Reaction Products Unstable Against Prompt Particle Decay

(V.McLane, N. Otsuka, O. Schwerer and S. Dunaeva, 2010-06-10, Memo CP-D/646;
N. Otsuka, 2020-06-03, Memo CP-D/995)

Note added to this Working Paper

Memo CP-D/646 was presented as WP2011-29. The new branch code ISP was approved in the NRDC 2011 meeting (Conclusion 14) but only a part of the first paragraph (Proposed branch code ISP) has been in LEXFOR ("Partial Reactions"). I propose addition of the rest part of the memo in LEXFOR (e.g., "Light-Nuclei Reactions (Z ≤6)).

Memo CP-D/995 reports application of the rules described in CP-D/646 to compilation of the data measured with emulsions by Antolković, and it was added to this working paper just for your information.

Memo CP-D/646

At the 2010 NRDC meeting, a conclusion was reached that intermediate nuclides that are unstable against prompt particle decay will be coded in SF4 when the states are exclusively identified by the experiment. The purpose of this memo is to define the rules for when the unstable nuclide is coded vs. when the break-up particles should be coded.

Proposed branch code ISP

As part of this exercise, we saw the need for a new branch code. We propose the addition of the following code to Dictionary 30:

`ISP` Partial with respect to a level in an intermediate nucleus that is not coded in SF4.

This code may be used in combination with `PAR` when levels are given for both the intermediate nucleus and the final nucleus.

Example:

$^{9}Be(^{10}C,x)^{10}C^{*} \rightarrow p + {}^{9}B_{g.s.} \rightarrow 2p + 2\alpha$

```
REACTION   (4-BE-9(6-C-10,P+X)5-B-9,ISP/PAR,SIG)
…
EN-SEC     (E-LVL1,5-B-9)
           (E-LVL2,6-C-10)
```

General rule for compilation of reaction products:

When a reaction proceeds through an intermediate nucleus that is unstable and breaks up with the emission of particles (*e.g.* n, p, α), the reaction is coded with the products of the breakup as the output particles.

Example: The cross section for $^{9}Be(n,2n\ 2\alpha)$ is compiled as:

```
REACTION   (4-BE-9(N,2N+A)2-HE-4,,SIG)
```

Reaction products that are unstable against prompt particle decay

The ground states of the following nuclides have been identified as unstable:

- ^{5}He → n + d
- ^{5}Li → p + α
- ^{6}Be → 2p + α
- ^{8}Be → 2α
- ^{9}B → p + 2α

Also, some nuclides have a particle decay threshold

Example: 6-C-12 → 3 α; threshold E_x = 7.65 MeV

Therefore, an exception is made to the above general rule for only those cases *where the reaction is not a function of the final product* and when one or both of the following is true:

- The reaction is a function of the unstable product, e.g., proceeds through a given excited state of the unstable product.
- The unstable product is identified unambiguously, and the data given is for only the reaction that proceeds through that reaction channel, e.g., where the unstable product is measured with a track detector.

In the above cases, the intermediate nucleus is coded in SF4. The branch code PAR is used to specify the level of the intermediate nucleus. The definition of the nucleus using the BIB keyword EN-SEC is optional.

Example:

^{9}Be(n,2n)^{8}Be(g.s.) → 2α

```
REACTION   (4-BE-9(N,2N)4-BE-8,PAR,SIG)
```

However, if the reaction is a function of one or more of the final products it must be coded with the final products in SF3 and SF4. In this case, if the reaction is also a function of a level the intermediate nucleus, the intermediate state is specified using the branch code ISP. The intermediate nucleus must be given under the BIB keyword EN-SEC.

Example:

^{12}C(^{14}N,d)^{24}Mg* → α + ^{20}Ne(g.s.)

```
REACTION   (6-C-12(7-N-14,D+A)10-NE-20,ISP/PAR,……
…
EN-SEC     (E-LVL1,12-MG-24)
           (E-LVL2,10-NE-20)
```

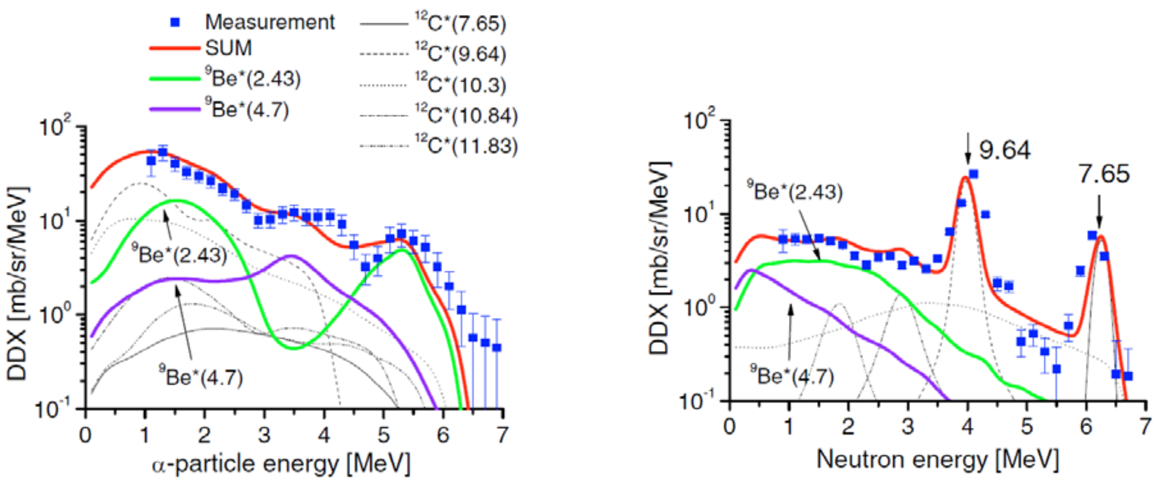
B. Antolković performed "kinematical complete measurements" of ^{12}C(n,n+3α) twice by detection of three alpha particles by emulsions (EXFOR 22231 and 30635). During review of EXFOR 40359 retransmitted in PRELIM.4187, I found their data sets are useful to check whether our REACTION coding rule works well for breakup reactions (c.f. Memo CP-D/646), and I reviewed the REACTION strings of these entries.

Various ^{12}C+n reactions leaving n+3α as the final products

(^{12}C*: Carbon-12 in an excitation state other than $^{12}C_{4.4}$. ^{9}Be*: Bellyrium-9 in an excitation state. SB: simultaneous breakup.).

#	Reaction	Product	1st decay	2nd decay	Remark
1	^{12}C(n,n')	^{12}C* ^{12}C*	 →α+^{8}Be ^{8}Be	 →α+α	
2	^{12}C(n,n')	^{12}C* ^{12}C*	 →α+α+α		
3	^{12}C(n,α)	^{9}Be* ^{9}Be*	 →n+^{8}Be ^{8}Be	 →α+α	
4	^{12}C(n,α)	^{9}Be* ^{9}Be*	 →α+^{5}He ^{5}He	 →n+α	
5	^{12}C(n,n+α)	^{8}Be ^{8}Be	 →α+α		Three-body SB
6	^{12}C(n,α+α)	^{5}He ^{5}He	 →n+α		Three-body SB
7	^{12}C(n,n+α+α+α)				Four-body SB

Below are the outgoing alpha and neutron spectra for 14 MeV neutrons (K. Kondo et al., ND2007 Conf. Proc. p.407), which show the contribution of various sequential decay channels following the (n,n') and (n,α) reactions.



EXFOR 22231 (B. Antolković et al., Nucl. Sci. Eng.**107**(1991)1. PTB D-T neutron source)

TABLE III

Cross Sections of the $^{12}C + n \rightarrow n + 3\alpha$ Reaction

Reactions		Neutron Energy (MeV) 11.9	12.9	14.0	14.8	17.0	19.0
		Cross Section (mb)					
$^{12}C(n,n')^{12}C^*(3\alpha)$ excitation energy							
Boundaries (MeV)	Mean Energy (MeV)						
< 10.25	9.6	110.8 ± 17.0[a]	71.7 ± 8.5	76.5 ± 8.1	69.0 ± 8.4	44.5 ± 4.9	45.9 ± 5.3
10.25 to 11.25	10.8	16.4 ± 8.6[a]	49.8 ± 12.4[a]	47.0 ± 3.6	36.1 ± 4.0	25.0 ± 2.5	21.3 ± 2.8
11.25 to 12.25	11.8	1.6 ± 0.5	7.4 ± 7.0[a]	37.6 ± 12.2[a]	50.2 ± 4.9[a]	35.7 ± 2.8	33.3 ± 3.2
12.25 to 13.50	12.8		1.2 ± 1.0	8.4 ± 5.9[a]	48.7 ± 12.1[a]	71.1 ± 4.1	39.4 ± 3.4
13.50 to 14.50	14.0				5.6 ± 0.7	42.9 ± 4.6[a]	39.9 ± 3.5
14.50 to 15.50	15.0					29.4 ± 5.4[a]	44.1 ± 3.4
15.50 to 16.50	16.0					9.4 ± 2.8	41.3 ± 6.1[a]
16.50 to 17.50	17.0						18.4 ± 4.8[a]
17.50 to 18.50	18.0						7.4 ± 2.6
$^{12}C(n,\alpha')^9Be_{2.43}$		48.0 ± 12.0	37.0 ± 17.0	32.0 ± 20.0	18.0 ± 14.0	14.0 ± 8.0	9.0 ± 9.0
$^{12}C(n,n'3\alpha)$		176.8 ± 18.2	167.1 ± 14.0	210.5 ± 14.6	227.6 ± 14.8	272.0 ± 16.9	300.0 ± 17.9

[a]The ^{12}C excitation energy range overlaps the $^{12}C(n,\alpha')^9Be_{2.43}$ reaction.

22231.005 (Last line of Table III – "$^{12}C(n,n'3\alpha)$")
It gives the cross section for the ***all*** (#1 to #7) paths resulting n+3α as the final products (but excluding #1+#2 via $^{12}C_{7.6}$, which was undetectable due to too low α energies). It is currently compiled with

```
REACTION    (6-C-12(N,N+2A)2-HE-4,,SIG,,MSC)
            12C(n,n+3a) cross section excluding 12C(n,n2)12C
            contribution
```

where MSC is needed because of exclusion of #1+#2 via $^{12}C_{7.6}$.

This code reminds us the following basic rule for break upcoding in Memo CP-D/646:

> When a reaction proceeds through an intermediate nucleus that is unstable and breaks up with the emission of particles (*e.g.* n, p, α), the reaction is coded **with the products of the breakup as the output particles**.

22231.004 (Second line from the bottom of Table III – "$^{12}C(n,\alpha')^9Be_{2.43}$", also in Fig.8)
It gives the cross section for #3+#4 vith $^9Be^* = {}^9Be_{2.43}$. It is currently compiled with

```
REACTION    (6-C-12(N,A)4-BE-9,PAR,SIG)
```

with E-LVL=2.43 MeV, and it is correct.

22231.002 (Lines with $^{12}C(n,n')^{12}C^*(3\alpha)$ excitation energy in Table III and in Fig.8.)
It gives 005 minus 004, namely for the paths #1+#2 (excluding the path via $^{12}C_{7.6}$), #3+#4 (excluding paths via $^9Be_{2.43}$), and #5 to #7. The data set is divided by the ^{12}C excitation energy group, and I proposed

```
REACTION    (6-C-12(N,N+2A)2-HE-4,ISP,SIG)
EN-SEC      (E-EXC,6-C-12)
```

during the last retransmission. This RECTION code is questionable since some paths (#3 to #7) do not go through ^{12}C as an actual intermediate state (N.B. We can define the ^{12}C excitation energy for any 3α system). The article mentions that the simultaneous breakup contribution (#5 to #7) is less than 10% of the $^{12}C_{9.64}$ but becomes considerable for higher ^{12}C states, and therefore the paths other than #1+#2 are not negligible. On the other hand the authors plot the 22231.002 data as inelastic scattering cross sections in Fig. 8, and especially assign the three ^{12}C levels 9.64, 10.8 and 11.8 MeV to the first three energy groups in Table

III – [.10.25 MeV], [10.25 MeV to 11.25 MeV] and [11.25 to 12.25 MeV]. Under this situation, now I consider

```
REACTION    (6-C-12(N,INL)6-C-12,PAR,SIG,,MSC)
EN-SEC      (E-EXC,6-C-12)
```

with free text explanation like "cross section for all (n,n3a) reactions characterized by the three-alpha energy excluding (n,n2) and (n,a1)" could reflect author's intention better than the current REACTION code.

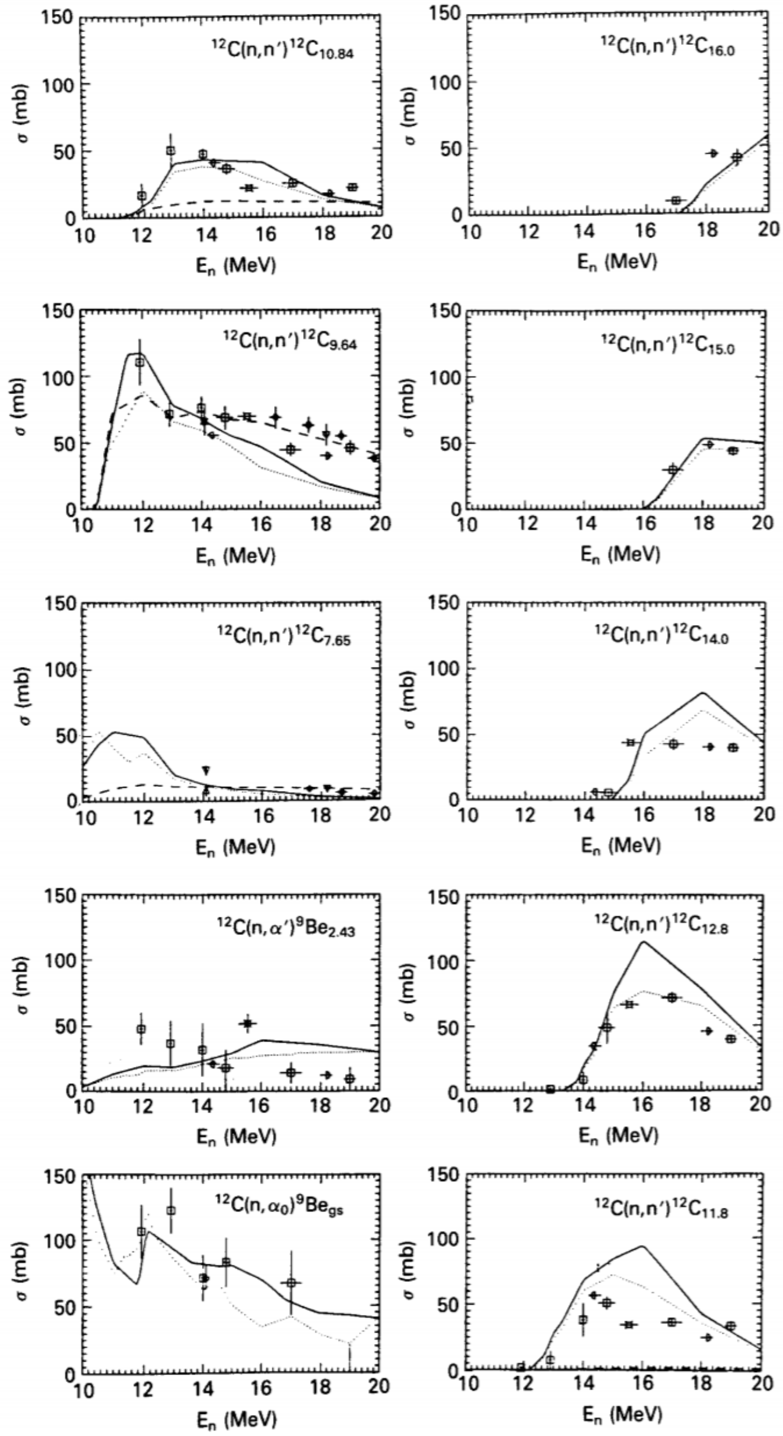


Fig. 8. Partial cross sections of neutron-induced reactions on carbon. The experimental data are taken from nuclear emulsion measurements (□ = present work, ◖ = Ref. 18, and ◗ = Ref. 19); cloud chamber measurements (⌘ = Ref. 39, reanalyzed); and scattering experiments (△ = Ref. 5, ◇ = Ref. 6, and ▽ = Ref. 37). The $^{12}C(n,\alpha_0)$ data are taken from alpha-particle spectrometry (⌓ = Ref. 7) and this work (□). Also included are evaluated data from ENDF/B-V (Ref. 3) (solid line) and Axton[34] (dotted line) and data from coupled-channel calculations[38] (dashed line).

TABLE IV

Partial Cross Sections for the Transition Only Via $^8Be_{gs}$ in the $n + {}^{12}C^* \rightarrow n + 3\alpha$ Breakup Reaction

Reactions		Neutron Energy (MeV) 11.9	12.9	14.0	14.8	17.0	19.0
		Cross Section (mb)					
$^{12}C(n,n')^{12}C^*(3\alpha)$ excitation energy							
Boundaries (MeV)	Mean Energy (MeV)						
< 10.25	9.6	113.0 ± 12.8[a]	67.3 ± 8.3	67.3 ± 7.2	64.3 ± 8.1	36.6 ± 4.2	42.3 ± 5.0
10.25 to 11.25	10.8	21.0 ± 3.0[a]	51.6 ± 4.7[a]	30.8 ± 2.6	22.5 ± 2.9	14.7 ± 1.8	10.7 ± 1.9
11.25 to 12.25	11.8	1.5 ± 0.7	10.3 ± 1.7[a]	20.6 ± 1.8[a]	20.6 ± 2.6[a]	11.9 ± 1.5	6.0 ± 1.3
12.25 to 13.50	12.8		0.7 ± 0.5	6.3 ± 0.9[a]	16.7 ± 2.0[a]	17.6 ± 1.9	6.0 ± 1.1
13.50 to 14.50	14.0				1.1 ± 0.3	10.7 ± 1.4[a]	7.3 ± 1.4
14.50 to 15.50	15.0					6.8 ± 1.1[a]	3.6 ± 0.9
15.50 to 16.50	16.0					1.4 ± 0.8	5.1 ± 1.1[a]
16.50 to 17.50	17.0						2.5 ± 0.8[a]
17.50 to 18.50	18.0						0.5 ± 0.4
$\sigma(^8Be_{gs})/\sigma[^{12}C(n,n'3\alpha)]$ (%)		76.7	76.6	63.0	55.1	36.6	26.9

[a]The ^{12}C excitation energy bins overlap with the reaction $^{12}C(n,\alpha')^9Be_{2.43}$ and the contribution of this reaction is included.

22231.006 (Table IV with $^{12}C(n,n')^{12}C^*(3\alpha)$ excitation energy)
It gives the cross section for the path #1+#3+#5 with $^8Be_{g.s.}$ characterized by the 3α energies but excluding #1 via $^{12}C_{7.6}$ (undetectable in this experiment). I proposed

```
REACTION    (6-C-12(N,N+A)4-BE-8,ISP/PAR,SIG)
EN-SEC      (E-EXC,6-C-12)
            (E-LVL,4-BE-8)
```

with E-LVL=0 MeV in the last retransmission. However, #3 and #5 do not go through ^{12}C as an intermediate state, and now I consider

```
REACTION    (6-C-12(N,N+A)4-BE-8,ISP/PAR,SIG,,MSC)
EN-SEC      (E-EXC,6-C-12)
            (E-LVL,4-BE-8)
```

with free text explanation like "cross section for all (n,n3a) reactions via 8Be(g.s.) and characterized by the three-alpha energy" could be better.

The authors superseded this data set by **22231.009** (=Table 1 of B. Antolković et al., Radiat. Prot. Dosim.**44**(1992)31). The Table 2 of this 1992 article gives the same quantity for $^8Be_{3.03}$, and it is compiled in **22231.010** by the same manner.

Table 1. Partial cross sections for the transition via $^8Be_{gs}$ in the $n+{}^{12}C \rightarrow n+3\alpha$ break-up reaction.

^{12}C exitation energy Boundaries (MeV)	Mean energy (MeV)	Neutron energy (MeV) 11.9	12.9	14.0	14.8	17.0	19.0
		Cross section (mb)					
< 10.25	9.6	134.8 ± 4.6	71.7 ± 8.5	76.5 ± 8.1	69.0 ± 8.4	44.5 ± 4.9	45.9 ± 5.3
10.25 – 11.25	10.75	21.0 ± 3.0	51.6 ± 4.7	30.8 ± 2.6	22.5 ± 2.9	14.7 ± 1.8	10.7 ± 1.9
11.25 – 12.25	11.75	1.5 ± 0.7	10.3 ± 1.7	23.1 ± 1.8	20.6 ± 2.6	11.9 ± 1.5	6.0 ± 1.3
12.25 – 13.25	12.75		0.7 ± 0.5	4.5 ± 0.6	15.1 ± 1.9	14.6 ± 1.8	4.7 ± 1.0
13.25 – 14.25	13.75			0.5 ± 0.2	2.7 ± 0.7	11.2 ± 1.5	5.7 ± 1.1
14.25 – 15.25	14.75					8.9 ± 1.4	5.5 ± 1.1
15.25 – 16.25	15.75					1.9 ± 0.9	4.7 ± 1.0
16.25 – 17.25	16.75						3.9 ± 1.0
17.25 – 18.25	17.75						0.5 ± 0.4

Table 2. Partial cross sections for the transition via $^8Be_{1.ex.st.}$ in the $n+{}^{12}C \rightarrow n+3\alpha$ break-up reaction.

^{12}C exitation energy Boundaries (MeV)	Mean energy (MeV)	Neutron energy (MeV) 11.9	12.9	14.0	14.8	17.0	19.0
		Cross section (mb)					
10.25 – 11.25	10.75	19.3 ± 2.1	23.7 ± 2.4	16.1 ± 1.8	13.6 ± 1.7	10.3 ± 1.6	10.7 ± 1.7
11.25 – 12.25	11.75	0.1 ± 0.1	10.6 ± 1.7	35.2 ± 2.6	32.6 ± 2.5	23.8 ± 1.8	27.2 ± 2.4
12.25 – 13.25	12.75		0.5 ± 0.3	14.3 ± 1.9	41.1 ± 4.0	44.2 ± 3.8	26.1 ± 2.4
13.25 – 14.25	13.75			0.7 ± 0.3	10.1 ± 1.7	39.7 ± 3.5	31.6 ± 2.8
14.25 – 15.25	14.75					31.8 ± 3.3	39.6 ± 3.6
15.25 – 16.25	15.75					14.2 ± 2.0	43.4 ± 3.8
16.25 – 17.25	16.75						28.2 ± 2.6
17.25 – 18.25	17.75						10.2 ± 1.9

22231.008 (Table V)

This is *not* from the emulsion experiment but from another measurement with a NE213 liquid scintillator as the target material. The pulse-height spectrum in the smooth line in Fig.4 is calculated with n-p scattering and $^{12}C(n,n_0+n_1)^{12}C$ as the first interaction in the scintillator. Then its difference from the measured pulse-height spectrum (histogram in Fig.4) was attributed to the "neutron-induced reaction cross section" by the authors. The cross section in Table V is for the paths #1 to #7 (but excluding #1+#2 via $^{12}C_{7.6}$ due to the detection limit.), $^{12}C(n,\alpha_0)^9Be_{g.s.}$, $^{12}C(n,p)^{12}N$ (E_{thr}=13.6 MeV) and $^{12}C(n,d)^{11}C$ (E_{thr}=14.9 MeV). It is currently coded by

```
REACTION    (6-C-12(N,N+2A)2-HE-4,,SIG,,MSC)
             Three-alpha break up cross section (excluding
             12C(n,n'2)12C(7.65MeV)(3alpha) contribution) plus
             12C(n,alpha0)9Be cross section.
```

and it looks fine.

As the free text explains, this approximates the cross section for the all (n,3a) breakup paths observed in the emulsion measurement plus $^{12}C(n,\alpha_0)^9Be_{g.s.}$, but also includes the (n,p) and (n,d) contribution above E_n~14.0 MeV. (Indeed the authors derive the $^{12}C(n,\alpha_0)^9Be_{g.s.}$ cross section by subtraction of 22231.005 plus evaluated (n,p) and (n,d) cross sections from this data set. The derived (n,α_0) cross section is in Fig.8 but not tabulated and not in the EXFOR entry.

TABLE V

Sum of Neutron Reaction Cross Sections on ^{12}C Excluding $^{12}C(n,n')^{12}C_{7.65}(3\alpha)$

Neutron Energy (MeV)	Measured Cross Section (mb)	Cross Section from ENDF/B-V (mb)
11.51	223.9 ± 8.5	204.8
11.92	283.2 ± 9.1	225.9
12.56	238.8 ± 9.8	247.3
12.90	289.6 ± 10.4	253.6
13.53	281.9 ± 9.3	269.6
13.0	287.6 ± 9.5	256.4
13.5	283.3 ± 8.4	268.4
14.0	272.6 ± 8.9	301.8
14.2	272.0 ± 9.3	311.3
14.4	303.9 ± 9.9	320.2
14.6	320.8 ± 11.3	334.3
14.8	311.3 ± 11.1	350.4
15.0	311.3 ± 10.1	367.9
15.5	327.1 ± 12.1	413.4
16.0	355.4 ± 12.9	474.1
16.5	405.1 ± 15.7	472.6
17.0	392.9 ± 16.8	462.9
17.5	435.5 ± 19.8	464.8
18.0	394.1 ± 23.0	474.1
18.5	411.6 ± 20.2	461.3
19.0	379.6 ± 19.9	444.5

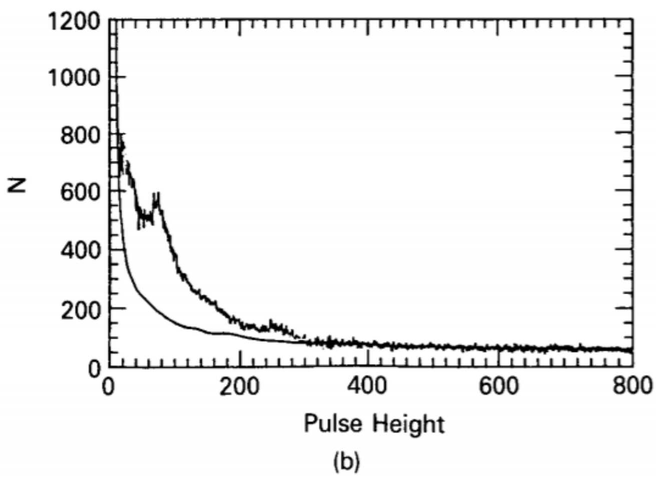


Fig. 4. Experimental pulse-height spectra (histogram) and calculated spectra (line) from an NE-213 scintillation detector (2.54 cm thick and 10.16 cm in diameter) irradiated by 14-MeV neutrons: (a) low-gain spectra and (b) high-gain spectra (the calculation neglects the neutron-induced reactions on carbon).

EXFOR 30635 (B. Antolković et al., Nucl. Phys.**A394**(1983)87. Louvain Be(d,n) source)
This is a similar kinematically complete emulsion experiment performed by the same author but published 8 years before. The breakup via $^{12}C_{7.65}$ was not detectable in this experiment, too.

30635.002 (Table 1)
This gives the quantity compiled in 22231.005. It is coded by

```
REACTION    (6-C-12(N,N+2A)2-HE-4,,SIG)
```

Currently exclusion of the breakup via $^{12}C_{7.65}$ is mentioned in free text under COMMENT. But it would be better to be mentioned under REACTION with addition of SF8=MSC to be consistent with 22231.005.

TABLE 1
Cross section for the reaction $^{12}C(n, 3\alpha)n$

E_0 (MeV)	F $\left(\frac{10^{10}n}{\mu C \cdot MeV \cdot sr}\right)$	ΔF (%)	C_1C_2	$\Delta(C_1C_2)$ (%)	C_3	ΔC_3 (%)	ΔN (%)	σ (mb)	$\Delta\sigma$ (mb)
11	1.45	10	1.22	7.4	2.61	28	37.8	33	20
12	1.58	10	1.21	6.5	2.24	25	20.9	76	40
13	1.68	10	1.19	5.8	1.90	23	19.2	130	49
14	1.76	10	1.18	5.1	1.69	21	12.7	301	89
15	1.89	10	1.18	4.4	1.52	18	11.9	312	84
16	2.05	10	1.17	3.8	1.46	15	9.3	429	97
17	2.26	10	1.17	3.4	1.40	13	9.9	349	76

30653.003 (Table 2)
It gives the cross section is for the paths #1, #3 and #5 with $^{8}Be_{g.s.}$ but excluding #1 via $^{12}C_{7.6}$ (undetectable in this experiment). It is very similar to 22231.006 but the cross section is not divided to the 3α energy groups. It is coded by

```
REACTION    (6-C-12(N,N+A)4-BE-8,PAR,SIG)
EN-SEC      (E-LVL,4-BE-8)
```

and it looks fine.

TABLE 2
Cross section for the reaction $^{12}C(n, n\alpha)^{8}Be_{g.s.}(2\alpha)$

E_0 (MeV)	C_3	σ (mb)	$\Delta\sigma$ (mb)	$\frac{\sigma[^{12}C+n \rightarrow n+^{8}Be_{g.s.}+\alpha]}{\sigma[^{12}C(n,3\alpha)n]}$ present data	ref. [1]
11	2.61	27	17	0.82	
12	2.30	56	24	0.73	
13	2.06	76	33	0.69	0.87
14	1.87	187	64	0.62	0.78
15	1.74	147	46	0.47	
16	1.64	155	42	0.36	0.66
17	1.57	146	39	0.42	

30653.004 (Table 3)
It gives the cross section for the paths #1 and #2 via $^{12}C_{9.63}$. It is just the $^{12}C(n,n_3)^{12}C$ cross section, and compiled by

```
REACTION    (6-C-12(N,INL)6-12-C,PAR,SIG)
```

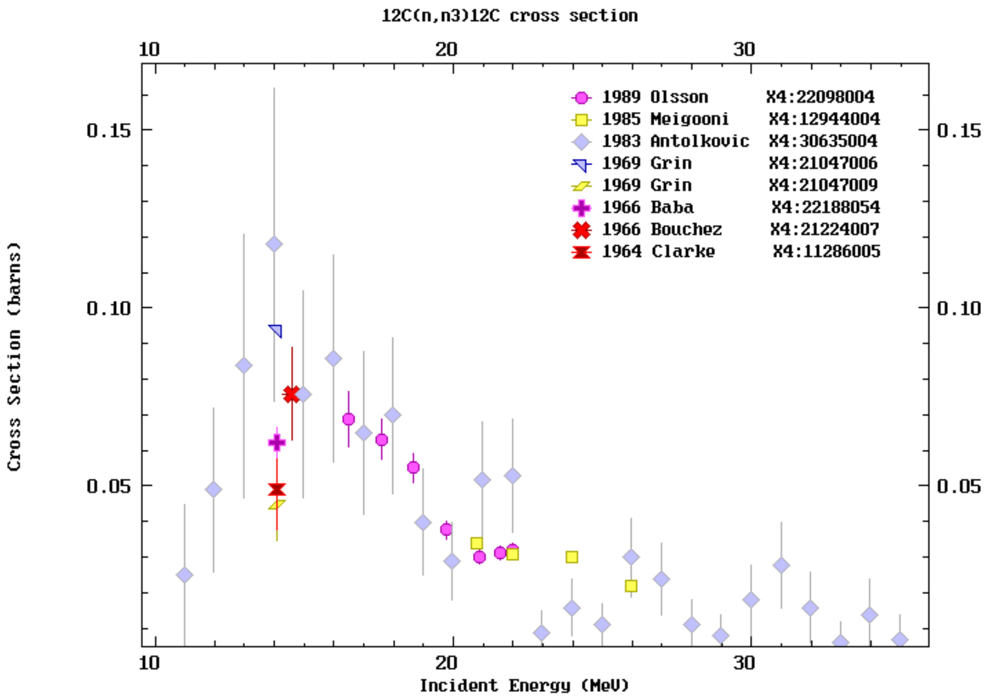
EN-SEC (E-LVL,6-C-12)

with E-LVL=9.63 MeV. This data set agrees very well with other data sets from the standard technique (neutron detection with TOF).

TABLE 3

Cross section for the reaction $^{12}C(n,n')^{12}C_{9.63}(3\alpha)$

E_0 (MeV)	C_3	σ (mb)	$\Delta\sigma$ (mb)	$\sigma[^{12}C(n,n')^{12}C_{9.63}]/\sigma[^{12}C(n,3\alpha)n]$		
				present data	ref. [1]	ref. [6]
11	2.61	25	20	0.77		0.31
12	2.53	49	23	0.64		0.36
13	2.44	84	37	0.55	0.45	0.35
14	2.36	118	44	0.39	0.33	0.28
15	2.28	76	29	0.24		0.28
16	2.21	86	29	0.20	0.24	0.25



Additional remarks:

- I found the rules formulated in Memo CP-D/646 (=WP2011-29), are very practical for breakup compilation, and all important statements of this Memo should be kept in our manuals.
- I discussed EXFOR 40359.002 and 003 with Stanislav Simakov further after their retransmission in TRANS.4186, and we concluded that the cross sections are for any reaction leaving a neutron slower than the (n,n3) neutron. The upper boundary energies at four outgoing angles in the laboratory system are in Table 1 of the source article, and the corresponding energy in the centre-of-mass system was estimated to 3.37 MeV by Stanislav. This is similar to 22231.002, and I propose addition of SF8=MSC to the REACTION codes of these subentries to indicate that the channels other than the inelastic scattering also contribute.