed.

4. Examples of good use of RAD-DET

4.1)

```
SUBENT      10018001
BIB              16       27                              10018001    2
......
DECAY-DATA (98-CF-253,17.8D,B-)                              10018001   21
RAD-DET    (98-CF-252,A)                                    10018001   22
         (99-ES-253,A)                                      10018001   23
…
ANALYSIS   Measured ratios fitted to equations of growth and decay
         by least squares fit.
…
SUBENT      10018002
BIB              2        3                               10018002    2
REACTION   (98-CF-252(N,G)98-CF-253,,SIG)                        10018002    3
.....
```

Reaction product is Cf-253. However, authors measured alpha decay of Es-253 which is product of beta decay of Cf-253. Also, alpha decay of target nucleus Cf-252 was measured.

The other area 1 usages of RAD-DET are similar cases (10294, 10363, 10376, 12250).

4.2)

```
SUBENT      C0092004
BIB              3        6                               C0092004    2
REACTION   (51-SB-121(P,4N)52-TE-118,,SIG)                      C0092004    3
DECAY-DATA (52-TE-118,6.0D)                                  C0092004    4
         (51-SB-118-G,3.6MIN,DG,1229.6,0.025)                 C0092004    5
RAD-DET    (51-SB-118-G,DG) 118Te activity estimated from        C0092004    6
```

```
          measured gamma count rate of 118Sb in secular        C0092004    7
          equilibrium with the parent.                       C0092004    8
```

4.3)

```
SUBENT       C0498005
BIB               5        7
REACTION   (37-RB-85(P,N)38-SR-85-G/M,,SIG/RAT)
SAMPLE     Rubidium chloride, enriched to 99.54% in 85Rb,
           loaded into thin aluminum tube.
DECAY-DATA (38-SR-85-M,68.0MIN,EC,,0.137)
          (38-SR-85-G,65.0D,EC,,1.0)
RAD-DET    (38-SR-85,XR)
```

Here, DECAY-DATA is used to specify decay path (EC) and its branching ratio, and RAD-DET is used to specify X rays as detected radiation. Note that XR can be given also under DECAY-DATA but the coding used here is a valid alternative.

4.4)

```
SUBENT       C0709011
BIB               4        5                              C0709011    2
REACTION   (92-U-238(A,F),,SIG)                             C0709011    3
SAMPLE     Natural uranium metal foils.  Areal density about 30   C0709011    4
           mg/cm2.                                          C0709011    5
RAD-DET    (56-BA-140,B-)                                    C0709011    6
DECAY-DATA (56-BA-140,12.80D,B-)                              C0709011    7
```

Here, a fission product is measured which does not appear in the REACTION code.
Even though RAD-DET has only information given also under DECAY-DATA, we believe that this is justified because the appearance of Ba-140 is not obvious in these data. (Formally it would be legal to give DECAY-DATA alone.) Note that the percent yield of Ba-140 in total fissions of U-238 was estimated from a previous investigation.

5. Examples of redundant usage of RAD-DET

The majority of present occurences of RAD-DET in the master file are redundant, i.e. repeating information given under DECAY-DATA where DECAY-DATA alone would be sufficient. We assume that most occurences in areas A, B, D4, O, and R (see table above in section 2. of this memo) belong to this category.
Three typical examples are given below.

5.1)

```
SUBENT       A0021002
BIB               8       12                              A0021002    2
REACTION   (21-SC-45(P,2N)22-TI-44,,TTY,,DT)                   A0021002    3
RAD-DET    (22-TI-44,DG)                                    A0021002    4
DECAY-DATA (22-TI-44,48.YR,DG,67.8,0.9,DG,78.4,0.98,DG,1159.,1.0) A0021002    5
```

DECAY-DATA is sufficient as the product in SF4 was measured. RAD-DET is unnecessary.

5.2)

```
SUBENT       A0074002
BIB               7       11                              A0074002    2
REACTION   (38-SR-86(P,N)39-Y-86-M/G,,SIG/RAT)                 A0074002    3
REL-REF    (N,,W.LU+,J,RCA,12,62,1969). Method of data processing.A0074002    9
RAD-DET    (39-Y-86-G,DG)                                     A0074002   10
          (39-Y-86-M,DG)                                    A0074002   11
```

```
DECAY-DATA (39-Y-86-G,14.74HR,DG,1077.,0.845,DG,1153.,0.313)     A0074002   12
         (39-Y-86-M,48.MIN,DG,208.,0.945)                      A0074002   13
```

It follows from the DECAY-DATA entry that decay gammas from both isomers were measured, therefore RAD-DET is redundant.

5.3)

```
SUBENT       F0937002
BIB                4         4                                F0937002    2
REACTION   (48-CD-116(D,P)48-CD-117-M,,SIG,,REL)                    F0937002    3
DECAY-DATA (48-CD-117-M,,DG)                                      F0937002    4
RAD-DET    (48-CD-117-M,DG)                                       F0937002    5
```

According to the current rule, RAD-DET is redundant as it repeats the DECAY-DATA information. Such cases are particularly disturbing as the RAD-DET info is not only included in the DECAY-DATA info, but the information content of both keywords is completely identical. This is not only redundant but could even be disturbing for the user.
Our proposal is to change the current rule so that in this case RAD-DET should be kept and DECAY-DATA should be deleted, because no decay **data** at all are given, not even the half-life.
(Note that we used this entry to illustrate the general point. We did not check the reference. If the article actually contains the half-life, then it should be added to DECAY-DATA and RAD-DET should be deleted.)

6. Some cases to be corrected

6.1)

```
SUBENT       C1597002
BIB                4         7                                C1597002    2
REACTION   (4-BE-9(12-MG-30,X)12-MG-29,,SIG)                        C1597002    3
RAD-DET    (12-MG-29)                                             C1597002    4
```

If this would be all the available information, and radioactive decay of Mg-29 was measured, this could be a logical solution. (Note however that presently it is illegal to omit the radiation field in RAD-DET; we propose to allow it). Also, this would be an example where it should be allowed to give RAD-DET without DECAY-DATA.
However, in this experiment the cross section is derived from (prompt) gamma-cascade in Mg-29. Branching ratios are deduced by intensity balancing in the measurement. Measured gamma-lines and their intensities are given in TABLE II of the article. Therefore, RAD-DET should be replaced by PART-DET (G) as it is a measurement of prompt gammas.

6.2)

```
SUBENT       E1411018
BIB                6        10                               E1411018    2
REACTION   (92-U-233(P,F)40-ZR-97,(CUM),SIG)                      E1411018    3
DECAY-DATA (40-ZR-97,16.9HR,DG,658.,0.985)                       E1411018    4
         In equilibrium with 97Nb.                               E1411018    5
RAD-DET    (41-NB-97-G,DG)                                       E1411018    6
```

The use of RAD-DET is correct, but DECAY-DATA information is incorrect. As decay gammas from Nb-97 (daughter of Zr-97) were measured, their energy and intensity should be coded with `41-NB-97`.

DECAY-DATA must be corrected as follows (similar corrections are required for many subentries):

```
DECAY-DATA (40-ZR-97,16.9HR)
         In equilibrium with 97Nb.
         (41-NB-97-G,,DG,658.,0.985)
RAD-DET    (41-NB-97-G,DG)
```

The same applies to several other subentries of the same entry. DECAY-DATA and RAD-DET must be corrected.

6.3)

```
SUBENT       E1522006
BIB               7        8                              E1522006    2
REACTION   (83-BI-209(7-N-14,5N)90-TH-218,,SIG)               E1522006    3
DECAY-DATA (90-TH-218,,A,7130.)                              E1522006    4
RAD-DET    (88-RA-214,A)                                     E1522006    5
```

Similar to the above. As decay alphas from Ra-214 (daughter of Th-218) were measured, their energy must be coded with `88-RA-214`.
DECAY-DATA must be corrected as follows (similar correction is required for E1522.008):

```
DECAY-DATA (88-RA-214,,A,7130.)
RAD-DET    (88-RA-214,A)
```

7. Table for using RAD-DET, DECAY-DATA and PART-DET

	DECAY-DATA *)	**RAD-DET**	**PART-DET**	**Remarks**
Data about measured radioactivity which can be seen in REACTION	YES	-	-	
Data about measured radioactivity not obvious from REACTION	YES	YES	-	
Only decaying nuclide, or decaying nuclide with radiation type, no numerical information	-	YES	-	
Info on measured prompt radiation not obvious from REACTION ****)**	-	-	YES	and/or EN-SEC if partial or differential data
Info on measured prompt radiation which can be seen in REACTION	-	-	-	Explanation under METHOD and/or DETECTOR is sufficient

*) Numerical information in DECAY-DATA is usually in coded form, but can also be in free text only (e.g. when the compiler cites data only assumed to be used by the authors)

**) This is when PART-DET should be used anyway. Note that nevertheless, DG (decay gammas) may also occur under PART-DET (see explanation in section 1 of this memo)

8. Requested Actions

We do not request any retransmission just because of RAD-DET. We ask

- to introduce the proposed changes to the Manual, and

- whenever an entry containig RAD-DET is retransmitted for any other reason, to check its usage with respect to the above. In particular we recommend to delete RAD-DET when it is redundant.

(We believe that including redundant information is not only unnecessary but sometimes can be more confusing than helpful for the user. It may mislead the user to believe that there must be a deeper reason for the repetition which he does not understand; furthermore, if this type of redundancy is included in some entries but is not in others, the user may be led to believe that there is a difference (which is actually not there). Therefore we urge compilers to include redundant information only when there is a good reason specific to the particular entry. Furthermore, we should not increase the length of our BIB sections when neither additional information nor a better explanation is offered - this makes the entry less user friendly.)

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