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Calculation of Reactions Cross Section for Neutron-Induced Reactions on ^{127}I Isotope

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Abstract

In this work, the reaction cross-section for neutron-induced reactions on ^{127}I isotope was calculated using EXIFON code in the energy range of incident particle from 0 MeV to 30 MeV. The code is based on an analytical model for statistical multistep direct and multistep compound reactions (SMD/SMC model). In order to see the effect of nuclear structure on cross sections, the calculation was done using nuclear shell structure effect and without considering shell structure effect. Obtained results and statistical analysis showed that shell structure effect does not give significant changes to the cross-section at considered energy ranges. This shows that EXIFON code is a good tool for investigation of nuclear reaction cross section and is useful in the production of the radioisotopes of Iodine, Antimony and tellurium of high purity and in an efficient manner using cyclotron or nuclear reactors, these isotopes have potential application for field of medical science especially for diagnostics and therapeutic purposes.

Keywords

Nuclear Reaction, Cross-Section, Excitation Function, Radioisotope, Statistical Multistep Reaction, Nuclear Model

1. Introduction

The artificially produced radioactive isotopes are important for many different applications [1]. Radioactive isotopes play an important role in the field of medical science in terms of beneficial applications in both diagnosis and therapy purposes [2].

In radioisotope production programs, nuclear reactions data are mainly needed for optimization of production routes [3].

At present day, radioisotope production for nuclear medicine is important because of its common use in tomography devices. Both single photon emissions computed tomography (SPECT) and positron emission tomography (PET) are used for diagnosis in nuclear medicine. In particular, the radionuclide of iodine is used for these purposes. Therefore, this radionuclide plays an important role in medical applications and research. For example, Gamma-emitted short-lived ^{123}I and long live ^{124}I [1] isotopes can be used as the diagnostic image in SPECT and PET. Besides, the ^{124}I allows for studying of important organs such as brain and heart [2]. The long-lived ^{125}I isotope is used as a source for internal radiotherapy, bone dosimetry and a biological tracer [3]. Another iodine radionuclide ^{122}I is a very short-lived isotope and used in PET for brain blood-flow studies [4].

For the last 50 years, the International Atomic Energy Agency (IAEA) Nuclear Data Section (NDS) has been collating, compiling and reviewing nuclear data in a collection of databases and publications, aim of making these data available to a global audience to create an awareness of the wide-ranging data available in support of nuclear-related applications [4] [5] [6]. Nuclear reaction by neutron interactions on bismuth-208 was studied for the production of lead isotopes and thallium isotopes [7].

Today, the nuclear databases are accessible online through the website provided by the IAEA Nuclear Data Section (NDS). This site offers access to tens of thousands of nuclear data sets that can be used for research, innovation, development and dissemination. By such materials and files, the authors conducted the calculation on the reaction cross-section for neutron-induced reactions on ^{127}I isotope.

2. Theoretical Background

Over the years, the concept of statistical multistep processes has become more and more important for the understanding of nuclear reaction mechanism, especially above 20 MeV. An analytical model for both statistical multistep direct (SMD) and statistical multistep compound (SMD) processes was applied for describing nuclear reactions up to 30 MeV. This can be generalized in several respects:

The extension to higher energies is performed including s-step direct processes for s = 1 up to 5.

The same residual interaction is used for computing both formation and decay of the compound nucleus within SMC as well as SMD processes. Thus, there is no reference to the optical model (OM) reaction cross section. The OM cross section for charged particles was used to simulate coulomb effects in the threshold region only [5].

α and γ-Processes are included Spin-isospin conservation during the two-body collision is considered.

The calculation of Multiple Particle Emission (MPE) is generalized. Up to three decays of the compound nucleus are considered.

This model is formulated in detail for predicting emission spectra for neutrons, protons, alphas and photons including equilibrium, pre-equilibrium, direct as well as MPE processes in a consistent way.

Calculations are performed with one physical parameter set for several nuclei, several energies, and several reaction types.

2.1. Statistical Multistep Reaction

Statistical multistep models are very successful in describing nuclear reactions at energies up to about 100 MeV. These models enable the description of direct, pre-equilibrium, and equilibrium processes in a consistent way for a wide mass number range and various reaction channels, e.g. neutrons, protons, alpha, and gamma particles.

The application of a statistical multistep model to heavy nuclei requires the consideration of fission as a competing process to particle and "gamma-ray" emissions. Therefore, statistical multistep models should be extended to the fission channel.

In the statistical multistep model, the total emission spectrum of the process (a, xb) is divided into three main parts [8] [9],

$$\frac{\mathrm{d}\sigma_{a,xb}(E_a)}{\mathrm{d}E_b} = \frac{\mathrm{d}\sigma_{a,b}^{\mathrm{SMD}}(E_a)}{\mathrm{d}E_b} + \frac{\mathrm{d}\sigma_{a,b}^{\mathrm{SMC}}(E_a)}{\mathrm{d}E_b} + \frac{\mathrm{d}\sigma_{a,xb}^{\mathrm{MPE}}(E_a)}{\mathrm{d}E_b} \tag{2.1}$$

The first term on the right hand side of Equation (2.1) represents the statistical multistep direct (SMD) part which contains from single-step up to five-step contributions. The second term represents the statistical multistep compound (SMC) emission which is based on a master equation. Both terms together (SMD + SMC) represents the first-chance emission process [5] [7] [10]. The last term of Equation (2.1) represents the multiple particle emission (MPE) reaction which includes the second-chance, third-chance emissions, etc. These terms are summarized below:

$$\frac{\mathrm{d}\sigma_{a,xb}^{\mathrm{MPE}}(E_a)}{\mathrm{d}E_b} = \sum_c \frac{\mathrm{d}\sigma_{a,cb}(E_a)}{\mathrm{d}E_b} + \sum_{c,d} \frac{\mathrm{d}\sigma_{a,cdb}(E_a)}{\mathrm{d}E_b} + \cdots \tag{2.2}$$

2.2. Activation Cross-Sections

The following relations between the optical model (OM) reaction Cross-section and the energy-integrated partial Cross-sections should be satisfied (at each incident energy (E_a))

$$\sigma_a^{\mathrm{OM}} = \sum_b \sigma_{a,b} \tag{2.3}$$

$$\sigma_{a,b} = \sum_c \sigma_{a,cb} \quad \text{and} \quad \sigma_{a,cb} = \sum_d \sigma_{a,cdb} \tag{2.4}$$

with $\sigma_{a,b} = \sigma_{a,b}^{\mathrm{SMD}} + \sigma_{a,b}^{\mathrm{SMC}}$ the total first-chance emission, in this context, activation Cross-sections are given by

$$\sigma_{a,b\gamma} = \sigma_{a,b} - \sum_{c \neq \gamma} \sigma_{a,cb} \tag{2.5}$$

$$\sigma_{a,cb\gamma} = \sigma_{a,cb} - \sum_{d \neq \gamma} \sigma_{a,cbd} \tag{2.6}$$

where $b,c,d \neq \gamma$

For example, the (n, p)-activation Cross-sections have the form

$$\sigma_{a,p\gamma} = \sigma_{n,p} - \sigma_{n,pn} - \sigma_{n,2p} - \sigma_{n,p\alpha} \tag{2.7}$$

The SMD Cross-section is a sum over s-step direct processes given by: [11]

$$\frac{\mathrm{d}\sigma_{a,b}^{SMD}(E_a)}{\mathrm{d}E_b} = \sum_{s=1} \frac{\mathrm{d}\sigma_{a,b}^{s}(E_a)}{\mathrm{d}E_b} \tag{2.8}$$

The SMD Cross-section has the form

$$\frac{\mathrm{d}\sigma_{a,b}^{\mathrm{SMC}}(E_a)}{\mathrm{d}E_b} = \sigma_a^{SMC}(E_a) \sum_{N=N_0}^{N^I} \frac{\tau_N(E)}{\hbar} \sum_{(\Delta V)} \Gamma_{N,b}^{(\Delta V)}(E, E_b)\uparrow \tag{2.9}$$

where τ_N satisfies the time-integrated master equation

$$-\hbar\delta_{NN_0} = \Gamma_{N-2}^{(+)}(E)\downarrow \tau_{N-2}(E) + \Gamma_{N+2}^{(-)}(E)\downarrow \tau_{N+2}(E) - \Gamma_N(E)\tau_N(E) \tag{2.10}$$

and

$$\Gamma_N^{(\Delta v)}(E)\downarrow = 2\pi I_{SS}^2 \rho_N^{(\Delta v)}(E) \tag{2.11}$$

The multiple particle emission is expressed as:

$$\frac{\mathrm{d}\sigma_{a,xb}^{\mathrm{MPE}}(E_a)}{\mathrm{d}E_b} = \sum_c \frac{\mathrm{d}\sigma_{a,cb}(E_a)}{\mathrm{d}E_b} + \sum_{cd} \frac{\mathrm{d}\sigma_{a,cdb}(E_a)}{\mathrm{d}E_b} + \cdots \tag{2.12}$$

To keep the model tractable, a simple two-body interaction is assumed: [5]

$$I(r_1, r_2) = -4\pi \frac{F_0}{A}\left[\chi_{nl}(R)\right]^{-4} \delta(r_1 - r_2)\delta(r_1 - R) \tag{2.13}$$

$F_0 = 27.5\ \mathrm{MeV}$ taken from nuclear structure considerations [11].

The factor $\left[\chi_{nl}(R)\right]^{-4}$ contains the wave function at the nuclear radius $R = r_0 A^{1/3}$.

The single-particle state density of particles $C = n, p, \alpha$ with mass μ_c is given by

$$\rho(E_c) = \frac{4\pi V \mu_c (2\mu_c E_c)^{1/2}}{(2\pi\hbar)} = \left(4.48\times10^{-3}\ \mathrm{fm}^{-3}\cdot \mathrm{MeV}^{-3/2}\right) r_0^3 A E_C^{1/2} \tag{2.14}$$

where $V = \frac{4\pi R^3}{3}$ is equal to the nuclear volume [9].

The single-particle state density of bound particles (at Fermi energy) is then defined by

$$g = 4\rho(E_F) \tag{2.15}$$

where factor 4 considers the spin and isospin degeneracy

3. Methodology

EXIFON code is a nuclear reaction software which provides a continuous and smooth description of nuclear reactions over a wide energy and mass range which is based on an analytical model for statistical multistep direct and multistep compound reactions (SMD/SMC model). It predicts emission spectra, angular distributions, and activation Cross-sections for neutrons, protons, alpha particles, and photons. Multiple particle emissions are considered for up to three decays of the compound system. EXIFON is a fast, easy-to-handle code which predicts Cross-sections from one global parameter set. The only adjustable quantity is the pairing shift. The INPEXI code creates input files for EXIFON2.0 from mass and shell-correction tables. The MAKE6 code transforms EXIFON output into an ENDF-6 format file [9].

The model is based on random matrix physics with the use of the Green's function formalism [12] [13]. All calculations are performed without any free parameters. Results were presented for bombarding energies below 30 MeV [14] [15].

3.1. Procedure

3.1.1. Nuclear Model Calculations

Theoretical calculations of Cross-section were performed by nuclear model code EXIFON the program was run and the input and output directory were defined, and then the target nucleus is specified. The incident particle and target nucleus were selected and excitation function in the general options section for this calculation was chooses.

The number of incident energy was specified followed by the first incident energy, and then the incident energy step is also specified. The Cross-section correspond to each particular energy was obtained.

The output data (OUTEXI) for the calculation was then stored in the set output directory. Also, DAT file name is stored in the set output directory.

Secondly, the option without shell effect is also used for each target nucleus, also an output data (OUTEXI) for the calculation is then stored in the set output directory. Also, DAT file is stored in the set output directory.

3.1.2. Shell Structure Effects

The shell structure effects are considered in SMC processes. Under such a situation, the single-particle state density g, in Equation (2.18) is multiplied by the factors

$$\left(1+\frac{\delta W}{E_X}\left[1-\exp\left(-\gamma E_X\right)\right]\right) \tag{2.16}$$

With $\gamma = 0.05\ \text{MeV}^{-1}$ and δW as the shell correction energy taken from tables [16]. The quantity $E_X = E \text{ or } U$ denotes the excitation energy of the composite or residual systems respectively.

The calculations in this study were performed with $(\delta W \neq 0)$ and without $(\delta W = 0)$ shell corrections.

4. Results and Discursions

4.1. Results

The calculated cross-section data for neutron-induced reactions on ^{127}I are given in Table 1 and Table 2.

The calculations in which the shell correction was taken into consideration are denoted by “With” on the graph’s legend, while those without the shell correction effects are denoted by “Without”.

Table 1. Cross section (mb) obtain without shell structure effect of I-127 interactions with neutron particle at different energies (MeV).

Energy	(n, a)	(n, na)	(n, ag)	(n, an)	(n, g)	(n, ng)	(n, pg)	(n, 2ng)	(n, n)	(n, 2n)	(n, pn)	(n, 3n)	(n, p)	(n, np)	(n, 2p)	(n, 2np)
1	0	0	0	0	1316.9	1713.8	0	0	1713.8	0	0	0	0	0	0	0
2	0	0	0	0	267.4	2355.1	0	0	2355.1	0	0	0	0	0	0	0
3	0	0	0	0	83.1	2390.3	0	0	2390.3	0	0	0	0	0	0	0
4	0	0	0	0	35	2353.9	0	0	2353.9	0	0	0	0	0	0	0
5	0	0	0	0	17.8	2312.5	0	0	2312.5	0	0	0	0	0	0	0
6	0	0	0	0	10.5	2274.2	0	0	2274.2	0	0	0	0	0	0	0
7	0	0	0	0	7.1	2239.4	0.1	0	2239.4	0	0	0	0.1	0	0	0
8	0	0	0	0	5.6	2207.2	0.2	0	2207.2	0	0	0	0.2	0	0	0
9	0.1	0	0.1	0	4.8	2177	0.5	0	2177	0	0	0	0.5	0	0	0
10	0.3	0	0.3	0	4.4	2130.9	1	17.5	2148.4	17.5	0	0	1	0	0	0
11	0.8	0	0.8	0	4.1	1870.5	1.8	250.2	2120.7	250.2	0	0	1.8	0	0	0
12	1.4	0	1.4	0	3.8	1384.5	2.9	709	2093.4	709	0	0	2.9	0	0	0
13	2.4	0	2.4	0	3.7	954.4	4.5	1111.9	2066.4	1111.9	0	0	4.5	0	0	0
14	3.6	0	3.6	0	3.6	674.2	6.5	1365.1	2039.3	1365.1	0	0	6.5	0	0	0
15	5	0	5	0	3.4	516.2	8.7	1495.9	2012	1495.9	0.3	0	9	0	0	0
16	6.6	0	6.6	0	3.4	425.2	11	1559.4	1984.6	1559.4	0.9	0	11.9	0	0	0
17	8.3	0	7.9	0.3	3.3	374	13.4	1583	1957.1	1583	1.9	0	15.3	0.1	0	0
18	10	0	9.1	0.9	3.2	343.5	15.7	1582.9	1929.4	1585.7	3.3	2.8	19	0.2	0	0
19	11.7	0	10	1.7	3.2	323.6	17.9	1341.6	1901.7	1577.8	5.1	236.2	23.1	0.3	0	0
20	13.4	0.1	10.7	2.7	3.2	309.1	19.9	816.6	1873.9	1564.2	7.5	747.7	27.4	0.5	0	0
21	15.1	0.2	11.2	3.9	3.1	297.6	21.6	419.1	1846.1	1547.7	10.4	1128.6	32	0.7	0	0
22	16.7	0.3	11.4	5.3	3.1	287.7	22.9	205.1	1818.4	1529.5	13.8	1324.4	36.7	1	0	0
23	18.2	0.4	11.4	6.8	3.1	278.8	24.4	101.6	1790.7	1510.3	17.2	1408.6	41.6	1.3	0	0
24	19.7	0.6	11.3	8.4	3	270.5	25.4	52.8	1763.1	1490.4	21.3	1437.5	46.7	1.6	0	0.1
25	21.1	0.8	11.1	10	3	262.8	26.1	29.5	1735.6	1470	25.7	1440.3	51.8	2	0	0.1
26	22.4	1.1	10.8	11.6	3	253	26.7	18.1	1708.1	1451.6	30.3	1433.2	57	2.4	0	0.3
27	23.7	1.4	10.5	13.2	3	246.3	27.2	12	1680.8	1430.3	35	1417.7	62.3	2.9	0	0.5
28	24.8	1.7	10.1	14.7	2.9	239.6	27.6	8.6	1653.6	1408.9	40	1399.4	67.6	3.4	0	0.8
29	25.9	2	9.7	16.2	2.9	233.2	27.9	6.5	1626.5	1387.4	45.1	1379.5	73	3.9	0	1.1
30	26.8	2.4	9.3	17.5	2.9	227.1	28.1	5.2	1599.5	1365.6	50.3	1358.5	78.4	4.4	0	1.6

Table 2. Cross section (mb) obtain with shell structure effect of I-127 interactions with neutron particle at different energies (MeV).

Energy	(n, a)	(n, na)	(n, ag)	(n, an)	(n, g)	(n, ng)	(n, pg)	(n, 2ng)	(n, n)	(n, 2n)	(n, pn)	(n, 3n)	(n, p)	(n, np)	(n, 2p)	(n, 2np)
1	0	0	0	0	1208	1822.6	0	0	1822.6	0	0	0	0	0	0	0
2	0	0	0	0	240.5	2382.1	0	0	2382.1	0	0	0	0	0	0	0
3	0	0	0	0	75.4	2398	0	0	2398	0	0	0	0	0	0	0
4	0	0	0	0	31.8	2357.1	0	0	2357.1	0	0	0	0	0	0	0
5	0	0	0	0	16.5	2313.9	0	0	2313.9	0	0	0	0	0	0	0
6	0	0	0	0	9.8	2274.9	0	0	2274.9	0	0	0	0	0	0	0
7	0	0	0	0	6.7	2239.8	0.1	0	2239.8	0	0	0	0.1	0	0	0
8	0	0	0	0	5.3	2207.4	0.2	0	2207.4	0	0	0	0.2	0	0	0
9	0.1	0	0.1	0	4.6	2177.2	0.5	0	2177.2	0	0	0	0.5	0	0	0
10	0.3	0	0.3	0	4.2	2131	1.1	17.4	2148.4	17.4	0	0	1.1	0	0	0
11	0.8	0	0.8	0	4	1877.9	1.9	242.7	2120.6	242.7	0	0	1.9	0	0	0
12	1.5	0	1.5	0	3.8	1403.8	3.1	689.6	2093.3	689.6	0	0	3.1	0	0	0
13	2.4	0	2.4	0	3.6	976.4	4.7	1089.7	2066.2	1089.7	0	0	4.7	0	0	0
14	3.6	0	3.6	0	3.5	692.7	6.8	1346.3	2039	1346.3	0	0	6.8	0	0	0
15	5.1	0	5.1	0	3.4	530.2	9.1	1481.5	2011.7	1481.5	0.3	0	9.3	0	0	0
16	6.7	0	6.6	0	3.3	435.1	11.4	1549.1	1984.2	1549.1	0.9	0	12.3	0	0	0
17	8.3	0	8	0.3	3.3	381	13.7	1575.4	1956.6	1575.4	2	0	15.8	0.1	0	0
18	10	0	9.1	0.9	3.2	348.6	16	1576.1	1928.8	1580	3.5	3.9	19.6	0.2	0	0
19	11.7	0	10	1.7	3.2	327.5	18.2	1293.9	1901	1573.1	5.5	279.2	23.7	0.4	0	0
20	13.4	0.1	10.7	2.7	3.1	312.3	20.2	760.4	1873.1	1560.2	8	799.8	28.2	0.6	0	0
21	15.1	0.2	11.2	3.9	3.1	300.2	21.9	383.1	1845.3	1544	11	1160.9	32.8	0.9	0	0
22	16.7	0.3	11.4	5.3	3.1	290	23.2	185.4	1817.5	1525.9	14.4	1340.6	37.7	1.2	0	0
23	18.3	0.5	11.4	6.8	3	280.9	24.7	91.3	1789.7	1506.8	18	1415.4	42.6	1.6	0	0
24	19.7	0.7	11.3	8.4	3	272.4	25.6	47.5	1762	1486.9	22.1	1439.3	47.7	2.1	0	0.1
25	21.1	0.9	11.1	10.1	3	264.5	26.4	26.5	1734.4	1466.4	26.5	1439.7	52.9	2.6	0	0.2
26	22.5	1.2	10.8	11.7	3	254.7	27	16.2	1706.9	1447.9	31.2	1431.3	58.2	3.1	0	0.3
27	23.7	1.5	10.4	13.3	3	247.9	27.5	10.7	1679.5	1426.4	36.1	1415	63.5	3.7	0	0.6
28	24.8	1.8	10.1	14.8	2.9	241.2	27.8	7.7	1652.2	1404.9	41.1	1396.1	68.9	4.3	0	0.9
29	25.9	2.2	9.7	16.2	2.9	234.7	28.1	5.8	1625.1	1383.3	46.2	1375.7	74.3	5	0	1.4
30	26.8	2.6	9.3	17.6	2.9	228.5	28.3	4.6	1598.1	1361.4	51.4	1354.4	79.8	5.6	0	1.9

4.2. Excitation Functions

Excitation function is defined as the graphical plots of cross-section against the energy of the incident particle, it is an important parameter in nuclear data analysis describes the probability that nuclear reactions can occur at particular energy of incident particle. Below are the excitation functions of the reactions.

4.3. Discursion

Neutron on ^{127}I

Iodine-127 is a naturally occurring stable element with 100% abundance isotope of iodine when neutron particle introduced into its nucleus, the nuclear reaction processes occurred and produced other stable and radioactive elements.

Figure 1 is the knockout reaction in which neutron displaced alpha particle from the nucleus of iodine-127. Figure 2 is a compound nucleus formation of iodine-128 and it emits alpha particle to produce Antimony-124.

Figure 1 and Figure 2 shown the excitation function of the interaction between neutron particle and iodine-127 nucleus for the production of Antimony-124 which is one of the radioisotopes of Antimony, it has a half-life of 60 days 21 minute and decays through beta emission and gamma particle.

Figure 3 and Figure 4 shows the excitation function of the production of Antimony-123, is a stable isotope of Antimony.

Figure 5 shown the compound nucleus formation of iodine-128, is a radioactive isotope of iodine with a half-life of twenty-five (25) minutes, it decays either by e^- and γs radiations. The shell correction effect was considered in both two graphs and the results show no significant different observed.

Figure 6 is an inelastic collision between the neutron and the nucleus of iodine-127, the graph shows that cross section decreases with increases in the incident energy and Figure 7 is an elastic collision between neutron and nucleus of iodine-127.

Tellurium-127 is an isotope of Tellurium with a half-life of 9.3 h, it decays by beta emission, Figure 8 and Figure 9 shown the compound nucleus formation of this important isotope. The shell correction effect was considered in both two graphs and the results show no significant different observed.

Iodine-126 is a radioactive isotope of iodine with a half-life of thirteen (13) days, it decays either by e^-, e^+ and γs radiations. Figure 10 and Figure 11 shown the compound nucleus formation of this important isotope, the shell correction effect was considered in both two graphs and the results show no significant different observed.

Tellurium-126 is a stable isotope of Tellurium which can be produced through the reaction in Figure 12 and Figure 13. Figure 12 shows that no change observed for both reactions with shell effect correction and without shell effect correction. Figure 13 shows that changes were observed in the cross sections with and without shell correction.

Iodine-125 is a radioisotope of iodine with a half-life of 56 days and it decays through K-capture and gamma particle. Figure 14: Excitation function for production iodine-125.

Figure 15 is an excitation function for the production of Antimony-126 which is a radioactive isotope of Antimony with a half-life of 9 hour and it decays through beta and gamma particle.

Figure 16 is an excitation function for the production of Tellurium-125 which is a radioactive isotope of Tellurium with a half-life of 58 days and it decays

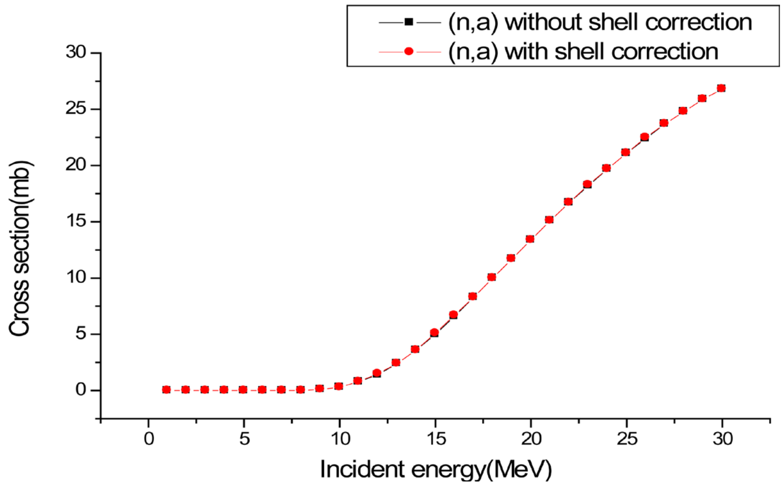

Figure 1. Excitation function of $^{127}I(n,a)$ reaction.

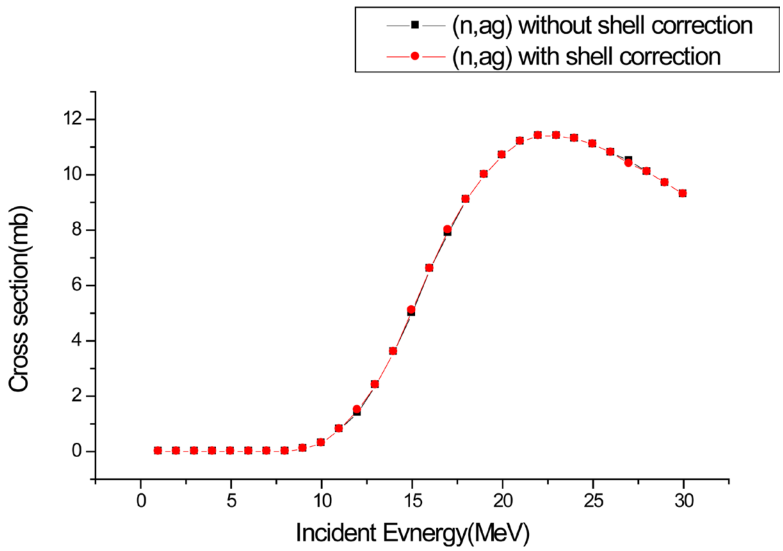

Figure 2. Excitation function of $^{127}I(n,ag)$ reaction.

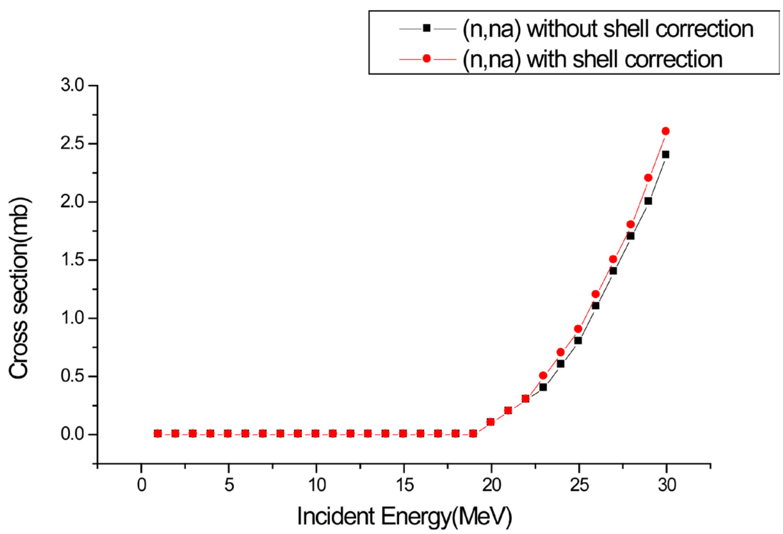

Figure 3. Excitation function of $^{127}I(n,na)$ reaction.

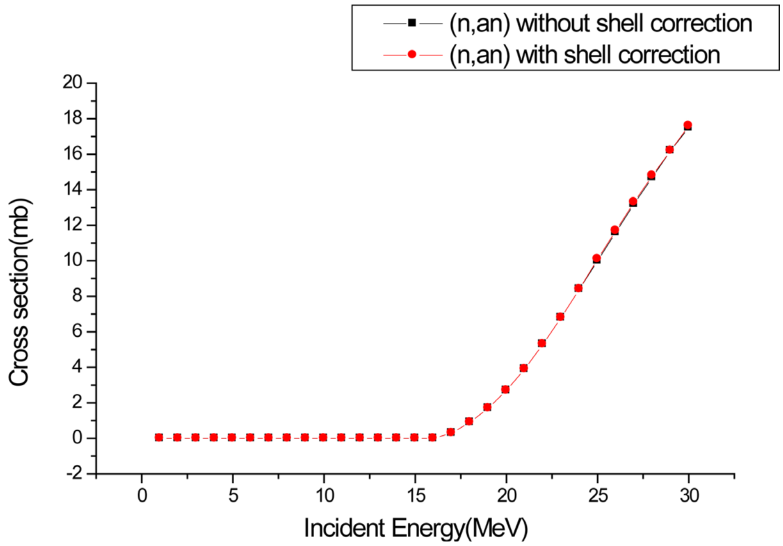

Figure 4. Excitation function of $^{127}I(n, an)$ reaction.

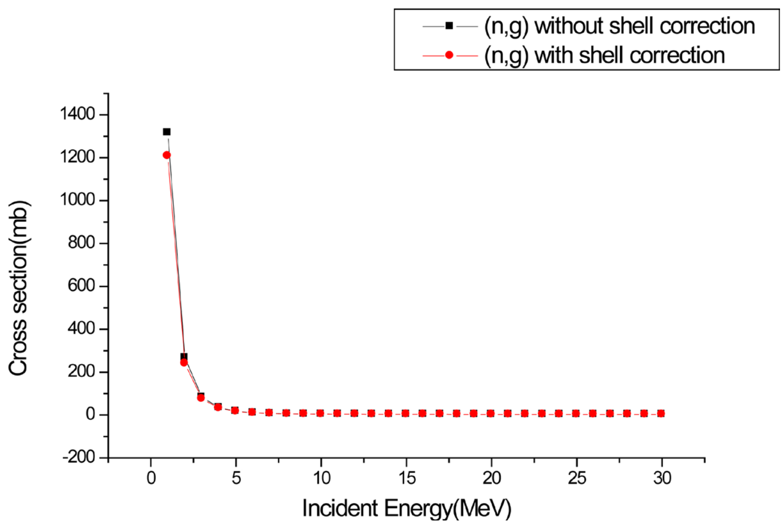

Figure 5. Excitation function of $^{127}I(n, g)$ reaction.

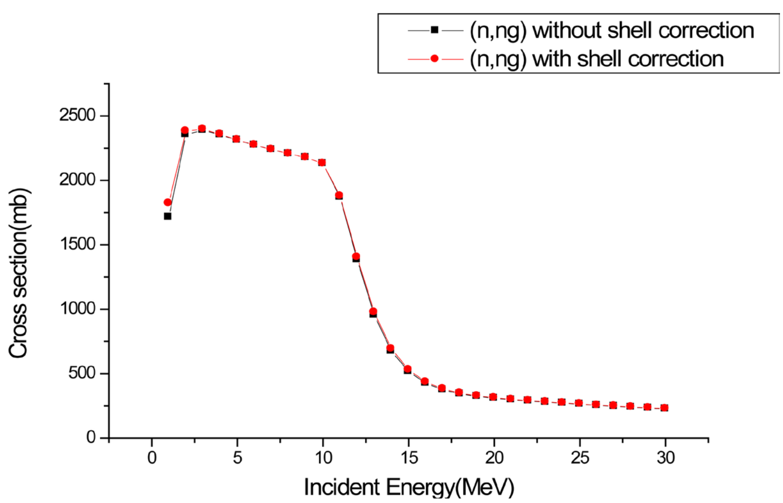

Figure 6. Excitation function of $^{127}I(n, ng)$ reaction.

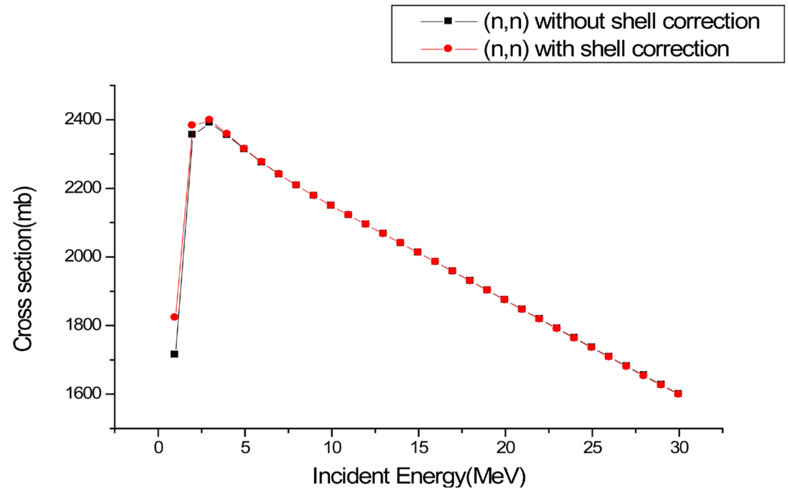

Figure 7. Excitation function of $^{127}I(n,n)$ reaction.

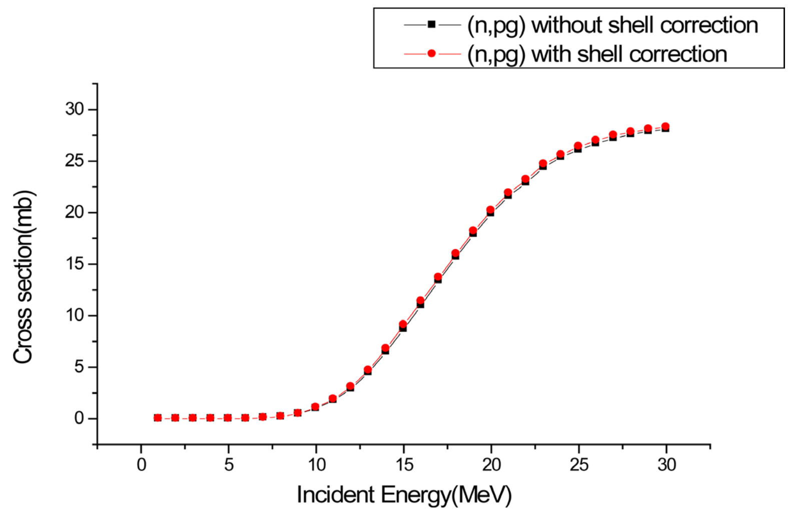

Figure 8. Excitation function of $^{127}I(n,pg)$ reaction.

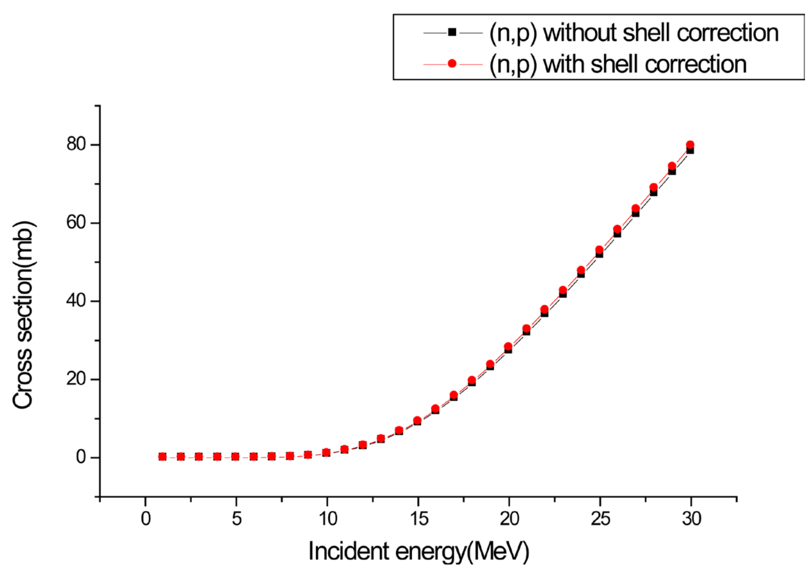

Figure 9. Excitation function of $^{127}I(n,p)$ reaction.

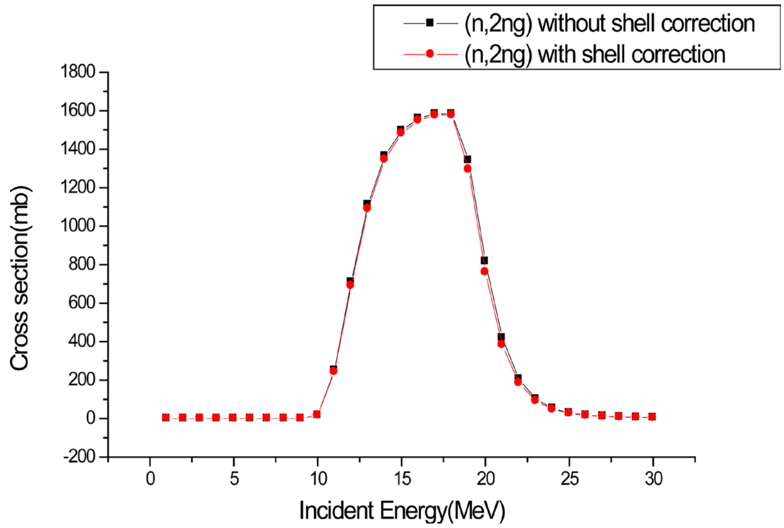

Figure 10. Excitation function of $^{127}I(n,2ng)$ reaction.

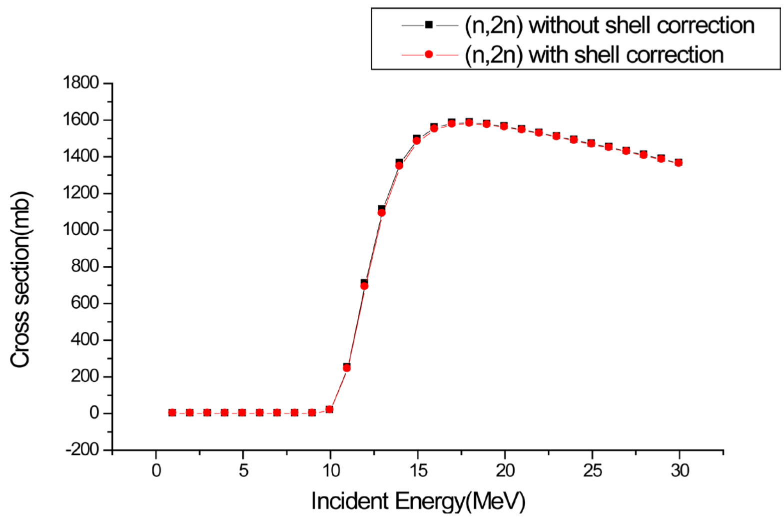

Figure 11. Excitation function of $^{127}I(n,2n)$ reaction.

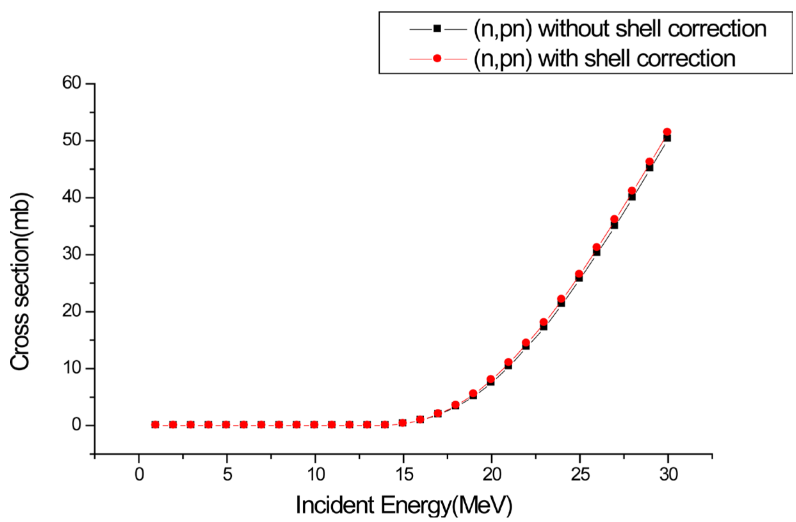

Figure 12. Excitation function of $^{127}I(n,pn)$ reaction.

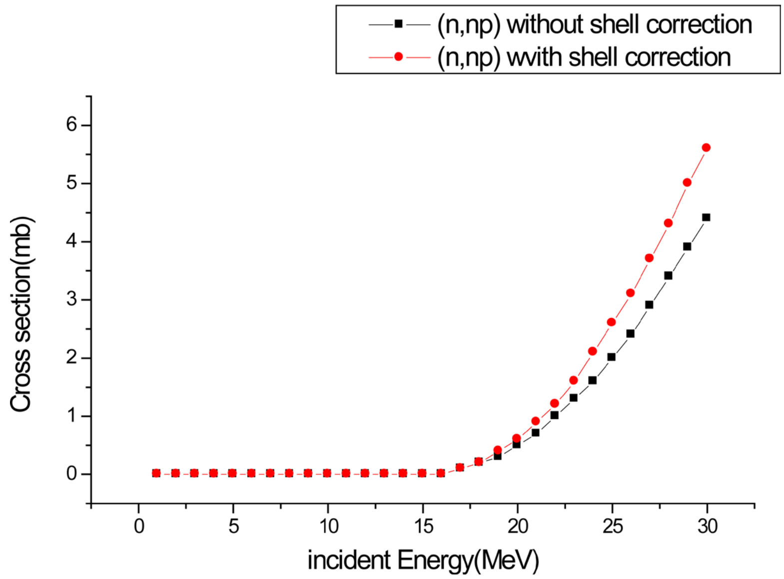

Figure 13. Excitation function of $^{127}I(n,np)$ reaction.

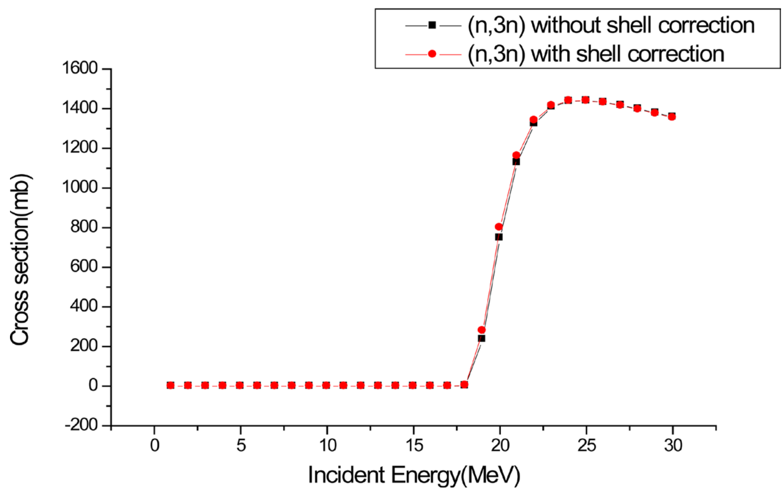

Figure 14. Excitation function of $^{127}I(n,3n)$ reaction.

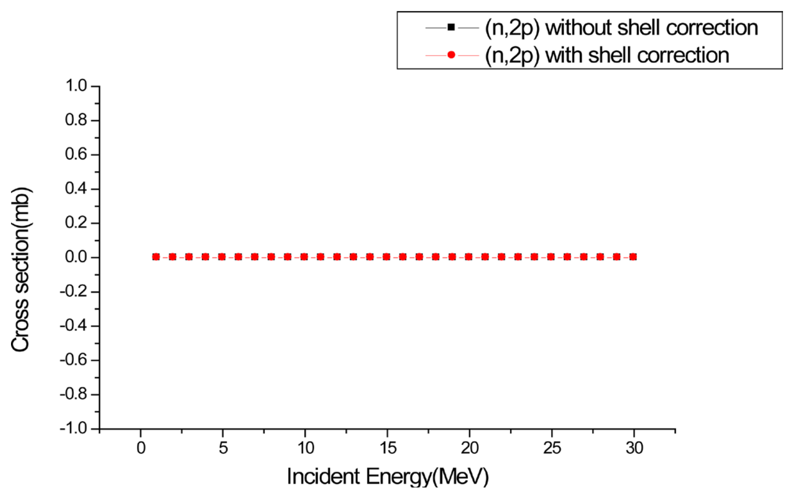

Figure 15. Excitation function of $^{127}I(n,2p)$ reaction.

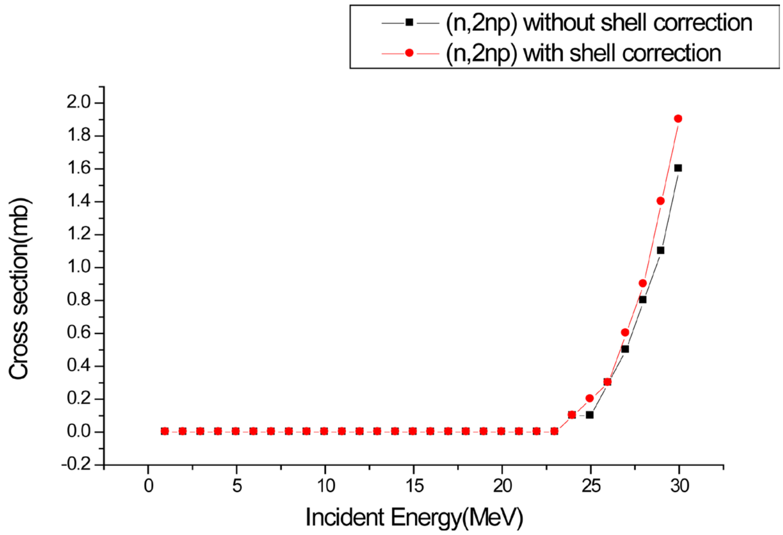

Figure 16. Excitation function of $^{127}I(n,2np)$ reaction.

Table 3. The correlation between different reaction charnels of Cross section without shell structure effect.

	(*n, a*)	(*n, na*)	(*n, ag*)	(*n, an*)	(*n, g*)	(*n, ng*)	(*n, pg*)	(*n,* 2*ng*)	(*n, n*)	(*n,* 2*n*)	(*n, pn*)	(*n,* 3*n*)	(*n, p*)	(*n, np*)	(*n,* 2*p*)	(*n,* 2*np*)
(n, a)	1															
(n, na)	0.842678	1														
(n, ag)	0.905853	0.547052	1													
(n, an)	0.931184	0.970678	0.689102	1												
(n, g)	−0.23406	−0.13422	−0.27572	−0.16311	1											
(n, ng)	−0.83086	−0.51001	−0.93824	−0.61381	0.216737	1										
(n, pg)	0.984922	0.740846	0.965033	0.854474	−0.26057	−0.89539	1									
(n, 2ng)	−0.12267	−0.35988	0.181287	−0.36644	−0.17015	−0.40979	−0.00267	1								
(n, n)	−0.88165	−0.71572	−0.83169	−0.7925	−0.11442	0.858062	−0.88318	−0.02084	1							
(n, 2n)	0.759082	0.405167	0.914168	0.511707	−0.31569	−0.98428	0.841315	0.517776	−0.75387	1						
(n, pn)	0.926171	0.979781	0.680797	0.998521	−0.16306	−0.61293	0.847471	−0.34733	−0.79014	0.51137	1					
(n, 3n)	0.93918	0.774942	0.825113	0.896969	−0.18485	−0.68865	0.916989	−0.36759	−0.8	0.605294	0.878798	1				
(n, p)	0.988579	0.913262	0.832782	0.974512	−0.21241	−0.76144	0.948052	−0.20926	−0.86227	0.676774	0.972314	0.93021	1			
(n, np)	0.903298	0.990214	0.640351	0.994167	−0.15399	−0.58098	0.816708	−0.35605	−0.76919	0.47765	0.997963	0.850229	0.957552	1		
(n, 2p)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	1	
(n, 2np)	0.681459	0.945289	0.369433	0.847588	−0.09821	−0.37721	0.567041	−0.28157	−0.58159	0.281337	0.872384	0.567348	0.772382	0.898936	#DIV/0!	1

through gamma. The shell correction effect was considered and the results show no much difference observed.

Table 3 and Table 4 gives the correlation between exit charnels of the interaction of neutron at different energies with I-127 as a target, both Table 3 and Table 4 shown that the correlation between (n, 2p) charnel and other charnels is not defined, because the value of cross sections of (n, 2p) reaction is zero throughout the energy range considered from 0 MeV to 30 MeV. This shows that this energy range is below the threshold energy for this reaction.

Table 4. The correlation between different reaction charnels of Cross section with shell structure effect.

	(*n, a*)	(*n, na*)	(*n, ag*)	(*n, an*)	(*n, g*)	(*n, ng*)	(*n, pg*)	(*n*, 2*ng*)	(*n, n*)	(*n*, 2*n*)	(*n, pn*)	(*n*, 3*n*)	(*n, p*)	(*n, np*)	(*n*, 2*p*)	(*n*, 2*np*)
(n, a)	1															
(n, na)	0.845345	1														
(n, ag)	0.905096	0.549077	1													
(n, an)	0.930637	0.972695	0.686736	1												
(n, g)	−0.23354	−0.13438	−0.27531	−0.16238	1											
(n, ng)	−0.83517	−0.51533	−0.94249	−0.61674	0.235641	1										
(n, pg)	0.983961	0.740888	0.965923	0.850868	−0.26131	−0.90238	1									
(n, 2ng)	−0.12549	−0.36104	0.177819	−0.36718	−0.16769	−0.40227	−0.00033	1								
(n, n)	−0.90666	−0.7335	−0.85947	−0.81038	−0.03203	0.878107	−0.91059	−0.03175	1							
(n, 2n)	0.763111	0.409918	0.918367	0.514298	−0.31393	−0.98624	0.848642	0.508476	−0.78693	1						
(n, pn)	0.928438	0.979776	0.683906	0.998706	−0.16345	−0.61983	0.847872	−0.34706	−0.8107	0.518159	1					
(n, 3n)	0.939159	0.773241	0.829076	0.891761	−0.1854	−0.69659	0.916915	−0.36727	−0.82078	0.614154	0.877458	1				
(n, p)	0.989003	0.91431	0.833487	0.973498	−0.21246	−0.76716	0.947318	−0.20941	−0.88598	0.682365	0.973022	0.928775	1			
(n, np)	0.901491	0.991468	0.635552	0.994283	−0.15259	−0.58127	0.811293	−0.35876	−0.78476	0.477332	0.997344	0.844039	0.955514	1		
(n, 2p)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	1	
(n, 2np)	0.680139	0.941884	0.367921	0.846462	−0.09775	−0.37895	0.562994	−0.27882	−0.59244	0.282698	0.86827	0.560305	0.769782	0.897665	#DIV/0!	1

5. Conclusions

A nuclear reaction in the intermediate-energy region is a matter of interest in some fields of science and technology such as medical radionuclide production. Radioisotope production for nuclear medicine is important because of its common use in tomography devices. Both single photon emissions computed tomography (SPECT) and positron emission tomography (PET) are used for diagnosis in nuclear medicine. In the present work, we have investigated the excitation functions for the formation of $^{128,127,126}I, ^{123,124,126}Sb, ^{127,126,125}Te$ in the interactions of alpha particle with nucleus of iodine-127 isotope for the production of some medical radioisotopes.

The shell structure effects were considered and the statistical analysis shows that no significant change in the cross-section observed at the energy range from 0 - 30 MeV considered.

This study shows that EXIFON code is a good tool for investigation of nuclear reaction cross section and this research work can be useful in the production of the radioisotopes of Iodine, Antimony and tellurium of high purity and in an efficient manner using cyclotron or nuclear reactors, these isotopes have potential application for field of medical science especially for therapeutic purposes embracing current and possible future needs.

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