The ^{41}Ar(n,γ)^{42}Ar reaction

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The ^{40}Ar(2*n*,γ)^{42}Ar double-neutron capture reaction is considered a candidate for the observation of a rapid neutron capture process in the high-density plasma created by the laser-induced implosion [1] of a deuterium-tritium (DT) capsule at the National Ignition Facility (Lawrence Livermore National Laboratory, USA). The particular choice of ^{40}Ar as a seed to be introduced in the DT mixture is motivated by the chemical inertness of the Ar noble gas, enabling collection of its reaction products. ^{39}Ar($t_{1/2}$= 268 y) and ^{42}Ar (33 y) long-lived reaction products from the ^{40}Ar(*n*,2*n*)^{39}Ar and ^{40}Ar(2*n*,γ)^{42}Ar reactions, respectively, are planned to be analyzed by ultra-high sensitivity Noble-Gas Accelerator Mass Spectrometry (NOGAMS) at Argonne National Laboratory [2,3] in a residual gas sample. In a preparatory experiment reported here, we seek to re-measure the ^{41}Ar(*n*,γ)^{42}Ar reaction cross section at thermal neutron energy by a controlled intense neutron irradiation of ^{40}Ar, leading via (slow) double neutron ^{40}Ar(*n*,γ)^{41}Ar(*n*,γ)^{42}Ar to ^{42}Ar. The ^{41}Ar(*n*,γ)^{42}Ar thermal neutron capture was determined in 1965 with a value of 0.5(1) b in [4], where the ^{42}Ar half-life (32.9 (11) y) was measured. Experimental knowledge of this cross section helps us in the estimate of the cross section at the higher energies (up to 14 MeV) which are relevant to the NIF experiment. Two ampoules (denoted B and C, each of 0.77 cm3 internal volume) made of high-purity quartz were filled with isotopically enriched ^{40}Ar (99.99%) gas at 314 Torr. Ampoules B and C were irradiated separately in the V4 beam tube at the high-flux reactor of Institut Laue-Langevin for 8 and 35 days, respectively, at a nominal thermal neutron flux of 1.0×10^{15} n cm^{-2} s^{-1}. In order to prepare a gas sample adequate also to NOGAMS analysis which necessitates a gas volume

of the order of 10 cm^3 STP, the irradiated quartz ampoule is broken in a gas manifold at high vacuum and quantitatively diluted with a known amount of high-purity Ar of natural composition, reaching an expected $^{42}Ar/^{40}Ar$ isotopic abundance of the order of 1×10^{-11}. Production of ^{42}Ar in the irradiation is determined, independently from the NOGAMS determination, by the measurement of the ^{42}K (12.4 h) activity in secular equilibrium with ^{42}Ar (33 y). Figure 1 shows the in-growth curve of ^{42}K measured shortly after filling a 10 cm^3 stainless steel cylinder with the (diluted) irradiated gas (ampoule B). Measurements of the absolute ^{42}K-^{42}Ar activity produced in the irradiation are in progress and will be reported together with our determination of the $^{41}Ar(n,\gamma)^{42}Ar$ thermal neutron capture cross section.

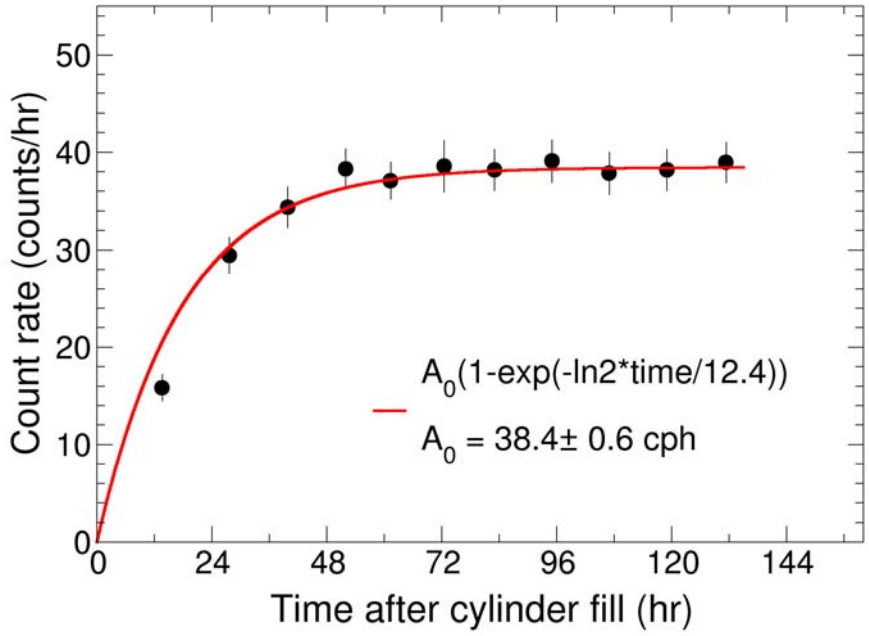

Figure 1: In-growth of ^{42}K (12.4 h) activity from decay of ^{42}Ar produced by slow double-neutron capture $^{40}Ar(n,\gamma)^{41}Ar(n,\gamma)^{42}Ar$(33 y) in a ^{40}Ar gas sample irradiated at the Institut Laue-Langevin.

References:

[1] Ch. J. Cerjan *et al.*, J. Phys. G: Nucl. Part. Phys. 45, 033003 (2018).

[2] M. Paul *et al.*, Nucl. Inst. and Methods in Phys. Res. B 456, 222 (2019).

[3} M. Tessler *et al.*, Phys. Rev. Lett. 121, 112701 (2018).

[4] R. W. Stoenner, O. A. Schaeffer and S. Katcoff, Science 148, 1325 (1965)