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Measurement of Cross Sections for $^{50}Cr(n,2n)^{49}Cr$ and $^{52}Cr(n,2n)^{51}Cr$ Reactions Induced by 13.5—14.6 MeV Neutrons*

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Abstract Cross sections for (n,2n) reactions are measured on chromium isotopes at the neutron energies of 13.5—14.6MeV using the activation technique. The data of the cross sections are reported for the following reactions: $^{50}Cr(n,2n)^{49}Cr$ and $^{52}Cr(n,2n)^{51}Cr$. The cross sections of $^{50}Cr(n,2n)^{49}Cr$ reaction are 3.4 ± 0.2, 6.8 ± 0.3, 21.5 ± 1.0 and 25.0 ± 1.2mb at the neutron energies of 13.5 ± 0.3, 14.1 ± 0.2, 14.4 ± 0.3 and 14.6 ± 0.3MeV, respectively. The cross sections of 185 ± 10, 193 ± 9, 258 ± 13 and 332 ± 16mb for $^{52}Cr(n,2n)^{51}Cr$ reaction are given at the neutron energies of 13.5 ± 0.3, 14.1 ± 0.2, 14.4 ± 0.3 and 14.6 ± 0.3MeV, respectively. The samples wrapped in cadmium foil are irradiated in order to avoid the effect of $^{50}Cr(n,\gamma)^{51}Cr$ reaction induced by thermal neutron to $^{52}Cr(n,2n)^{51}Cr$ reaction, and the measured results are compared with published data. Neutron energies are determined by the method of cross-section ratios of $^{90}Zr(n,2n)^{89m+g}Zr$ and $^{93}Nb(n,2n)^{92m}Nb$ reactions, and the neutron fluencies are determined using the monitor reaction $^{93}Nb(n,2n)^{92m}Nb$.

Key words chromium, cross section, activation technique, (n,2n) reaction, 14MeV neutron

1 Introduction

The cross sections for the $^{50}Cr(n,2n)^{49}Cr$ and $^{52}Cr(n,2n)^{51}Cr$ reactions have been measured by many authors, based on their use in fusion reactor design or in activation analysis, but most of them had only single energy point datum. Furthermore, these measurements differ by as much as a factor of 2.5 for the $^{50}Cr(n,2n)^{49}Cr$ reaction, and 3.8 for the $^{52}Cr(n,2n)^{51}Cr$ reaction, thus it is important to measure them again. During the experiment, samples are wrapped in cadmium foil during irradiation in order to avoid the effect of $^{50}Cr(n,\gamma)^{51}Cr$ reaction induced by thermal neutron to $^{52}Cr(n,2n)^{51}Cr$ reaction, and the measured results are compared with published data.

2 Experimental procedure

The irradiation of the samples are carried out at ZF-300-Ⅱ Intense Neutron Generator at Lanzhou University. The neutrons with the yield of about $(3\times10^{10} \sim 4\times10^{10})$ n/s, are produced by the $^{3}H(d,n)^{4}He$ reaction with an effective deuteron beam energy of 135keV and a beam current of 500μA. The thickness of the tritium-titanium (T-Ti) target is 1.35mg/cm^2. The variation of the neutron yield is monitored by the U-fission chamber so that the correction could be made for the fluctuation of the neutron flux during the irradiation. The cross sections for the $^{93}Nb(n,2n)^{92m}Nb$ reaction are obtained by interpolating the evaluated values of Ref.[1] and are used as monitor to measure the cross sections of $^{50}Cr(n,2n)^{49}Cr$ and $^{52}Cr(n,2n)^{51}Cr$ reactions. The Cr_2O_3 powder of 99.831% purity is made into circular thin samples with a diameter of 20mm and thickness of 3.73—8.04mm, and 99.99% pure natural niobium metal foil is made into circular samples with a diameter of 20mm and thickness of 0.08—0.86mm. In order to avoid the effect of $^{50}Cr(n,\gamma)^{51}Cr$ reaction induced by thermal neutron to $^{52}Cr(n,2n)^{51}Cr$ reaction,

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during the experiment the four groups of samples, which are respectively placed at 0°,45°,90° and 135° angles relative to the incident deuteron beam direction, are all sandwiched between two niobium foils and wrapped in cadmium foil. The neutron energies of samples' positions are determined by cross-section ratios for ^{90}Zr(n, 2n)$^{89m+g}$Zr and ^{93}Nb(n, 2n)^{92m}Nb reactions[2].

The gamma ray activities of ^{92m}Nb, $^{89m+g}$Zr, ^{49}Cr and ^{51}Cr are determined by a CH8403 coaxial high-purity germanium detector (sensitive volume 110cm^3) (made in the People's Republic of China) with a relative efficiency of 20% and an energy resolution of 3keV at 1.33MeV. The efficiency of the detector is calibrated by using standard gamma-ray source[3]. Standard Reference Material 4275 source was obtained from the National Institute of Standards and Technology, Washington, DC, USA. An absolute efficiency calibration curve is obtained at 20cm from the surface of the germanium crystal. At this distance the coincidence summing effects can be considered to be negligible. In our actual situation, however, the efficiency at 2cm is calibrated, because of the weak activity of the sample. Therefore, we select a set of monoenergetic sources and place them at two positions (20 and 2cm) successively to measure their efficiency ratios, so that we are able to evaluate the efficiency ratio curve as a function of energy. The absolute efficiency calibration curve at 2cm is obtained from the calibrated curve at 20cm and the efficiency ratio curve. The error in the absolute efficiency curve at 2cm is estimated to be ~1.5%, while the error of the standard source is ~1%.

The decay characteristics of the product nuclides and the natural abundance of the target isotope under the investigation are given in Table 1. The information in this table is taken from Ref.[4].

Table 1. Abundance of target isotopes and decay dada of the reaction products.

abundance of the target isotope(%)	reaction	$T_{1/2}$	E_γ/keV	I_γ(%)
4.345	^{50}Cr(n,2n)^{49}Cr	42.3m	152.928	30.324
83.789	^{52}Cr(n,2n)^{51}Cr	27.702d	320.0842	9.86
100	^{93}Nb(n,2n)^{92m}Nb	10.15d	934.44	99.07

3 Results and discussion

The cross sections are calculated by the equation used in Ref.[3]. The cross sections measured in the present work are summarized in Table 2 and plotted in Figs.1—2 together with the values given in the literatures[5—29] for comparison. The corrections are made for gamma-ray self-absorption in the sample, for gamma-gamma coincidence summing effects, for fluctuation of the neutron flux during the irradiation and for sample geometry. The major errors in the present work come from the errors of counting statistics, detector efficiency, monitor reaction cross sections, weight of samples, self-absorption of gamma ray, coincidence summing effect of cascade gamma rays, sample geometry and the effect of the scattering neutrons.

Table 2. The cross sections of ^{50}Cr(n,2n)^{49}Cr, ^{52}Cr(n,2n)^{51}Cr and ^{93}Nb(n,2n)^{92m}Nb reactions.

reaction	neutron energy/MeV			
	13.5±0.3	14.1±0.2	14.4±0.3	14.6±0.3
	cross sections/mb			
^{50}Cr(n,2n)^{49}Cr	3.4±0.2	6.8±0.3	21.5±1.0	25.0±1.2
^{52}Cr(n,2n)^{51}Cr	185±10	193±9	258±13	332±16
^{93}Nb(n,2n)^{92m}Nb	456.6±13.7	459.3±9.2	459.8±13.8	459.7±13.8

For the ^{50}Cr (n,2n)^{49}Cr reaction, it can be seen from Fig.1 that the cross sections increase quickly with increasing neutron energy around 14MeV and our results is in agreement, within experimental error, with those of Refs. [8—13]. The trend of our excitation curve is different from those of Refs.[5, 6, 14, 15], but our measurements agree with theirs at some experimental energy points. Furthermore, the cross section shown in Ref.[16] is much higher than the others.

The cross-section values of ^{52}Cr(n,2n)^{51}Cr reaction presented in Table 2 and Fig.2 show that the measurements of the present work increase quickly with increasing neutron energy around 14MeV and they agree, within experimental error, with those of a few literatures[14,17] at some experimental energy points. Furthermore, most of the experimental values of these literatures are higher than ours except a few literatures[6,8,14,18] at some experimental energy points. Especially, the cross section of Ref.[19] at 14.1MeV energy is higher than ours as much as 2.5 times. The reason may be that the effect of ^{50}Cr(n,γ)^{51}Cr reaction induced by thermal neutron made the cross section of the ^{52}Cr(n,2n)^{51}Cr reaction much higher.

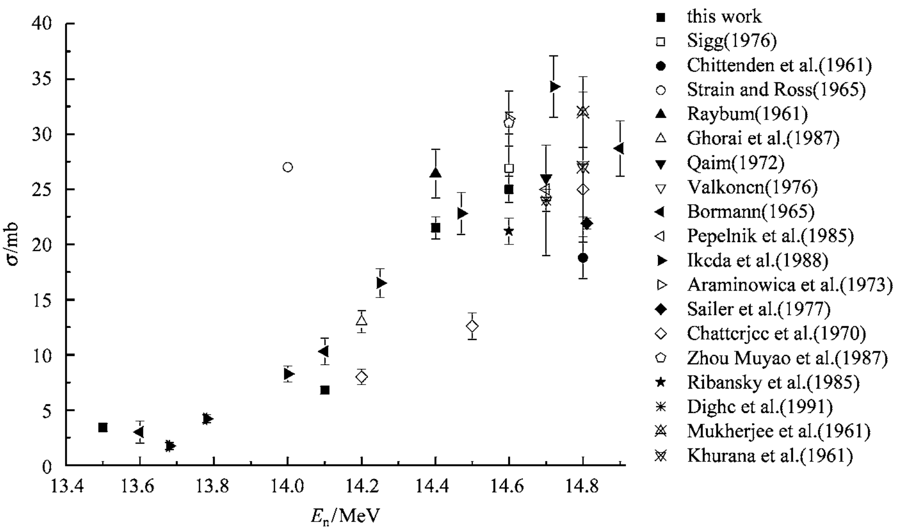

Fig.1. The cross sections for the $^{50}Cr(n,2n)^{49}Cr$ reaction.

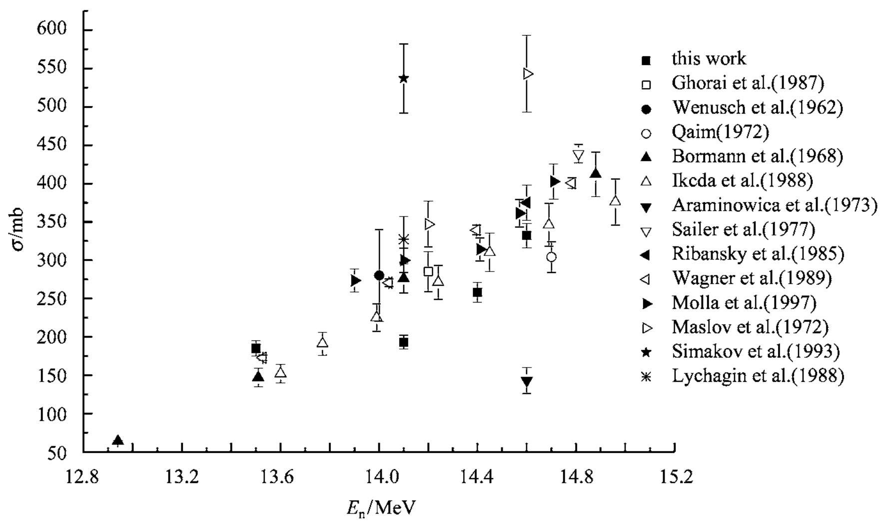

Fig.2. The cross sections for the $^{52}Cr(n,2n)^{51}Cr$ reaction.

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13.5—14.6MeV能区中子引起的^{50}Cr(n,2n)^{49}Cr和^{52}Cr(n,2n)^{51}Cr核反应截面的测量*

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摘要　报告了在13.5—14.6MeV中子能区,用活化法(以^{93}Nb(n,2n)^{92m}Nb反应截面为中子注量标准)测得的^{50}Cr(n,2n)^{49}Cr和^{52}Cr(n,2n)^{51}Cr的反应截面.由能量为13.5±0.3,14.1±0.2,14.4±0.3和14.6±0.3MeV的中子引起的^{50}Cr(n,2n)^{49}Cr反应截面值分别为3.4±0.2,6.8±0.3,21.5±1.0和25.0±1.2mb,^{52}Cr(n,2n)^{51}Cr的反应截面值分别为185±10,193±9,258±13和332±16mb.单能中子用T(d,n)^{4}He反应获得,其能量用铌锆截面比法测定.另外,为避免热中子引发的^{50}Cr(n,2γ)^{51}Cr对^{52}Cr(n,2n)^{51}Cr反应截面的影响,在样品被辐照过程中对样品进行了包镉处理,并将实验结果与尽可能收集到的其他实验数据进行了比较.

关键词　铬　反应截面　活化法　(n,2n)反应　14MeV中子

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