



**Nuclear Data Section
International Atomic Energy Agency
P.O.Box 100, A-1400 Vienna, Austria
Memo CP-D/933**

Date: 18 May 2017
To: Distribution
From: S. Takács, N. Otsuka
Subject: **Review of REACTION codes for thick target radioisotope yields**
Reference: CP-D/850

We have improved the quantity codes and LEXFOR “Thick- and thin-target yields” based on our article (N. Otsuka and S. Takács, Radiochim. Acta **103** (2015) 1). In order to improve the consistency in the REACTION codes with TTY in SF6 of existing EXFOR entries based on these improved dictionary and manual, all EXFOR entries compiling experimental thick target radioisotope yields were revised against our 2015 article by ATOMKI.

Compiled entries on 07 Febr. 2016

Area	Responsible centre	# of entries for revisions	# of REACTION codes checked
A	CNPD	67	932
B	NDS	23	83
C	NNDC	29	119
D0	NDS	65	313
D4	ATOMKI	41	164
D6	NDPCI	6	20
D7	KNDC	3	35
E	JCPRG	22	179
F	CNPD	11	59
M	CDFE	4	9
O	NEA DB	54	231
R	JCPRG	12	52
S	CNDC	2	4
T	NNDC	3	4
Sum		342	2204

Consistency in the REACTION codes with the possible codes in SF8 was checked.

.....TTY,,PHY)

.....TTY,,(PHY))

.....TTY,,SAT)

.....TTY,,(SAT))

.....TTY,,EOB)

.....TTY,,(EOB))

D4047.004	(52-TE-123(D,2N)53-I-123,,TTY,,DT)	(52-TE-123(D,2N)53-I-123,,TTY,,PHY,DERIV)
D4095.003	(8-O-18(P,N)9-F-18,,TTY)	(8-O-18(P,N)9-F-18,,TTY,,SAT,DERIV)
D4108.006	(45-RH-103(P,N)46-PD-103,,TTY,,DT,DERIV)	(45-RH-103(P,N)46-PD-103,,TTY,,PHY,DERIV)
D6082.002	(40-ZR-90(3-LI-7,X)2-HE-4,,TTY,,DT)	(40-ZR-90(3-LI-7,X)2-HE-4,,TTY,,EOB)
O1619.002	(36-KR-82(P,2N)37-RB-81-G,,TTY,,DT/A)	(36-KR-82(P,2N)37-RB-81-G,,TTY,,(PHY)/A)
O1619.003	(36-KR-82(P,N)37-RB-82-G,(M),TTY,,DT/A)	(36-KR-82(P,N)37-RB-82-G,(M),TTY,,SAT/A)
O1619.004	(36-KR-80(P,2N)37-RB-79,,TTY,,DT/A)	(36-KR-80(P,2N)37-RB-79,,TTY,,(SAT)/A)
O1619.005	(36-KR-83(P,N)37-RB-83,,TTY,,DT/A)	(36-KR-83(P,N)37-RB-83,,TTY,,PHY/A)
O2135.003	(37-RB-0(P,X)38-SR-82,,TTY,,PHY)	(37-RB-0(P,X)38-SR-82,,TTY,,EOB)
R0009.003.2	(53-I-127(A,5N+P)54-XE-125,,TTY,,EXP)	(53-I-127(A,5N+P)54-XE-125,,TTY,,(EOB))

SF3 – SF9 field were checked and corrected
REACTION lines were simplified

No correction is required.

According to the table caption EOB activity. But irradiation time is not provided. No details are given for yield calculation.

Data depend on the target material. Consider deletion of these subentries

Not enough information on yield calculation. Data may refer to EOB 1h 1uA irradiation, TIME-IRRAD should be included

Data are given at EOB. STATUS (CURVE) from fig 2. TIME-IRRAD should be inserted. The COMMENT and MISC-COL are in conflict.

The "yield" includes the chemistry efficiency too. Irradiation time not specified just the total charge in uAh. Most probably the data are = activity per total charge at EOB, but not specified. Refers to oxide target. Energy range is 22.4-20 MeV.

Explicit written that EOB activity is presented for 1h irradiation. Unit Should be changed accordingly. TIME-IRRAD should be coded

^{67}Cu and $^{71\text{m}}\text{Zn}$ data are wrong in table4, each was calculated with the half life of ^{64}Cu . The correct values are: 0.89 and 21.76 for ^{67}Cu and $^{71\text{m}}\text{Zn}$ respectively.

What is the yield?

$$Y = \frac{N^*}{N_b}$$

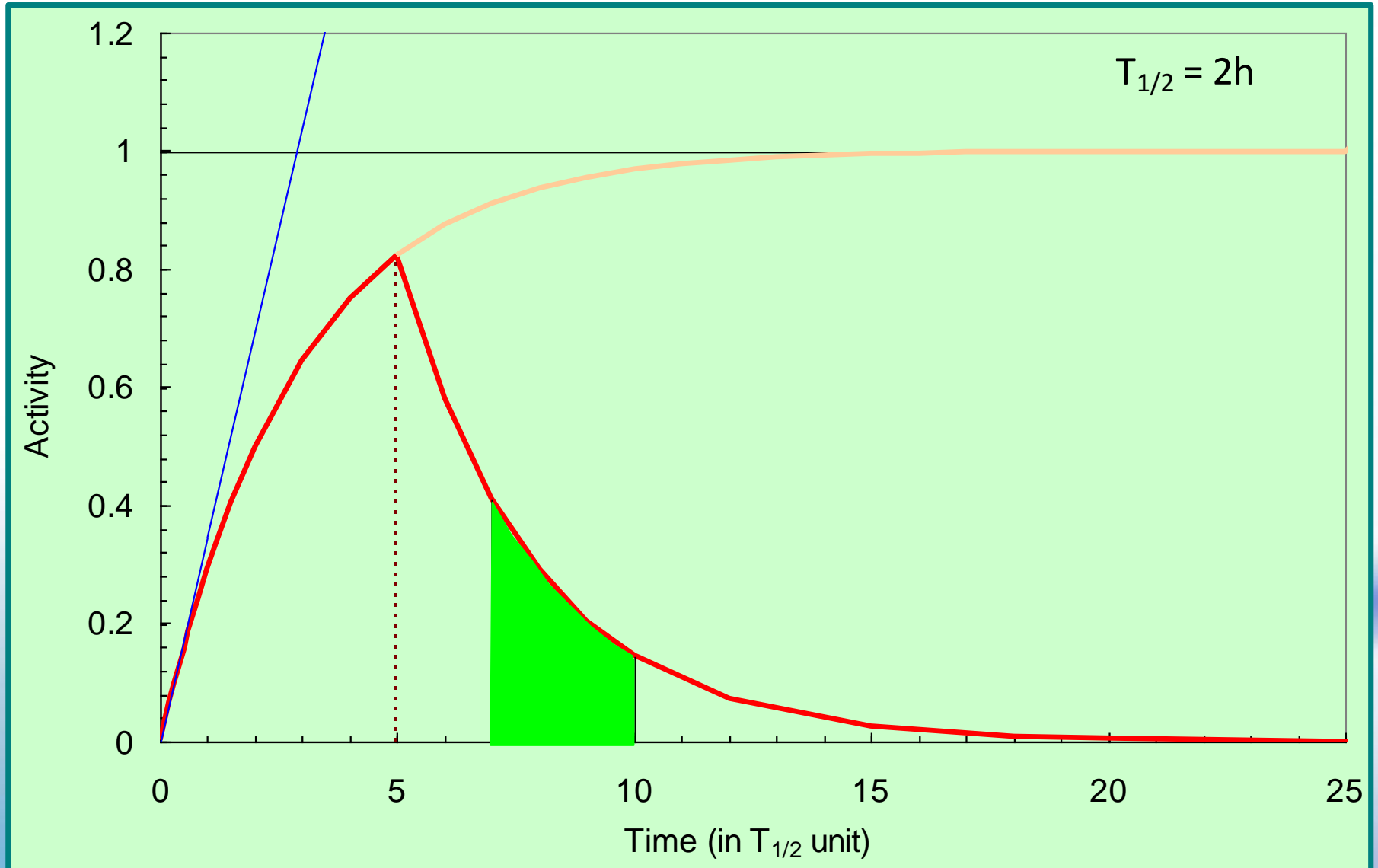
- The **yield** is a dimensionless quantity.

The yield for isotope production

- Problems of the yield for production of **radioisotopes** using **charged particle** induced nuclear reactions.

$$Y = \frac{N^*}{N_b} \left[\frac{\text{Activity}}{\text{Charge}} \right] \left[\frac{\text{mCi}}{\mu\text{Ah}} \right] \left[\frac{\text{MBq}}{\text{C}} \right]$$

- The number of reaction products is expressed by their activity.
- The number of bombarding particles is expressed by their charge.



Compilation of yield data

$$Y = \frac{N^*}{N_b}$$

- The **yield** is a target specific quantity.



- What can be compiled in EXFOR?
- Thin or thick target yield, **physical yield**, **saturation yield**, **EOB yield** ...
- Not every published “**yield**” data can be compiled.
- Articles are sometimes misuse the **yield** expression.
- Compilers should be careful!!!

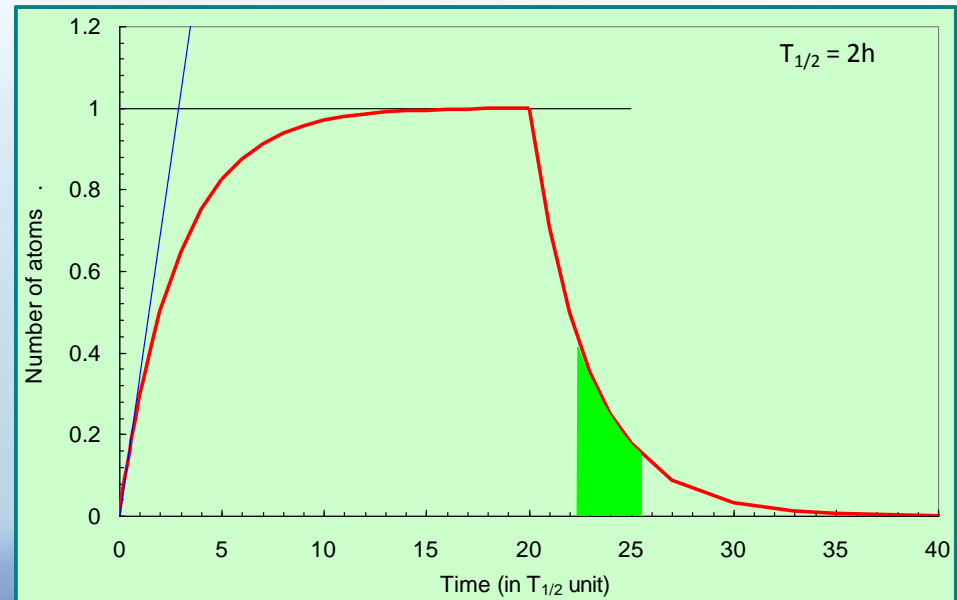
Compilation of SAT yield

- Incident energy
- Outgoing energy (or target thickness)
- Beam intensity
- Unit: Bq/μA (activity/beam int.)
- **Bq/μAh unit is not correct**

.....,TTY,,SAT)

EN-MAX	EN-MIN	DATA
MEV	MEV	MBQ/MUA

EN	DATA
MEV	MBQ/MUA



Compilation of PHY yield

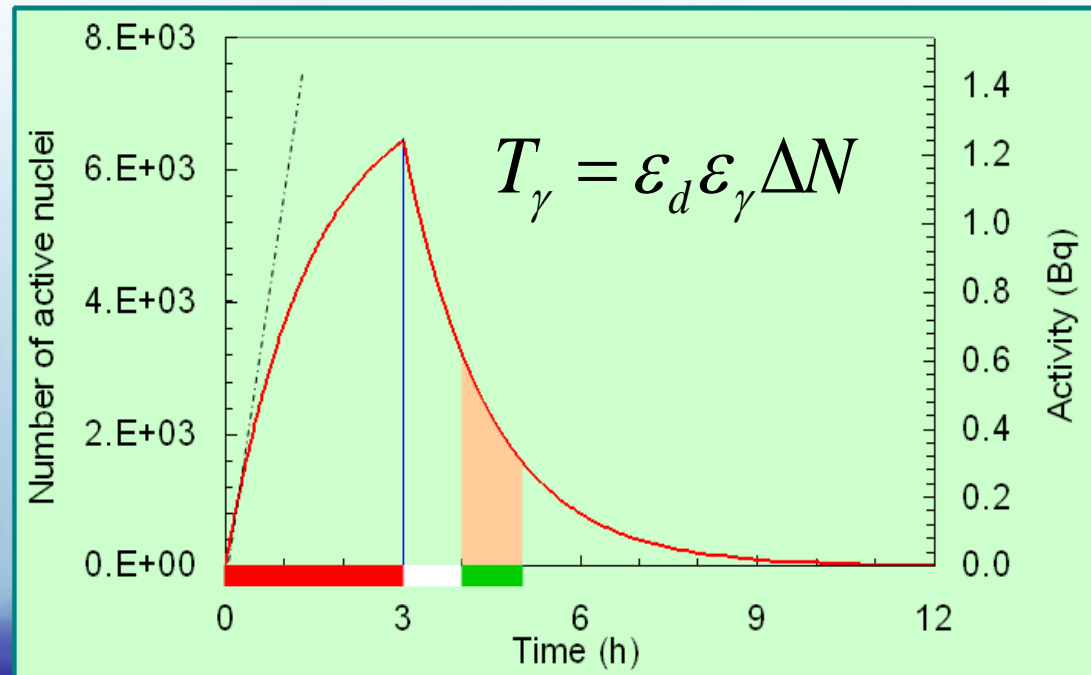
- Incident energy
- Outgoing energy (or target thickness)
- Unit: Bq/μAh (activity/charge)

.....,TTY,,PHY)

EN-MAX	EN-MIN	DATA
MEV	MEV	MBQ/MUAHR

.....

EN	DATA
MEV	MBQ/COUL



Compilation of EOB yield

- Incident energy
- Outgoing energy (or target thickness)
- Irradiation time
- Unit: Bq/μA (activity/beam int.)
- **Bq/μAh unit is not correct**

Energy window [MeV]	Yield ⁶⁴ Cu at EOB [MBq/μA h]
16 → 3	5.9
15 → 3	4.5

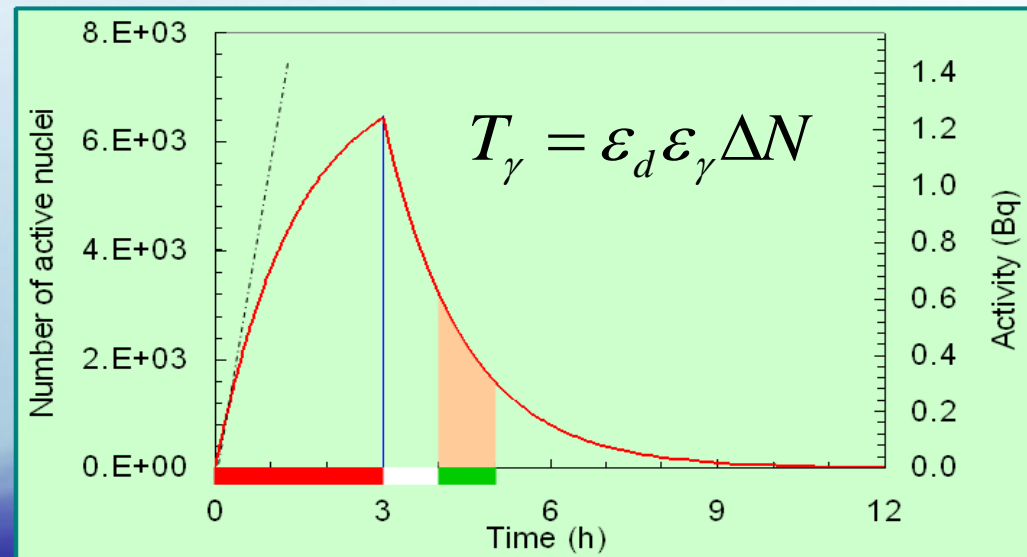
Table 3. Production yields of main isotopes.

Isotope	⁶⁴ Cu	⁶¹ Cu	⁵⁵ Co
Half-life	12.7 h	3.35 h	17.53 h
Yield at EOB [MB/μA h]	5.9	17.4	15.5

....,,TTY,,EOB)

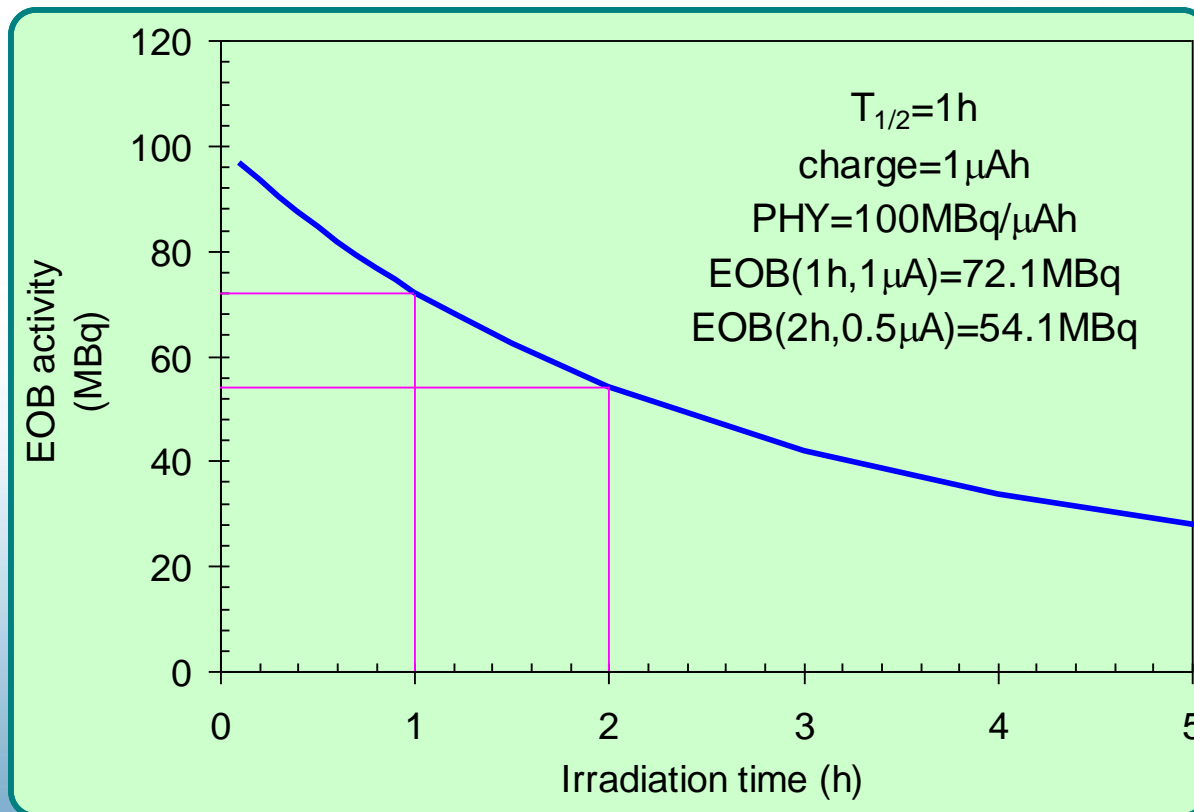
EN-MAX EN-MIN DATA TIME-IRRDR
MEV MEV MBQ/MUA HR

EN DATA TIME-IRRDR
MEV MBQ/MUA HR



Wrong practice

If EOB activity (yield) is presented in unit of $\text{MBq}/\mu\text{Ah}$ than most probably linear normalization was made. **Wrong practice !**



$$T_{1/2} > 36 \cdot t_b \quad \text{EOB} > 99 \text{ MBq} \quad (98.1)$$

Decay corrections

$$EOB = \frac{A}{e^{-\lambda t_c} (1 - e^{-\lambda t_m})}$$

$$PHY = \frac{\lambda EOB}{(1 - e^{-\lambda t_b})}$$

$$SAT = \frac{EOB}{(1 - e^{-\lambda t_b})}$$

$$SAT = \frac{PHY}{\lambda}$$

Problems

- No information on the measurement, no explanation of the “yield” just values are given and declared as yield. (Can be correct, can be completely wrong.)
- Measured activity divided by beam intensity and irradiation time and presented as yield. Not corrected for decay. (No details or explanations are given.)
- Measured activity divided by beam intensity and irradiation time and compared to physical yields.
- EOB activity calculated properly from the measured activity but normalized by irradiation time and presented in the unit of MBq/μAh.
- Activity of 1h and 1 μA irradiation is presented in the unit of MBq/μAh.
- No irradiation time is given for the EOB activity.
- Data measured on compound target not converted to elemental target.

SF8

PHY	391
(PHY)	243
PHY/REL	2
PHY/BRA/REL	1
(PHY)/MSC	7
EOB	298
EOB/FCT	106
EOB/A	0
EOB/REL	1
EOB?	6
SAT	42
(SAT)	16
TT	50
TT/REL	45
TT/BRA/REL	5
summa lines	2204
no changes	991

Conclusion

- When no proper information are given in the article on the yield calculation than better not to compile the suspicious yield data. Information should be asked from authors.
- If the author do not provide explanation on their yield calculation than it is the better not to compile the published data.