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DETERMINATION OF SOME (N,P), (N,N'P) AND (N,α) REACTION CROSS SECTIONS INDUCED BY 14.8 MEV NEUTRONS ON CR AND TI ISOTOPES

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INTRODUCTION

Cr and Ti are important reactor structural material components. Improved cross-section values of typical nuclear reactions induced by 14.8 MeV neutrons for these nuclides are obviously necessary and requested in WRENDA 81/82. In the framework of a Coordinated Research Programme supported by the International Atomic Energy Agency we carried out the determination of such data using up-to-date measuring system and data processing techniques.

EXPERIMENTAL

1. Sample Preparation

In the case of Cr we used samples with enriched isotopic abundances whereas for Ti thin metal foils with natural isotopic abundances were used (see table 1).

Table 1

Sample No.	Isotopic abundances % $^{52}Cr:^{53}Cr:^{54}Cr:^{50}Cr$	Chemical form	Mixture weight (mg)	Element weight (mg)	Sample thickness (mg/cm^2)
1	99.9:0.08:0.01:0.01	metal	1000	1000	318
2	1.85:98.0:0.12:0.03	metal	1000	1000	318
3	10.8:10.0:78.6:0.6	oxyde	1447	1000	461

All samples have disk form with diameter 20 mm. Each sample was sandwiched between two aluminium foils which were used as reference basing upon the reaction $^{27}Al(n,p)^{27}Mg$ or the reaction $^{27}Al(n,\alpha)^{24}Na$. The thickness of each aluminium foil is 51 mg/cm^2.

2. Irradiation

Irradiation was performed using a 120 kV neutron generator. The 14 MeV neutron yield is 10^{10} n/s. The ^{3}H-Ti target has 40 Ci activity, 45 mm dia. with 0.3 mm molybdenum backing and is cooled by water. The neutron energy calculated for the irradiation geometry was 14.8 ± 0.2 MeV. Neutron flux was monitored by a glass scintillation detector connected to the ND-66B multichannel analyzer working in multiscaling mode. The count numbers in each channel were used to correct the time variation of neutron flux.

3. Measurement and Data Processing

The measuring system consisted of a 62 cm^3 coaxial high purity Ge detector (ORTEC) with resolution 2.1 KeV at the 1332 KeV line of ^{60}Co, a spectroscopy amplifier (ORTEC model 572) and the ND-66 B mutlichannel analyzer (Nucl.Data.Corp.). The measured data recorded on floppy disks were processed by the PDP-11/23 computer. Peak areas were corrected for dead time, pile-up losses and also for coincidence summing effect using the Programme KORSUM (Debertin and Schotzig 1979). Full energy peak efficiencies and total efficiencies (needed for the KORSUM programme) at closed geometry were determined using single line gamma ray sources.

Table 2 gives the nuclear reactions under consideration together with the related decay data of the products and the coefficients for correction of summing cascade coincidence calculated by the programme KORSUM. Self-absorption of gamma rays in the samples was taken into account using attenuation coefficients given in /1/ with interpolation for missing values. Nuclear data needed for the calculation of cross-sections were taken from /2/ and /3/. Reference nuclear reaction cross-sections were accepted to be 71.6 mb for $^{27}Al(n,p)^{27}Mg$ and 113.7 mb for $^{27}Al(n,\alpha)^{24}Na$ /4/.

In order to decrease uncertainties each sample was measured with different cooling times (except the cases of very short half-lives such as ^{53}V, ^{54}V, ^{46m}Sc and ^{50}Sc). For each nuclide having multiple lines we calculated the weighted mean activity of all identified photopeaks with relative intensities greater than 20%.

Table 2

Nuclear reaction	Main gamma line energies (keV)	Intensity (%)	Half-life	Coefficient for correction of summing coincidence
$^{52}Cr(n,p)^{52}V$	1434.1	100	3.75 m	1.0012
$^{53}Cr(n,p)^{53}V$	1006.3	89.3	1.61 m	1.0041
$^{54}Cr(n,p)^{54}V$	834.8	97	49.8 s	1.1407
	989.0	80	-	1.1533
	2259.4	45.6	-	1.3173
$^{46}Ti(n,p)^{46m}Sc$	142.5	62.1	18.72 s	1
$^{47}Ti(n,p)^{47}Sc$	159.4	68.5	3.422 d	1
$^{48}Ti(n,p)^{48}Sc$	983.5	100	43.67 h	1.243
	1037.5	97.5	-	1.243
	1312.1	100	-	1.243
$^{50}Ti(n,p)^{50}Sc$	523.5	88	1.71 m	1.231
	1121.0	100	-	1.246
	1553.7	100	-	1.284
$^{54}Cr(n,\alpha)^{51}Ti$	319.7	93.4	5.8 m	1.0015
$^{27}Al(n,p)^{27}Mg$	843.7	70	9.46 m	1.0039
	1014.4	30	-	0.9981
$^{27}Al(n,\alpha)^{24}Na$	1368.6	100	15.03 h	1

In calculating the (n,p) cross-sections for ^{52}Cr and ^{53}Cr the contribution of the (n,n'p) reactions for ^{53}Cr and ^{54}Cr respectively was taken into account basing upon the known values of isotopic abundances of the samples used and the experimentally obtained (n,n'p) reaction cross-sections.

In cases of reaction cross-sections for Ti isotopes, as we used samples with natural isotopic abundances the interference from (n,n'p) processes can be quite serious. We made necessary correction basing upon the respective (n,n'p) reaction cross-sections given by /8/ and calculated the reaction yield ratios Y(n,p)/Y(n,n'p) leading to the same product.

Table 3 gives principal sources of systematic and statistical errors expressed in "one sigma".

Table 3

Source of errors	Rel. standard deviation %
Flux monitoring	3
Efficiency of detector	3
Irradiation and counting geometry	0.5
Nuclear data (cross-sections of reference reactions, decay constants of reaction products...)	5
Instrumental errors	1
Sample attenuation	0.5
Counting statistics	1-5

4. Results and discussion

Table 4 gives the cross-section values obtained in comparison with some given by other authors in the range 14.6-14.8 MeV.

Table 4

Nuclear reaction	This work	Cross-section (mb) References
$^{52}Cr(n,p)^{52}V$	81.5±6.2	80±6/5/;94±10/6/;70.7±3.1/7/
$^{53}Cr(n,p)^{53}V$	45.7±3.1	48±7/5/;40±7/6/;35.6±1.1/7/
$^{54}Cr(n,p)^{54}V$	14±2	18±3/5/;15±4/6/;14.7±0.61/7/
$^{53}Cr(n,n'p)^{52}V$	14±3	12±3/5/;7.3±0.6/7/
$^{54}Cr(n,n'p)^{53}V$	6.5±1.5	3.0±0.8/5/;1.53±0.14/7/
$^{46}Ti(n,p)^{46m}Sc$	56±4	55.0±2.2/8/48±8/9/
$^{47}Ti(n,p)^{47}Sc$	103±10	169.5±6.9/8/116±14/10/
$^{48}Ti(n,p)^{48}Sc$	60±4	71.7±2.6/8/53±6/9/
$^{50}Ti(n,p)^{50}Sc$	17±4	15.4±0.63/8/12±2/9/
$^{54}Cr(n,\alpha)^{51}Ti$	12.5±1;5	10.63±0.46/7/;15.0±1.6/10/

From the above table we can see that:

For the first three cases (^{52,53,54}Cr(n,p)) our values are consistent within quoted error limits with those reported by /5/,/6/ whereas the value given by /7/ for the 2nd case is too low. The (n,n'p) data (4th and 5th case) show relatively large discrepancies between reported values, especially with those given by /7/.

The use of samples with natural isotopic abundances strongly limited our work on those reactions with relatively high yields (cases of Ti samples). For ^{50}Ti(n,p)^{50}Sc the value obtained refers to the total (m+g) cross-section because the isomeric state of ^{50}Sc has very short half-life (0.35s) and could not be determined by us. The uncertainty in this case is high due to low counting statistics.

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