Comments on yield measurements and compilation

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What is the yield?

- The yield expression is widely used and not only in physics.
- In every day practice many measured quantity are called as yield.
- Any process in which something is produced can have a yield.
- In nuclear physics the reaction yield is well defined.

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

- The yield is a target specific quantity.
- The yield is not an absolute physical quantity.
- The yield is a dimensionless quantity.

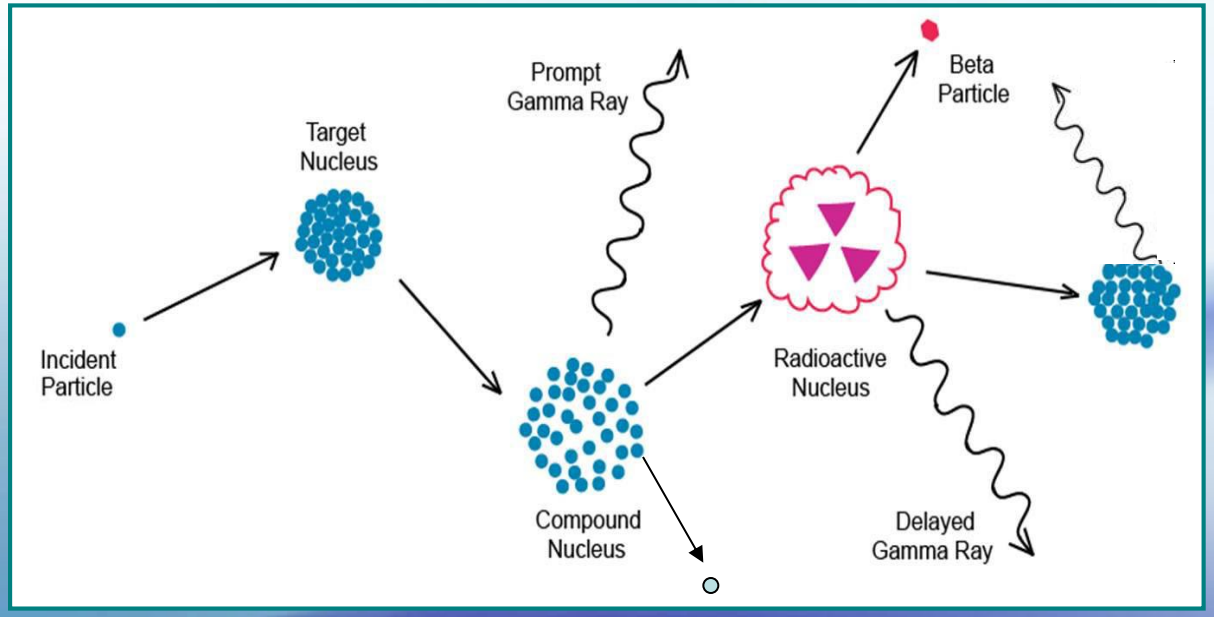
- The problems of the presented yields may be connected with production of radioisotopes using charged particle induced nuclear reactions.

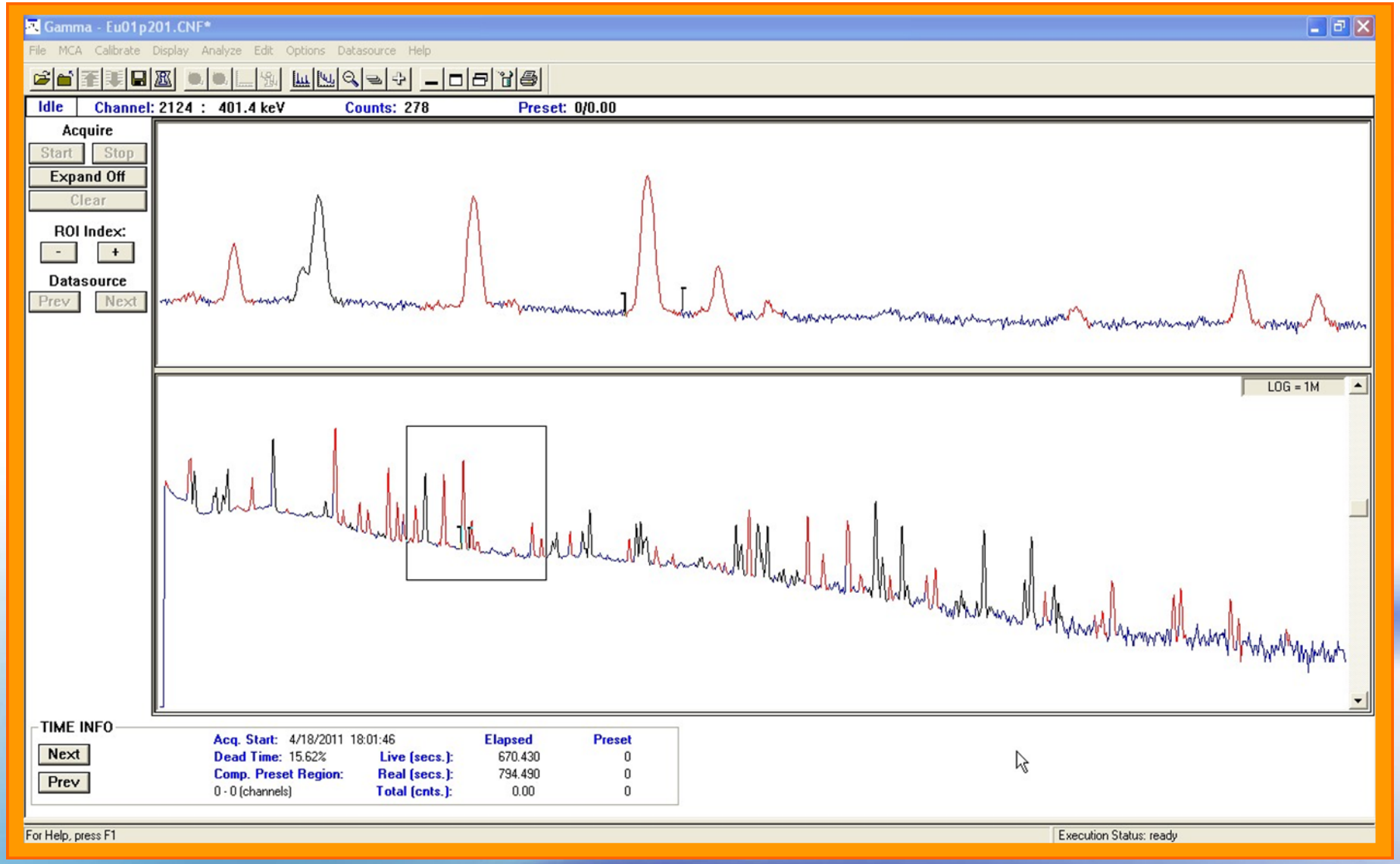
$$Y = \frac{N^*}{N_b}\left[\frac{Activity}{Charge}\right]\left[\frac{mCi}{\mu Ah}\right]\left[\frac{MBq}{C}\right]$$

- The number of reaction products is expressed by their activity.
- The number of bombarding particles is expressed by their charge.
- The main source of the confusion is the unit of charge μAh.

What can be measured?

- In an actual experiment yield or cross section is **never** measured directly
- The number of **events** can be measured under specific experimental conditions
- In-beam and off-line measurements
- An event can be: detection of a gamma-photon with certain energy
- The result is a gamma spectrum

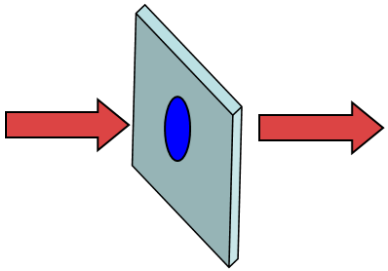



Gamma - Eu01p201.CNF*
File MCA Calibrate Display Analyze Edit Options Datasource Help
Idle
Channel: 2124 : 401.4 keV
Counts: 278
Preset: 0/0.00
Acquire
Start
Stop
Expand Off
Clear
ROI Index:
-
+
Datasource
Prev
Next
LOG = 1M
TIME INFO
Next
Prev
Acq. Start: 4/18/2011 18:01:46
Dead Time: 15.62%
Comp. Preset Region:
0 - 0 (channels)
Live (secs.):
Real (secs.):
Total (cnts.):
Elapsed
670.430
794.490
0.00
Preset
0
0
0
For Help, press F1
Execution Status: ready

Activation technique

$$R = n_t \phi \sigma$$

$$N(t) = n_t \phi \sigma t$$



$$\frac{dN}{dt} = n_t \phi \sigma - \lambda N$$

$$N(t) = n_t \phi \sigma \frac{1}{\lambda}\left(1 - e^{-\lambda t}\right)$$

$$N(t) = n_t \phi \sigma \frac{1}{\lambda}\left(1 - e^{-\lambda t_b}\right)e^{-\lambda t}$$

$$\Delta N = n_t \phi \sigma \frac{1}{\lambda}\left(1 - e^{-\lambda t_b}\right)e^{-\lambda t_c}\left(1 - e^{-\lambda t_m}\right)$$

R production rate

N number of nuclei at EOB

n_t number of target atoms/ cm^2

ϕ number of bombarding particles/s

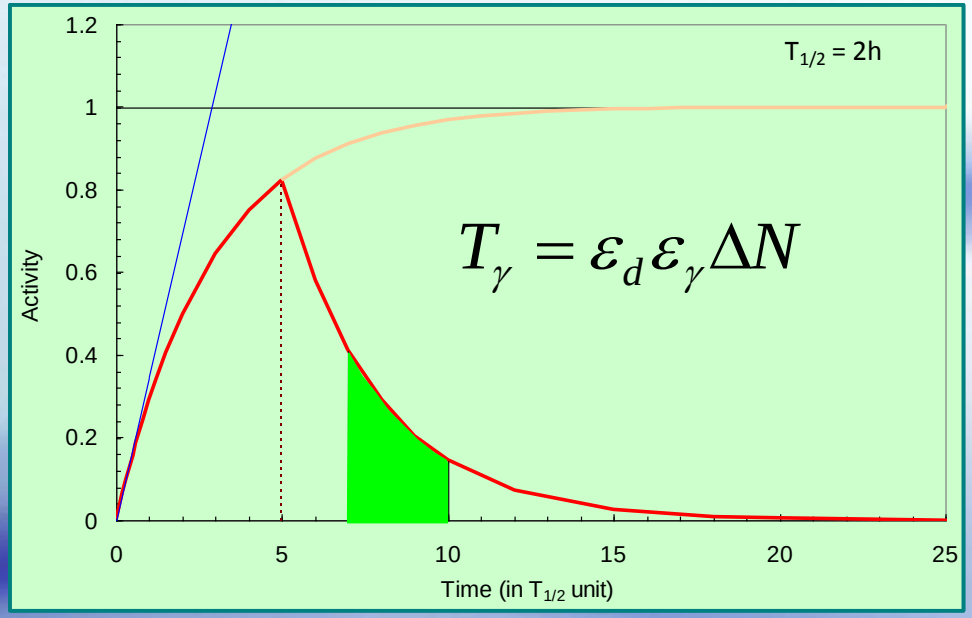
σ cross section

λ decay constant

t_b irradiation time

t_c cooling time

t_m measuring time



Compilation of yield data

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

- The yield is a target specific quantity.

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

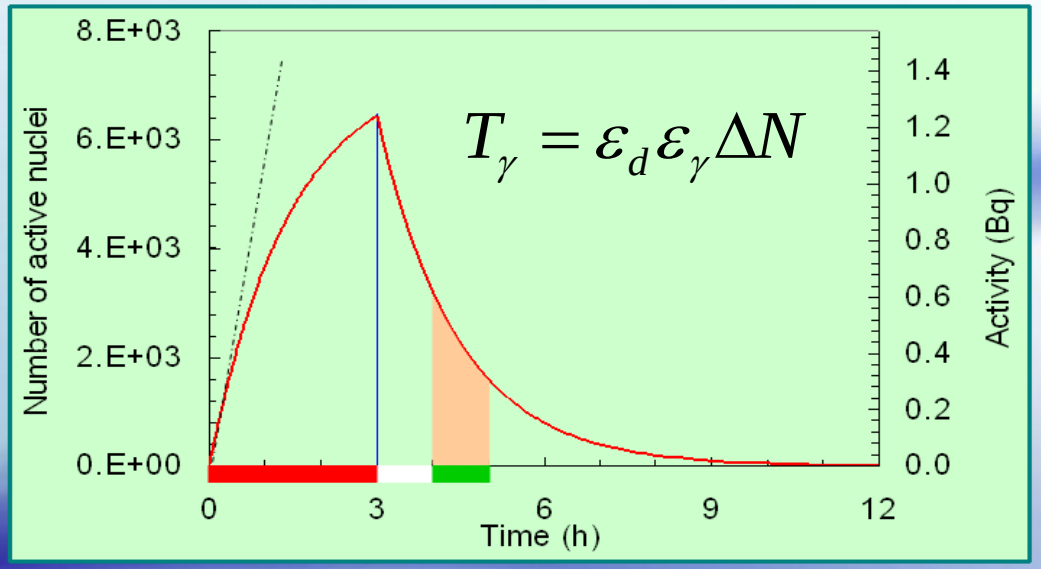
Compilation of measured activity

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

- Incident energy
- Outgoing energy (or target thickness)
- Irradiation time
- Beam intensity
- Cooling time
- Measured activity in Bq unit
- Unit: Bq/μA (activity/beam int.)

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

- No option for compilation
- Data can be transferred to EOB activity



Compilation of EOB activity

$$Y = \frac{N^*}{N_b}\left[\frac{Activity}{Ch\arg e}\right]\left[\frac{mCi}{\mu Ah}\right]\left[\frac{MB}{C}\right.$$

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

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

Table 3. Production yields of main isotopes.

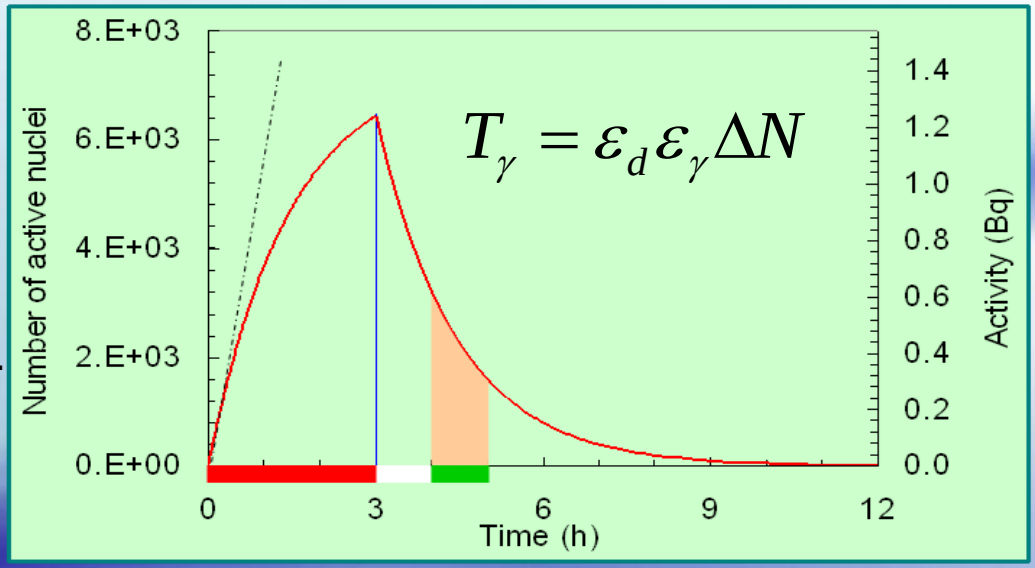
Isotope	^{64}Cu	^{61}Cu	^{55}Co
Half-life	12.7 h	3.35 h	17.53 h
Yield at EOB [MB/μA h]	5.9	17.4	15.5

…,,TTY,,EOB)

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

.....

EN DATA TIME-IRRD
MEV MBQ/MUA HR



Compilation of PHY yield

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

- Incident energy
- Outgoing energy (or target thickness)
- PHY (production rate for unit charge)
- Unit: Bq/μAh (activity/charge)

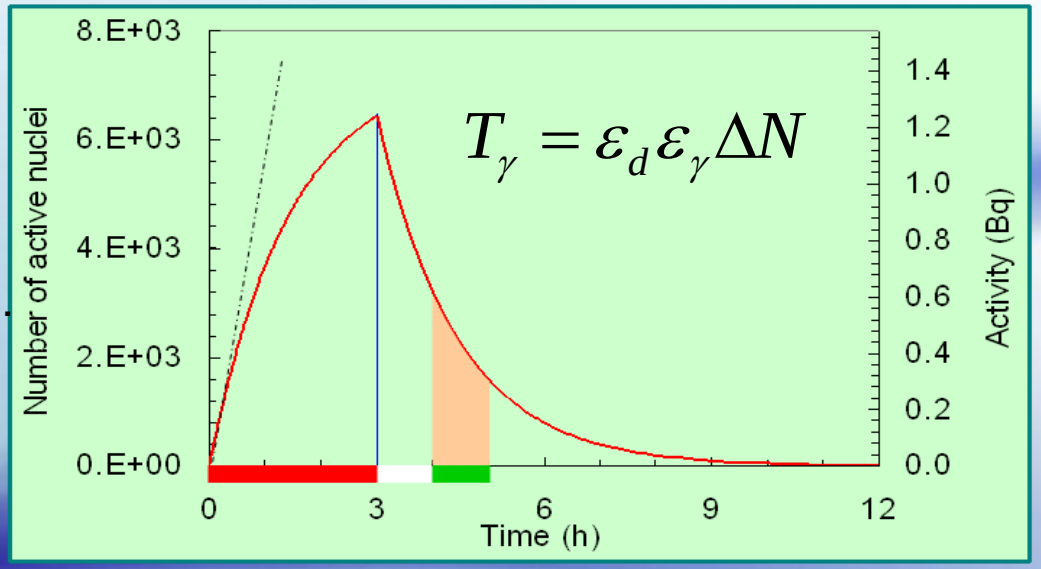
$$EOB = \frac{PHY}{\lambda}\left(1 - e^{-\lambda t}\right)$$

…,,TTY,,PHY)

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

.....

EN DATA
MEV MBQ/COUL



Compilation of SAT activity

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

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

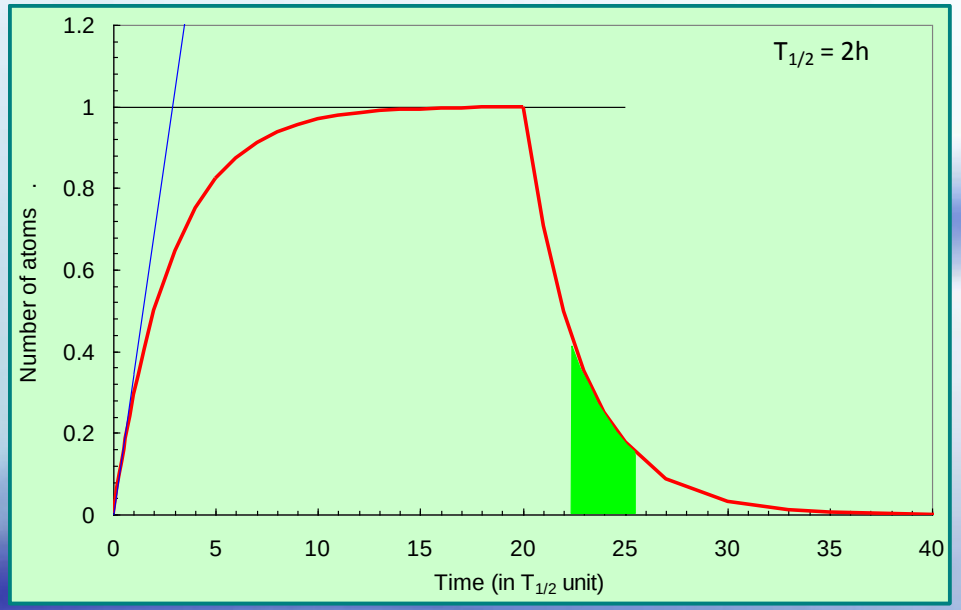
- Incident energy
- Outgoing energy (or target thickness)
- Beam intensity
- SAT activity in unit of Bq
- Unit: Bq/μA (activity/beam int.)
- Bq/μAh unit is not correct

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

…,,TTY,,SAT)

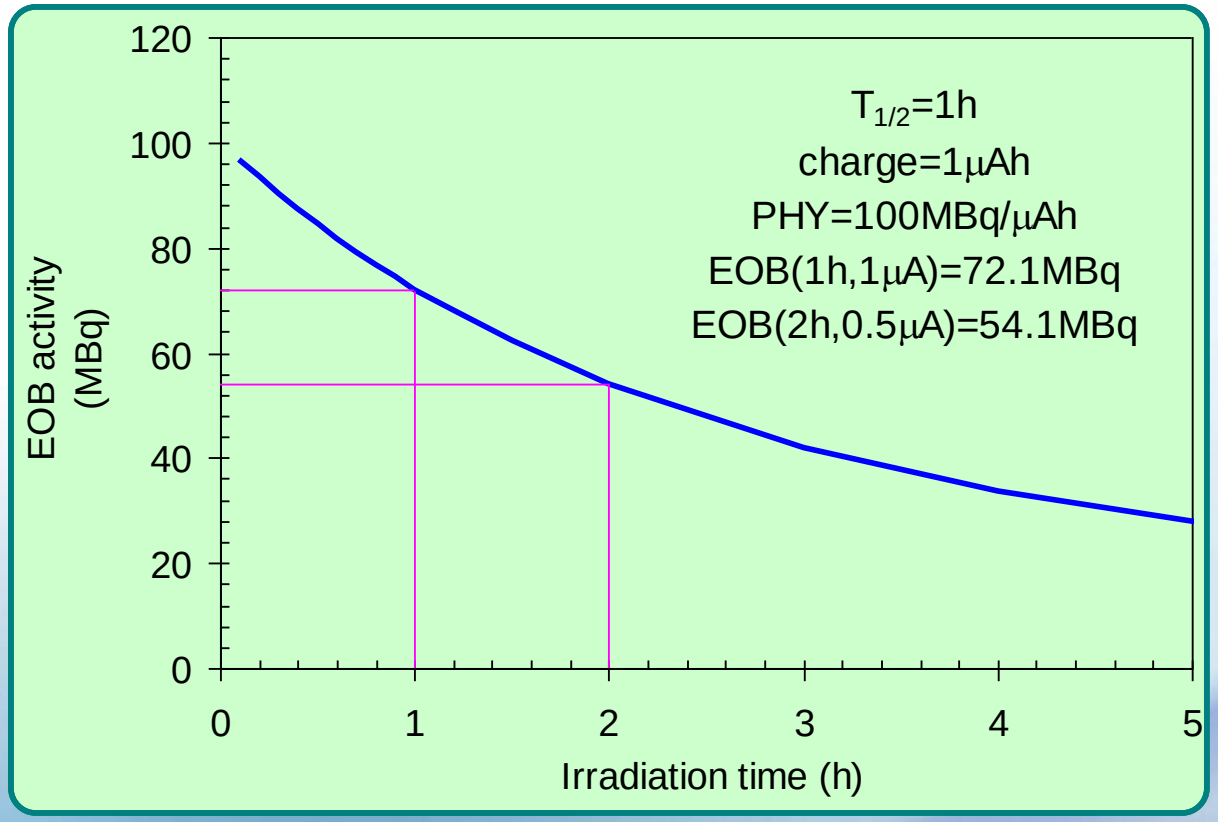
EN-MAX EN-MIN DATA
MEV MEV MBQ/MUA
……

EN DATA
MEV MBQ/MUA



Wrong practice

If EOB activity (yield) is presented in unit of MBq/μAh than most probably linear normalization was made. Wrong practice !



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…,,TTY,,EOB)

$T_{1/2} > 36*t_b$ **EOB > 99 MBq** (98.1)

EN DATA TIME-IRRD
MEV MBQ/MUA HR

Frequent problems

The worst case first

- 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.

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 data should not be compiled.

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

$$EOB = \frac{PHY}{\lambda}\left(1 - e^{-\lambda t}\right)$$

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

Thank You