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RADIATIVE CAPTURE CROSS SECTIONS FOR 14.7 MeV NEUTRONS[1]

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Cross sections have been measured for ^{115}In $(n, \gamma)^{116m(54m)}$In and ^{197}Au$(n, \gamma)^{198m}$Au reactions with 14.7 MeV neutrons, the values have been found to be (2.1 ± 0.2) mb and (2.0 ± 0.2) mb, respectively. These values are still higher than the prompt gamma results with a factor of 2. It has been shown that the agreement between some earlier activation and prompt gamma results is due to the faulty corrections. A new method is proposed to avoid the contribution of the scattered neutrons to the activation cross section.

The discrepancy between the cross sections obtained by the activation and prompt gamma method [1] has shown the high sensitivity of the activation method to scattered neutrons. Some earlier measurements [2—4] have been found [5—8] to be influenced by scattered neutrons. From this fact some works [5—7] have calculated that the activation method should give results of cross sections in agreement with the prompt gamma method. The aim of the present work is to check the applied corrections and to recommend a new method to avoid the contribution of scattered neutrons and the not reliable corrections as well.

The $(14.7 ^{+0.3}_{-0.6})$ MeV neutrons were produced with a 180 kV cascade generator using an analysed ion beam. The details of the irradiation geometry and the target holder are given in Fig. 1. The minimum distance from the walls was 1.2 m. To avoid the neutron scattering on monitor foils and the errors from flux-nonhomogeneity inner monitor reactions were used. The gamma-activity has been measured with a 40 cm^3 Ge(Li) spectrometer. The details of the cross section determination are given in Table 1. The monitor cross sections, the gamma-transition intensities and the efficiency of the spectrometer were checked by evaluating all the gamma transitions of the produced activities as well as by comparing the cross sections with the values obtained with ^{27}Al(n, p)

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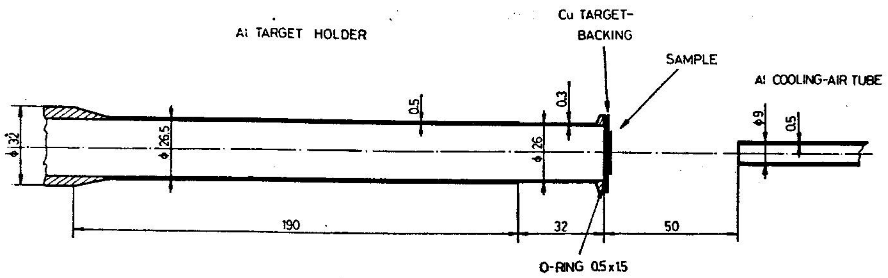


Fig. 1. Target-sample arrangement.

and ^{27}Al(n, α) monitor reactions assuming the cross sections [10] to be (73 ± 9) mb and (114 ± 10) mb, respectively. The cross sections obtained by the three different monitor reactions agree within 3 %, therefore we used this value in calculating the error instead of the 9.5 % [9] for indium.

In order to determine the effect of 0.3 mm copper targetbacking the apparent activation cross sections were measured as a function of target-backing thickness in the interval of 0.3—3 mm. The results are shown in Fig. 2 and 3. The copper disks were placed between the tritium target and the sample because the spectrum of the scattered neutrons considerably differs in forward and backward directions.

The In and Au sample-thickness dependences were determined in a similar way. Fig. 4 presents the apparent activation cross sections as a function of the sample thickness down to 5 mg/cm^2. Ponnert et al. [7] applied calculated non-linear correction functions to eliminate the effects of scattered neutrons. According to these calculations a sharp decrease appears at a sample thickness of less than 50 mg cm^{-2}. The present experimental results do not confirm this prediction.

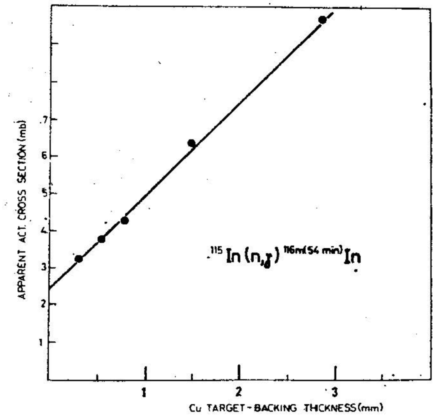


Fig. 2. Dependence of the apparent activation cross section for ^{115}In on copper target-backing thickness.

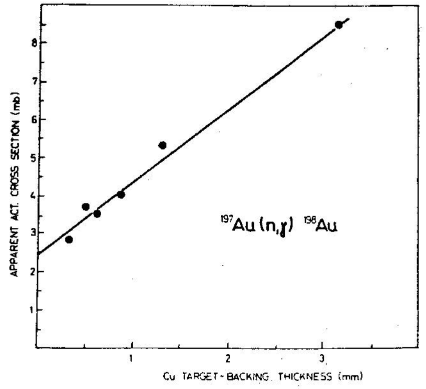
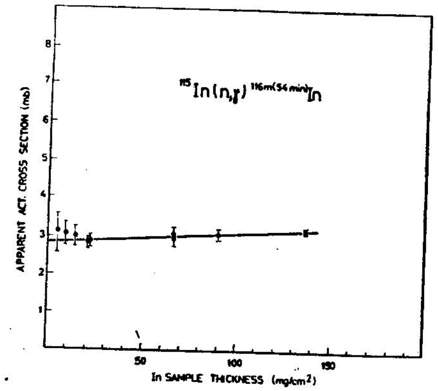


Fig. 3. Dependence of the apparent activation cross section for ^{192}Au on copper target-backing thickness.

Fig. 4. Dependence of the apparent activation cross section on indium sample thickness.



The target holder in the present experiment was an Al-tube with a wall thickness of 0.3 mm, the sample to be irradiated was fixed by the cooling air stream and so the increase in the apparent activation cross sections at a great target sample distance is due to the room-scattered neutrons mainly. According to our measurements the contribution of room-scattered neutrons to the activity was found to be constant at different directions to the ion beam within a 2 cm distance from the target.

It was easy to prove experimentally that the effect of the sample diameter on the apparent activation cross section cannot be attributed to the neutron scattering in the sample. Irradiating samples with a diameter of 7.5 mm and 19 mm, the inner part of the second was cut out with a diameter of 7.5 mm. For both samples with diameters of 7.5 mm the determined apparent activation cross sections were the same within the 3 % statistical errors. It means that the diameter dependence is caused also by the room-scattered neutrons. If the beam spot (neutron source) is larger than the sample, the apparent activation cross sections should not be too sensitive to the sample diameter. Irradiating samples with diameters of 7.5 mm and 3 mm, the apparent activation cross sections were the same. Increasing the distance between the beam spot and the small sample the apparent cross section was also found to increase. In the case of a large (19 mm) sample after correction for the room-scattered neutrons the same apparent cross section was obtained as for a small sample, where the correction was negligible. Applying [7] corrections for both the room-scattered neutrons and the diameter dependence, one makes the same correction twice.

In connection with some recent (n, γ) activation cross section measurements the following questions have arisen. Why have Valkonen and Kantele [5] not detected any effects of room scattered neutrons in their narrow cave? The only detail in the Vuletin et al. [8] measurements was that the sample and monitor foils were wrapped in a 1 mm cadmium foil. Valkonen and Kantele [5] have shown the disturbing effect of the cadmium shield. We have also found the apparent cross section of gold to be increased by 12 % when a 0.11 mm cadmium foil was used.

Table 1. gives the corrected cross sections determined for ^{115}In and ^{197}Au in the present work. The cross section for In is higher by a factor of 3 than the result of Ponnert et al. [7]. This discrepancy can arise in different ways of the above discussed corrections.

Assuming that the isomeric ratio σ_m/σ_g for ^{115}In(n, γ) at 14.7 MeV is close to the value measured at 1 MeV [11] and taking into account our value σ_m = 2.1 mb at 14.7 MeV,

Table 1

Details of the cross section determinations

Reaction	$^{115}\mathrm{In}(n, \gamma)^{116m}\mathrm{In}$ $T_{1/2} = (54 \pm 2)m$ $E_\gamma = 1293$ keV $I_\gamma = 84.6$ %	$^{197}\mathrm{Au}(n, \gamma)^{198}\mathrm{Au}$ $T_{1/2} = (2.696 \pm 0.002)d$ $E_\gamma = 411.8$ keV $I_\gamma = (95.47 \pm 0.1)$ %
Monitor reaction	$^{115}\mathrm{In}(n, n'^3)^{115m}\mathrm{In}$ $T_{1/2} = (4.50 \pm 0.02)h$ $E_\gamma = 336$ keV $I_\gamma = (47 \pm 2)$ % $\sigma = 63$ mb ± 9.5 % [9] ± 3 %	$^{197}\mathrm{Au}(n, 2n)^{196}\mathrm{Au}$ $T_{1/2} = 6.17d$ $E_\gamma = 426$ keV $I_\gamma = 6.5$ % $\sigma = 2109$ mb ± 5.2 % [10]
Sample thickness	21 mg/cm$_2$	19.2 mg/cm$_2$
Zero-thickness correction factor	1.0 ± 7 %	0.98 ± 2 %
Zero-copper-backing correction f.	0.77 ± 2 %	0.77 ± 4 %
Room-scattered neutron c. f.	0.87 ± 4 %	0.91 ± 2 %
Statistical error	±5.5 %	±4 %
Error from gamma-spectrometry	±3 %	±4 %
Corrected cross section	(2.14 ± 0.22) mb	(2.0 ± 0.18) mb

the total capture cross section $\sigma_{tot} = \sigma_m + \sigma_g$ can be estimated as 2.8 mb. This cross section is 3 times higher than the prompt gamma result [12]. Similar disagreements exist for gold [13] and rhodium [1, 6].

The activation capture cross sections strongly depend not only on the effect of the scattered neutrons but also on the corrections of several types applied several times. The only common fact in some of the previous papers [5, 7, 8] is the good agreement with the prompt gamma method independently of the ways of the corrections applied. Therefore we would like to recommend a new method for the activation cross section determination. The recoil energy of the residual nucleus is proportional to the neutron energy. The 14 MeV neutron capture for In gives a recoil energy of about 140 keV, while the 1 MeV scattered neutron only 10 keV. Measuring the range [14, 15] of the ^{116}In or any other residual nucleus one can determine the energy of the neutron inducing the reaction.

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