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Measurements of cumulative cross sections

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By definition a cumulative production cross section of a radionuclide includes formation via direct nuclear reactions and formation via radioactive decay of the precursor nuclide (considering isomeric transition too). In literature different definitions of the cumulative cross sections exist.

The solution of the coupled differential equation describing the radioactive growth and decay for a mother – daughter pair provides a formula which is used to determine the cumulative cross section by experimental activation technique. As most of the light charged particle induced reaction cross sections are measured using activation technique and gamma-spectrometry this formula is used for the definition of the cumulative cross section. Using this method the cross section deduced from the peak area evaluated from the gamma-spectra measured after the complete decay of the precursor and that is most time defined as cumulative cross section in the literature. Sigma(d,cum)=Sigma(d)+c*f*Sigma(p). Where Sigma(d,cum) is the experimental cumulative cross section of the daughter nuclide, Sigma(d) and Sigma(p) are the direct formation cross sections of the daughter and precursor respectively, c is the cumulative factor and f is the decay branching ratio. Calculating the cumulative cross section the tc cooling time is measured from the end-of-bombardment (EOB), but after EOB decay production of daughter nuclides is still continued. Therefore, defining the cumulative cross section this way is always larger then the sum of the direct cross sections of the precursor and the daughter nuclides since the c cumulative factor is larger than 1. However, using different experimental technique, for example, counting the number of neutrons formed in a (p,n) reaction producing an IT decaying isomeric state (m) and ground state (g) pair of a radionuclide the deduced cumulative cross section is the sum of the two direct cross sections Sigma(d,cum)=Sigma(d)+f*Sigma(p). Due to different definitions of the cumulative cross section data measured by activation method and other experimental techniques should be handled separately and carefully. The c cumulative factor is time dependent. For a precursor –daughter pair, when the half life of the precursor is shorter than the half life of the daughter, applying a very long cooling time c can be approximated as c=Td/(Td-Tp). However, applying short cooling time the value of c can be even less than 1 indicating the partial decay of the precursor. Doing measurement for a cumulative cross section one should avoid partial decay of the precursors, therefore the measurement should be done always after the total decay of the precursor(s). Otherwise, the deduced cross sections would be time dependent because of the time dependence of the c factor. Early measurements would result in scattered and too low cross sections. The time dependent experimental cumulative cross sections cannot be compared to other literature data and therefore they are useless.

Analysis of time dependence of the cumulative factor c and its consequences are discussed in the work.

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