Cross Section per Equivalent Quantum

(N. Otsuka, 2018-01-24, Memo CP-D/948)

Note added to WP2018-27

It is still not very clear if we should distinguish this quantity and Bremsstrahlung spectrum average cross section (BRA). Do we need codes specific for the cross section per equivalent quantum (e.g., PEQ instead of BRA)?

Cross section (yield) measured by activation under a Bremsstrahlung field is sometimes reported as "cross section per equivalent quantum" in the literature. This is equivalent to the definition of the Bremsstrahlung spectrum averaged cross section (,SIG,,BRA) in LEXFOR. As this quantity sometimes appear in transmission (*e.g.*, M0965.001 in PRELIM.M093), I decided to share my note on the definition of this quantity just for clarification.

Note: Cross-section per equivalent quantum [1]

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When a target is irradiated by bremsstrahlung photon field (end-point energy E_0), the number of the reaction products is

$$N = n_t \int_0^{E_0} \sigma(E) n(E, E_0) dE,$$

where n_t is the areal density of the target material, $\sigma(E)$ is the photonuclear cross section at the photon energy E, and $n(E,E_0)$ dE is the number of irradiated photons between E and E+dE. For the total energy measured by an Wilson quantameter,

$$E_T = \int_0^{E_0} E\, n(E, E_0) dE$$

$Q = E_T/E_0$ is corresponding to the total number of photons if the photon field is monoenergetic ($E=E_0$), and it is defined as the **number of equivalent quanta**. One may define the following **cross section per equivalent quantum**:

$$\sigma_Q(E_0) = \frac{N}{n_t Q} = \frac{\int_0^{E_0} \sigma(E) n(E, E_0) dE}{\int_0^{E_0} \left(\frac{E}{E_0}\right) n(E, E_0) dE}.$$

The number of equivalent quanta can be determined by using a quantameter (e.g., [2]) or using a reference reaction like $^{27}Al(\gamma,x)^{24}Na$ (e.g., [3]).

If we assume the photon energy distribution is proportional to the photon energy E, $n(E,E_0) = Q/E$, and the cross section per equivalent quantum is

$$\sigma_Q(E_0) = \frac{N}{n_t Q} = \int_0^{E_0} \frac{\sigma(E)}{E} dE$$

which is similar to the **resonance integral** considered in the low-energy neutron reaction. From this equation

$$\frac{d\sigma_Q(E_0)}{d\log(E_0)} = \frac{d\sigma_Q(E_0)}{dE_0}\frac{dE_0}{d\log(E_0)} = \sigma(E_0).$$

If the energy dependence of the cross section σ(E) is close to constant, we can estimate it from the slope of $\log(E_0)$ - $\sigma_Q(E_0)$ plot. This method overestimates $\sigma(E_0)$ when the contribution of the low-energy giant resonance to the measured reaction rate is not negligible, and it must be subtracted [4].

References

[1] F. Carbonara et al., Nucl. Phys. 73 (1965) 385 (not in EXFOR)

[2] B. Johnson *et al*., Z. Phys. **273** (1975) 97 (EXFOR G0038).

[3] H. Haba *et al*., Radiochim. Acta **90** (2002) 371 (EXFOR K2022).

[4] A. Järund et al., Z. Phys **262** (1973) 15 (not in EXFOR).