Excitation Functions of proton-induced reactions of 58Fe(p,n)58Co reaction from threshold energy to 21 MeV

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Introduction

Production of proton induced reaction cross-section of iron is important from accelerator point of view and many other applications. In reactors stainless steel is a very important element as it is used as the calandria vessel and pipe lines of secondary coolant circuit. In ADS the acceleration of proton beam is through stainless tubes. Hence, iron is often found in the beam line component. Also, stainless steel is one of the major components in low and high energy accelerators [1]. Iron has four stable isotopes (54Fe~5.85%, 56Fe~ 91.75%, 57Fe ~ 2.12%, and 58Fe~ 0.28%) and is an essential structural material [2]. Thus, it is very important to know about the proton, deuteron, alpha particles, and heavy ion induced reactions of natFe at various energies, which is the excitation function.

Experimental Details

The excitation functions of the proton-induced reaction on natural iron were measured by stack foil irradiation technique at 14 UD BARC-TIFR Pelletron facility at TIFR, Mumbai, India [3]. Natural iron foil of sizes 0.7x0.7 cm^2 were used as target and natural copper of sizes 0.8x0.8 cm^2 were used as energy degrader and monitor. A stack of aluminium foil of size 0.8x0.8 cm^2 followed by five identical pairs (Fe-Cu) of foil layers containing iron (99.99% purity, 100 micron thickness) and copper (99.99% purity, 108 micron thickness) was irradiated with a proton-beam of 21 MeV for 30 minutes. The beam current was kept constant at 28 nA during the irradiation. The stack was additionally wrapped with 0.025 mm thick Al.. The irradiated samples were counted for 0.08-1.25 hrs using HPGe detector coupled to PC based 4-k channel analyser.

A proton beam of 21 MeV hit on an Al foil of thickness ~108 micron (>99.99% purity) before hitting the target. Thus, the incident proton-beam was 19.63 MeV on the first target foil based on SRIM-2013 [4] calculation. The proton beam intensity was determined by using the $^{nat63}Cu(p,x)^{62}Zn$ reaction cross-section [3] from the activity induced on the monitor foils at the first position of the stack. The beam intensity was considered as constant to determine the cross-section of $^{58}Fe(p,n)^{58}Co$ reaction for each foil in the stack as the loss of proton beam flux was very small and very hard to deduce practically [1]. The degradation of the proton beam along the stack was calculated used the computer code SRIM-2013[2].

Calculation

The activation cross-section for the reaction $^{58}Fe(p,n)^{58}Co$ at the i-th sample was calculated using the activation formula[1]:

$$\sigma(i) = \frac{\lambda M A_{obs}}{E(E_\gamma) I_\gamma N \rho t \varphi (1-e^{-\lambda t_i}) e^{-\lambda t_c} (1-e^{-\lambda CL})}$$

where λ is the decay constant (λ= ln2/T1/2) of the reaction product of interest with half-life = T1/2. M is the atomic weight, t is the target thickness, A_{obs} is the net counts under the photo-peak area at the i-th sample, ε(Eγ) is the efficiency of the detector and I_γ is the branching intensity of the 810.7593 keV γ-line of ^{58}Co. N is the Avogadro's number, ρ is the density of the target(7.874 gm/cm^3). t_i, t_c and Cl are the irradiation time, cooling time and counting time, respectively. The nuclear spectroscopic data used in the above calculations are taken from the Ref. [6]. The threshold energies calculated on the basis of Q-tool system [7]. The standard cross-section of the beam monitor was taken from a charged-particle cross-section database for medical radioisotope production [4].

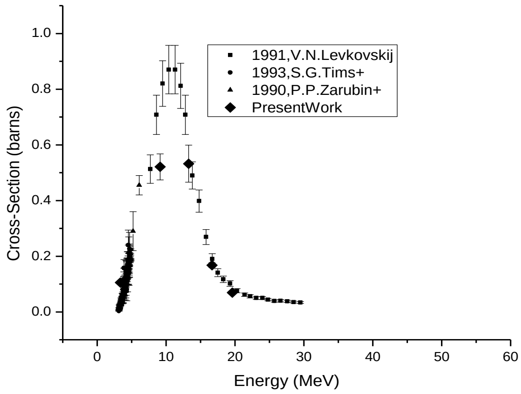
Result and Discussion

The experimentally determined cross-section at the excitation energies 19.626, 16.657, 13.264, 9.148 and 3.369 MeV from the present work are reported for the first time (Table 1). The excitation function of ^{58}Fe(p,n)^{58}Co reaction, calculated from its threshold to 19.66 MeV, is shown in Fig-1 in comparison with the earlier experimental data [8-10]. It can be seen from Fig. 1 that the calculated cross-sections are in good agreement with the earlier experimental trend. This indicates the correctness of the present approach.

Table 1: Cross-section of 58Fe(p,n)58Co reaction from threshold to 21 MeV

Proton Energy (MeV)	σ(mb) [3] ^{63}Cu(p.x)^{63}Zn reaction	(Φ) p-cm^{-2}s^{-1} x10^{15}	<σ> (mb) ^{58}Fe(p,n)^{58}Co reaction
18.21	46.248	1.05± 0.03	
19.62			61.68± 0.91
16.66			158.22± 9.59
13.27			504.26± 61.72
9.15			494.51± 44.62
3.37			99.65± 0.45

Fig-1: Excitation function of 58Fe (p,n) 58Co reaction compared with the literature data



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