

Determination of Nuclear Reaction Cross-sections for Neutron-Induced Reactions in Some Odd – A Nuclides

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Abstract
The effect of the odd-even nature and mass of target nucleus on neutron reaction cross-sections have been investigated for the energy range of 1 – 30 MeV for neutron-induced reactions in the odd – A nuclides: $^{23}_{11}$Na, $^{25}_{12}$Mg and $^{27}_{13}$Al using the EXIFON code. This code which uses one global parameter set and is based on the analytical model for statistical multistep direct and multistep compound reactions, was used to calculate cross-sections for the (n, α), (n, p), and (n, 2n) reactions. Calculations were compared with experimental data (EXFOR) and evaluated data (ENDF) from the IAEA nuclear data bank. Results show that charged particle emissions ((*n*, *α*) and (*n*, *p*)) are the most dominant reaction channels in the light and intermediate mass nuclei considered. Results also show that the Na (*n*, *2n*) reaction cross-section over predicted experimental and evaluated data, while the Na (*n*, *α*) reaction agrees with experimental data and was in fair agreement with evaluated data while the Na (n, p) cross-section under predicted experimental and evaluated data. For magnesium, the (*n*, *2n*) cross-section partially agree with evaluated cross-section, while the (*n*, *α*) and (*n*, *p*) cross-sections under predicted evaluated data. And for aluminium, the calculated (*n*, *2n*) cross-section over predicted experimental and evaluated data, the (*n*, *α*) data fairly reproduced experimental and evaluated cross-sections while the (*n*, *p*) reaction cross-section was in fair agreement with experimental and evaluated data. The explanations for the discrepancies and trends observed have been given.

Keywords: Nuclear reaction cross-section, Neutron-induced reaction, nuclear data, EXIFON code

Introduction

Development of nuclear technology for intermediate energy applications requires neutron cross-sections up to 30 MeV (Lamarsh and Baratta, 2001). The behaviour of systems, amount of radiation damage, heating, induced activities in elements present in structural materials and fission products in nuclear reactors and in other areas of exposure to neutrons have to be known. Some of this information will also be needed for shielding and radiation protection purposes. These require the knowledge of cross-sections of the appropriate neutron induced reactions. But, experimental cross-section data above 20 MeV are generally scanty or non-existent (Leeb et al, 2011). This is the case for the three nuclides considered in this work. ^{25}Mg has no experimental data for the (*n*, *2n*) reaction in the EXFOR library. Furthermore, disagreements exist between experimental data from different authors at energies below 20 MeV (Trkov, 2005). This paucity of nuclear reaction data affects the processes of designs, simulation and operation of nuclear systems and may result in inappropriate determination of effects of radiation in such systems.

The aim of the present work is to determine the cross-section for neutron induced reactions in some odd – A nuclides in order to predict nuclear reaction cross-section data for energy regions where experimental data are non-existent, scarce or unreliable. The cross-section for neutron-induced reactions (*n*, *α*), (*n*, *p*), and (*n*, *2n*) in $^{23}_{11}Na$, $^{25}_{12}Mg$ and $^{27}_{13}Al$in the energy range of 1 – 30 MeV will be calculated using the EXIFON code. The code uses one global parameter set to predict nuclear data and is based on the analytical model for statistical multistep direct and multistep compound reactions.

The nuclides considered in this study were chosen for their importance in the nuclear power industry. Sodium is used as a coolant in fast reactors (Rochman et al, 2010); magnesium alloy is the cladding material for fuel elements in magnox reactors (Stacey, 2007). Also, the precise cross-section for the ^{25}Mg (*n*, *α*) ^{22}Ne reaction is required to estimate neon concentration induced by cosmic rays in meteorites. This can be used to determine exposure times of lunar samples and will provide better interpretation of measurements in extraterrestrial samples (Lavielle et al, 1990). Aluminium finds use as cladding material in low temperature water cooled reactors and in research reactors. It also finds use as a structural material in fusion facilities, in accelerators

(Saran et al, 2012) and in monitor reactions for the measurement of unknown cross-sections by the activation method (Zolotarev, 2009).

The literature shows that there are no experimental cross-section data for Mg (*n*, *p*), Na (*n*, *p*), Na (*n*, *α*), Al (*n*, *p*), Al (*n*, *α*) and Al (*n*, *2n*) reactions beyond 20 MeV in the EXFOR library (Bass et al, 1966; Bormann et al, 1967; Tewes et al, 1960; Bayhurst and Prestwood, 1961; Grundl, 1967 and Ferguson and Albergotti, 1967). Also, the EXFOR library has no experimental data for the Mg (*n*, *2n*) reaction in the 0 – 30 MeV, while the Mg (*n*, *α*) reaction has data only at 5.2 and 7 MeV (Lavielle et al, 1990). Furthermore, some of these results are old, making it necessary for new measurements to be made. These excitation functions are needed in the testing of nuclear models.

The present study will investigate the effect of shell correction on the cross-section. Also, the effect of the odd-even nature and the mass of the target nucleus on the cross-section shall be examined. The present work also tries to establish a relationship between the cross-section of some odd nuclides and the number of nucleons in their nucleus. The works of Molla et al (1992); Galanopoulos et al (2007); Lalremruata et al (2009); and Lalremruata et al (2012) observed the isotopic effect for (*n*, *p*) reaction in which the cross-section decreases with increasing neutron number in the isotopes of titanium, germanium, nickel and chromium respectively. This trend was attributed to increased reaction threshold, Q-value effect, increased dominant competition for neutron and proton emission as number of neutrons increased, level densities of the residual nuclei due to pairing energy, and also to proton separation energy (proton emission is determined by compound nucleus model at low proton emission energy and by pre-equilibrium model at high emission energy).

Muhammed et al (2011) calculated the cross-section for (*n, 2n*), (*n, p*) and (*n, α*) reaction in ^{235}U, ^{238}U, ^{232}Th and ^{239}Pu, in the energy region 0 – 30MeV using the EXIFON code. For ^{235}U, ^{232}Th and ^{239}Pu, the (*n, 2n*) reaction is the most dominant reaction channel. Also, the cross-sections were higher when the shell correction was not taken into account and the values calculated with the shell correction taken into consideration tend to move closer to experimental data. There was only one possible (*n, p*) reaction in ^{238}U and the shell correction has no effect because of the high stability of its nucleus. Their work also shows that even-odd nuclei have higher cross-section than even-even nuclides.

Theoretical Formulation

The EXIFON code is based on the statistical multistep reaction model. In the statistical multistep model the total emission spectrum (represented by the term on the left hand side of eq. (1)) of the reaction (*a, xb*) is made up of three parts:

$$\frac{d\sigma_{a,xb}(E_a)}{dE_b} = \frac{d\sigma_{a,b}^{SMD}(E_a)}{dE_b} + \frac{d\sigma_{a,b}^{SMC}(E_a)}{dE_b} + \frac{d\sigma_{a,xb}^{MPE}(E_a)}{dE_b} \tag{1}$$

The first term on the right hand side is the statistical multistep direct (SMD) part containing from single-step up to five-step contributions, particle-hole excitations and collective phonon excitations. The second term is the statistical multistep compound (SMC) emission part. SMC and SMD together represent the first-chance emission process. The third term is the multiple particle emission (MPE) process which includes the second-chance, third-chance emissions, etc., given by

$$\frac{d\sigma_{a,xb}^{MPE}(E_a)}{dE_b} = \sum_{c} \frac{d\sigma_{a,cb}(E_a)}{dE_b} + \sum_{c,d} \frac{d\sigma_{a,cdb}(E_a)}{dE_b} + \cdots \tag{2}$$

The EXIFON code predicts emission spectra, angular distribution and activation cross-sections considering equilibrium, pre-equilibrium and direct processes and accounts for multiple particle emission of the compound system up to three decays and analyses reactions involving neutrons, protons and alpha particles with neutrons, protons, alphas and photons as emitted particles. It is limited to target nuclides of mass A > 20 and incident energies below 100 MeV.

The statistical multistep reaction model employed in the EXIFON code is based on many-body theory (Green's function formalism) and random matrix physics (Kalka, 1991). The code performs calculation by summing the contributions from statistical multistep direct (SMD), statistical multistep compound (SMC) and the multi-particle emission (MPE) processes. We consider the process (*a, xb*) in which *a* represents the projectile and *b* the emitted particle. For this work a = neutrons n and b = neutrons n, protons p, alpha α or gamma γ. At incident energy, E_a, the optical model (OM) reaction cross-section σ_a^{OM} and the energy-integrated partial cross-sections satisfy the relation:

$$\sigma_a^{OM} = \sum_b \sigma_{a,b} \tag{3}$$

$$\sigma_{a,b} = \sum_c \sigma_{a,bc} \tag{4}$$

$$\sigma_{a,bc} = \sum_d \sigma_{a,bcd} \tag{5}$$

Where

$$\sigma_{a,b} = \sigma_{a,b}^{SMC} + \sigma_{a,b}^{SMD} \tag{6}$$

represent the total first-chance emission. $\sigma_{a,b}^{SMC}$ is the statistical multistep compound reaction cross-section and $\sigma_{a,b}^{SMD}$ is the statistical multistep direct reaction cross-section. Activation cross-sections are then given by:

$$\sigma_{a,b\gamma} = \sigma_{a,b} - \sum_{c\neq\gamma} \sigma_{a,bc} \tag{7}$$

$$\sigma_{a,cb\gamma} = \sigma_{a,cb} - \sum_{d\neq\gamma} \sigma_{a,cbd} \tag{8}$$

Where $b, c, d \neq \gamma$.

For the present work, the target nuclides which are the input data files in the code are ^{23}Na, ^{25}Mg and ^{27}Al with neutron as the incident particle. The code is then run for the excitation function. In the modification, the code is run with and without the shell structure effect. The output of each run is in the file OUTEXI. The cross-sections of the (n, $2n$), (n, p) and (n, α) reactions are found in the A2N.DAT, AP.DAT and ALF.DAT files respectively.

Results and Discussion

The results are given in milibarns in Tables 1, 2 and 3. Graphs of cross-section against energy for the EXIFON calculation, experimental (EXFOR) and evaluated data (ENDF) are shown in Figures 1 to 9 for comparison. The EXFOR and ENDF data used in this work are from the nuclear data section of the IAEA available at https://www-nds.iaea.org (IAEA-NDS, 2013). 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 for neutron induced reactions in ^{23}Na in the 1 – 30 MeV energy range from EXIFON code.

Energy (MeV)	Cross-section With Shell Correction (mb)			Cross-section Without Shell Correction (mb)		
	$(n, 2n)$	(n, α)	(n, p)	$(n, 2n)$	(n, α)	(n, p)
1.000	0.000	0.000	0.000	0.000	0.000	0.000
2.000	0.000	0.000	0.000	0.000	0.000	0.000
3.000	0.000	0.000	0.000	0.000	0.000	0.000
4.000	0.000	0.000	0.000	0.000	0.000	0.000
5.000	0.000	0.000	0.047	0.000	0.000	0.059
6.000	0.000	0.000	1.338	0.000	0.000	1.516
7.000	0.000	4.427	4.752	0.000	4.390	5.566
8.000	0.000	15.993	9.154	0.000	15.800	10.922
9.000	0.000	37.790	13.625	0.000	37.600	16.294
10.000	0.000	60.424	17.960	0.000	60.300	21.390
11.000	0.000	79.299	22.013	0.000	79.100	26.037
12.000	0.000	94.509	25.883	0.000	94.100	30.396
13.000	0.000	105.810	29.631	0.000	105.000	34.549
14.000	34.287	116.060	33.137	31.584	114.000	38.387
15.000	142.220	124.770	36.620	132.670	122.000	42.170
16.000	220.690	131.490	39.525	207.650	129.000	45.312
17.000	302.120	133.250	39.394	288.290	130.000	45.101
18.000	357.710	123.910	36.021	344.190	121.000	41.395
19.000	390.300	109.820	30.941	377.740	108.000	35.717
20.000	397.730	88.320	25.875	385.870	88.000	29.960
21.000	405.060	68.441	22.819	394.310	68.900	26.380
22.000	402.320	52.186	19.090	392.240	53.100	22.012
23.000	395.210	39.477	16.202	385.630	40.500	18.577
24.000	363.300	32.457	14.006	354.780	33.400	15.927
25.000	242.350	25.396	13.058	237.980	26.300	14.730
26.000	167.640	20.346	11.699	165.720	21.100	13.059
27.000	102.400	16.661	10.658	102.010	17.300	11.769
28.000	61.385	13.901	9.8494	61.359	14.400	10.761
29.000	37.684	12.512	9.2176	38.253	12.900	9.9564
30.000	23.346	10.748	9.1293	23.876	11.100	9.7755

Table 2: Cross-section for neutron induced reactions in ^{25}Mg in the 1 – 30 MeV energy range from EXIFON code.

Energy (MeV)	Cross-section With Shell Correction (mb)			Cross-section Without Shell Correction (mb)		
	$(n, 2n)$	(n, α)	(n, p)	$(n, 2n)$	(n, α)	(n, p)
1.000	0.000	0.000	0.000	0.000	0.000	0.000
2.000	0.000	0.000	0.000	0.000	0.000	0.000
3.000	0.000	0.037	0.000	0.000	0.037	0.000
4.000	0.000	0.227	0.001	0.000	0.227	0.001
5.000	0.000	0.774	0.652	0.000	0.773	0.579
6.000	0.000	3.039	4.101	0.000	3.080	3.813
7.000	0.000	8.891	9.622	0.000	9.010	9.051
8.000	2.564	17.538	15.938	2.644	17.700	15.052
9.000	93.485	27.118	21.044	96.064	27.400	19.851
10.000	238.240	36.350	21.641	244.010	36.800	20.353
11.000	346.490	43.982	21.340	354.480	44.500	20.049
12.000	402.440	46.093	18.180	411.970	46.500	17.075
13.000	427.510	45.299	15.130	438.260	45.600	14.244
14.000	423.660	39.425	12.726	435.900	39.500	12.028
15.000	418.970	33.240	10.771	432.270	33.100	10.226
16.000	413.740	27.910	10.359	428.420	27.700	9.871
17.000	395.880	23.281	9.309	411.360	23.100	8.939
18.000	379.420	20.900	8.557	395.670	20.700	8.265
19.000	284.850	17.712	7.996	300.830	17.500	7.762
20.000	196.860	15.267	7.388	210.640	15.100	7.199
21.000	120.480	13.341	7.054	130.810	13.200	6.899
22.000	71.549	11.747	7.258	78.778	11.600	7.115
23.000	43.669	11.056	6.994	48.624	11.000	6.875
24.000	27.062	9.840	6.763	30.436	9.770	6.663
25.000	19.227	8.790	6.393	21.794	8.730	6.308
26.000	12.364	7.873	6.203	14.167	7.830	6.130
27.000	8.098	7.071	6.437	9.433	7.030	6.367
28.000	5.537	6.358	6.228	6.423	6.330	6.168
29.000	3.860	6.074	6.009	4.491	6.050	5.959
30.000	3.054	5.485	5.643	3.559	5.470	5.599

Table 3: Cross-section for neutron induced reactions in ^{27}Al in the 1 – 30 MeV energy range from EXIFON code.

Energy (MeV)	Cross-section With Shell Correction (mb)			Cross-section Without Shell Correction (mb)		
	$(n, 2n)$	(n, α)	(n, p)	$(n, 2n)$	(n, α)	(n, p)
1.000	0.000	0.000	0.000	0.000	0.000	0.000
2.000	0.000	0.000	0.000	0.000	0.000	0.000
3.000	0.000	0.000	0.030	0.000	0.000	0.034
4.000	0.000	0.000	2.500	0.000	0.000	2.654
5.000	0.000	0.000	11.400	0.000	0.000	12.022
6.000	0.000	0.386	22.300	0.000	0.341	23.645
7.000	0.000	9.562	32.700	0.000	8.452	34.838
8.000	0.000	23.688	41.900	0.000	20.834	44.732
9.000	0.000	45.382	49.600	0.000	40.104	52.956
10.000	0.000	66.173	56.200	0.000	58.596	60.007
11.000	0.000	83.619	61.900	0.000	74.023	66.181
12.000	0.000	98.138	67.100	0.000	86.744	71.811
13.000	0.000	110.030	71.700	0.000	97.021	76.681
14.000	1.030	119.560	75.800	1.000	105.120	81.068
15.000	75.200	128.120	78.800	74.200	112.460	84.398
16.000	187.000	135.160	78.000	186.000	118.490	83.629
17.000	254.000	135.500	70.700	253.000	119.010	76.097
18.000	322.000	124.740	59.900	322.000	110.270	64.729
19.000	360.000	105.020	48.800	361.000	93.789	52.827
20.000	376.000	83.485	39.300	377.000	75.527	42.550
21.000	381.000	69.131	33.800	381.000	63.318	36.645
22.000	377.000	53.420	27.800	377.000	49.644	30.097
23.000	363.000	41.366	23.400	363.000	38.883	25.186
24.000	337.000	32.184	20.200	336.000	30.634	21.589
25.000	240.000	25.563	17.900	240.000	24.597	18.943
26.000	144.000	20.861	16.100	143.000	20.248	16.981
27.000	84.300	18.485	15.600	84.300	18.040	16.279
28.000	49.500	15.690	14.500	49.600	15.396	15.073
29.000	29.400	13.533	13.700	29.500	13.333	14.134
30.00	20.200	11.804	13.000	20.200	11.664	13.370

From the A2N.DAT file in the EXIFON code, the cross-section for the $(n, 2n)$ reaction in sodium is obtained. The reaction channel opens up at 14 MeV as shown in Table 1 and experimental data is available up to 30 MeV. Fig. 1 shows that the results from the calculation largely over predict experimental data of Uwamino et al (1992) and evaluated data.

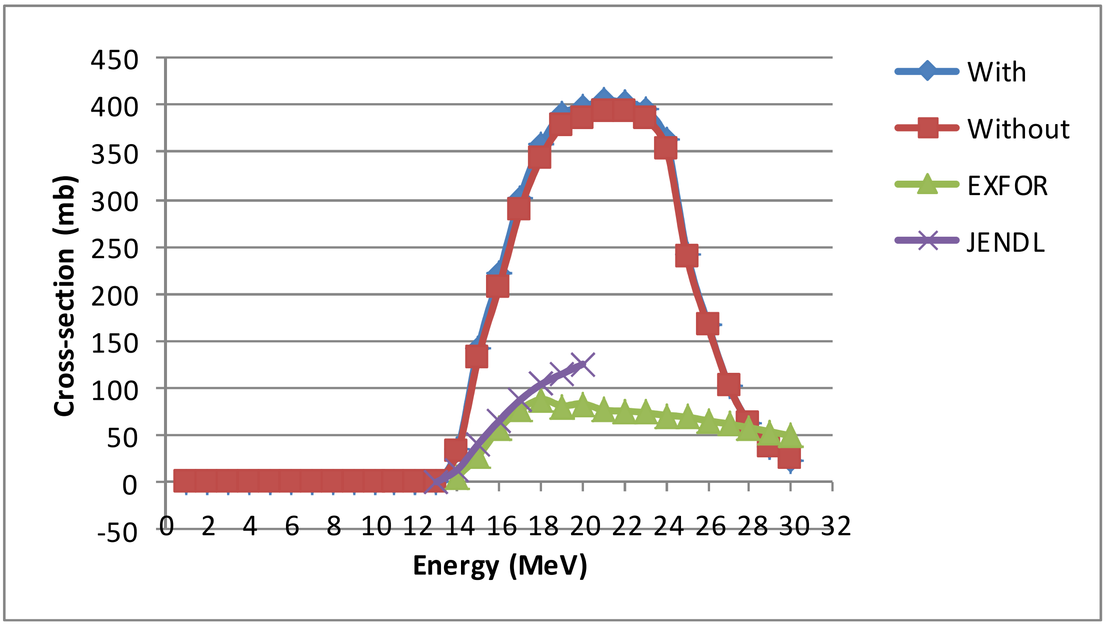

Fig. 1: Cross-section against energy for the ^{23}Na (n, $2n$) ^{22}Na reaction.

The cross-section for the ^{23}Na (n, α) ^{20}F reaction is in the ALF.DAT file and it begins to show values at 7 MeV as in Table 1. Fig. 2 shows that results of the EXIFON code calculation are in agreement with experimental data from Bass et al (1966), Janczyszyn and Gorski (1973) and Weigmann et al (1982) in the 7 – 14 MeV energy regions. There is fair agreement between theoretically calculated values and cross-sections from the Japanese Evaluated Nuclear Data Library (JENDL).

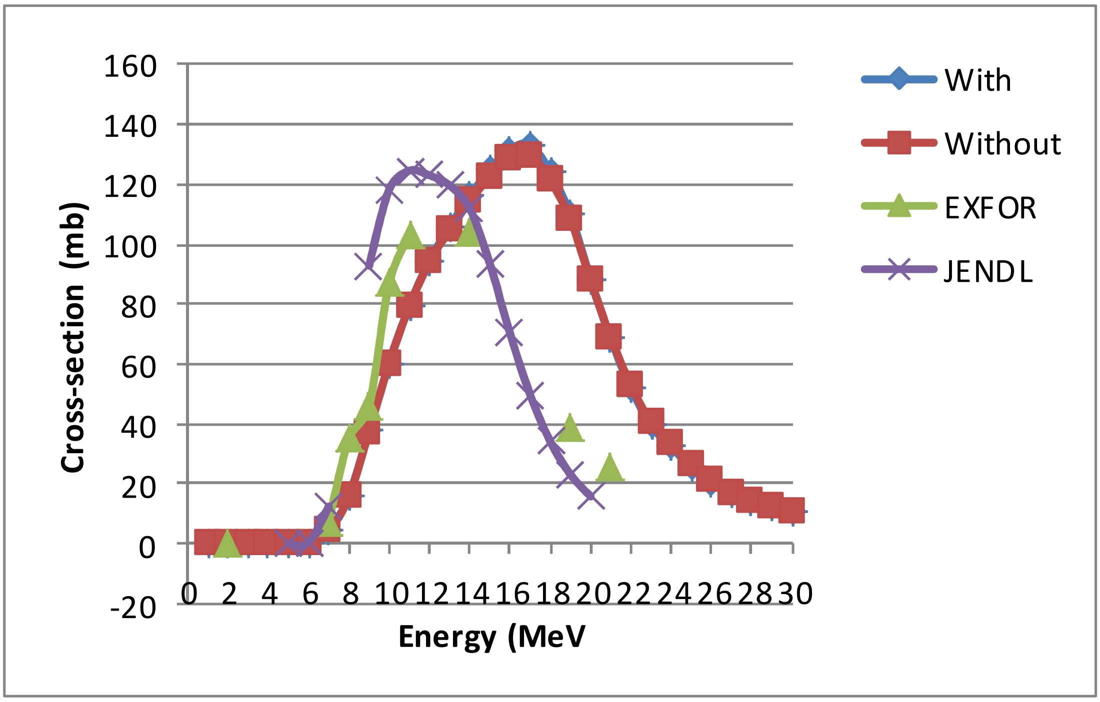

Fig. 2: Cross-section against energy for the ^{23}Na (n, α) ^{20}F reaction.

From Table 1, the cross-section for the ^{23}Na (n, p) ^{23}Ne reaction which is in the AP.DAT file begins to show values at 5 MeV. From 4 – 10 MeV, calculations under predict experimental cross-sections. At 11 and 14 MeV, results from code agree with experimental results of Bass et al (1966) and Weigmann et al (1982). Figure 3 show that the theoretical data also under predict cross-section from the Russian Evaluated Neutron Data Library (BROND-2).

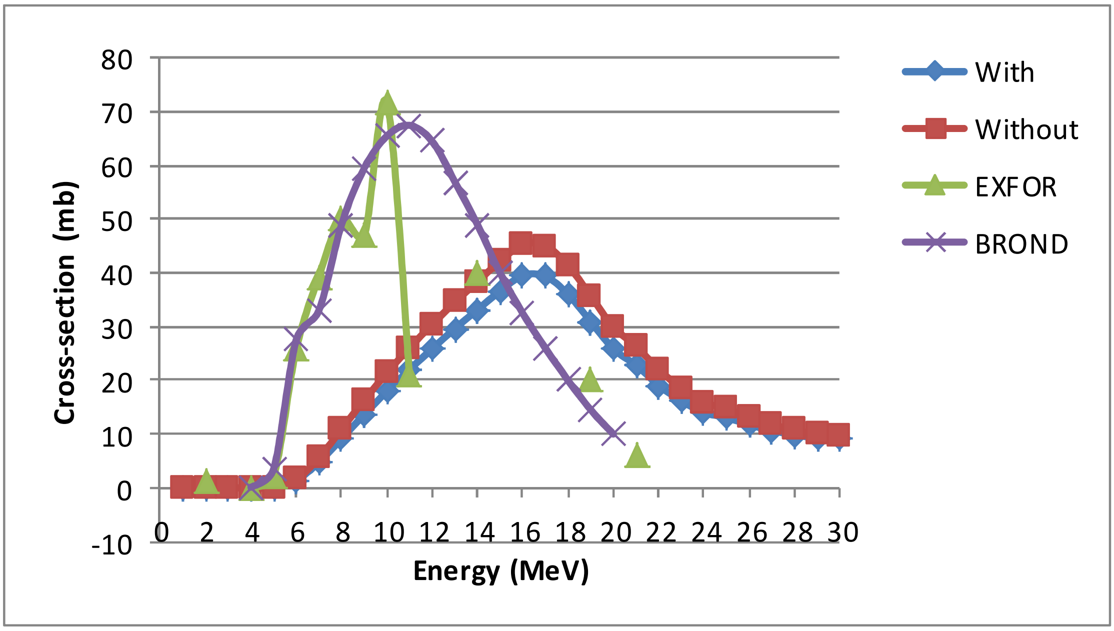

Fig. 3: Cross-section against energy for the ^{23}Na (n, p) ^{23}Ne reaction.

Table 2 shows that the code starts to generate values for the ^{25}Mg (n, $2n$) ^{24}Mnreaction cross-section at 8 MeV and evaluated data are available up to 20 MeV. There are no experimental results for the ^{25}Mg (n, $2n$) ^{24}Mnreaction cross-section in the EXFOR database. However, in Figure 4, EXIFON code calculation between 8 – 11 MeV is in good agreement with evaluated nuclear data. From 12 – 20 MeV, theoretical results under predict cross-sections from evaluated library.

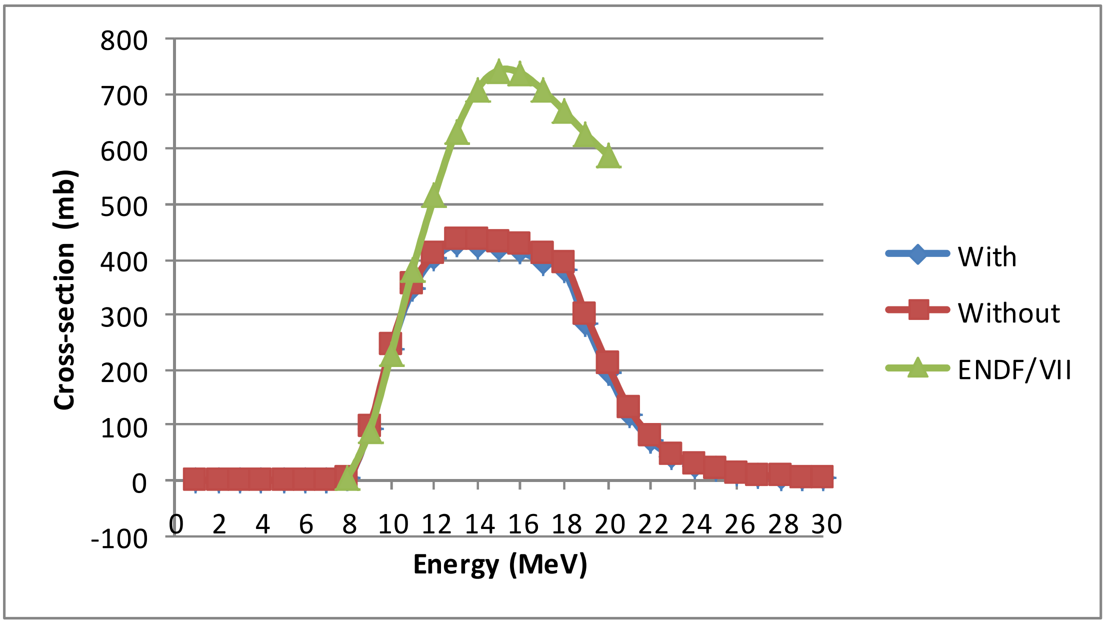

Fig. 4: Cross-section against energy for the ^{25}Mg (n, $2n$) ^{24}Mn reaction.

Experimental data from Lavielle et al (1990) in the EXFOR library for the ^{25}Mg (n, α) ^{22}Ne reaction exist at 5.2 MeV and 7 MeV. Evaluated data is available from 2 – 20 MeV. In the region of comparison (2 – 20 MeV) as shown in Fig. 5, the code calculations largely under predict the cross-sections from evaluated nuclear data library.

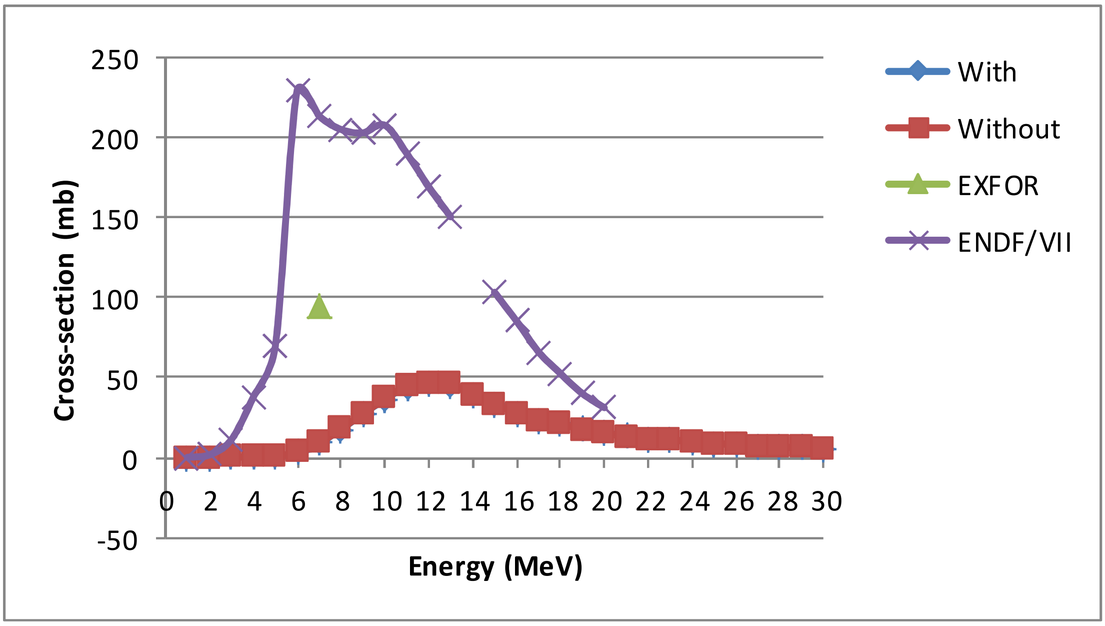

Fig. 5: Cross-section against energy for the ^{25}Mg (n, α) ^{22}Ne reaction.

The ^{25}Mg (n, p) ^{25}Na reaction channel opens up at 4 MeV (Table 2) and evaluated data is available from 4 – 20 MeV. Comparison with EXFOR values could only be made at 13 MeV and 14 MeV (Bormann et al, 1967). The calculated cross-sections between 4 – 20 MeV as shown in Figure 6 under predict data from evaluated library.

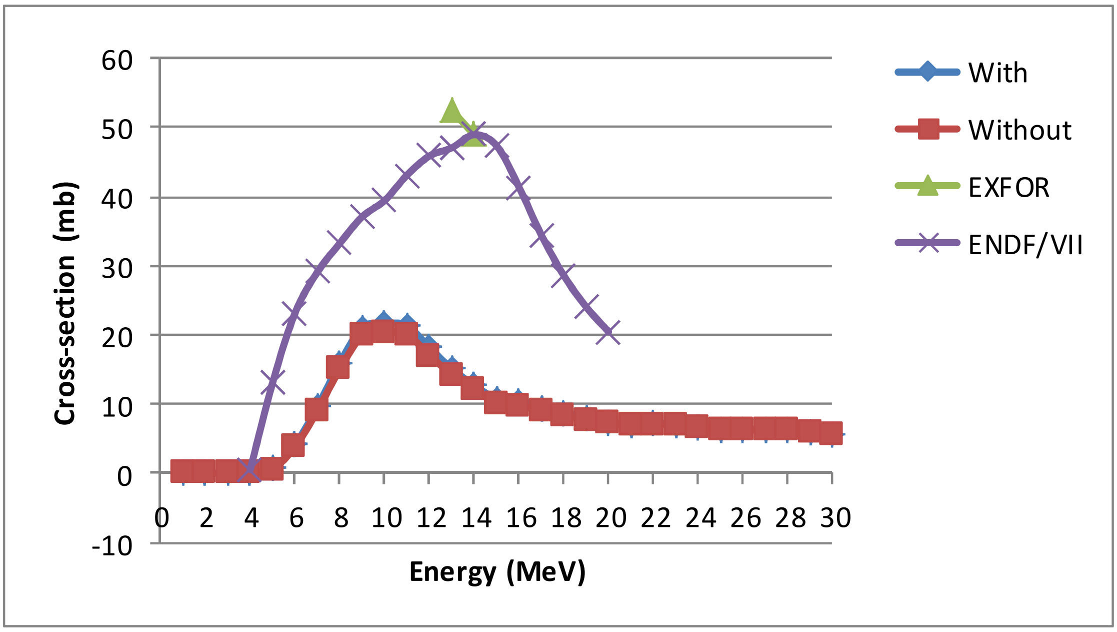

Fig. 6: Cross-section against energy for the ^{25}Mg (n, p) ^{25}Na reaction.

For the ^{27}Al (n, p) ^{27}Mg reaction, the code starts to generate values at 3 MeV (Table 3). Experimental data is available up to 23 MeV and evaluated data up to 20 MeV. For the energy range 3 – 23 MeV, there is fair agreement between the results of the EXIFON code calculation, evaluated nuclear data and the experimentally measured cross-sections from Bass et al (1966), Welch et al (1981) and Kobayashi and Kobayashi (1992). This is shown in Fig. 7.

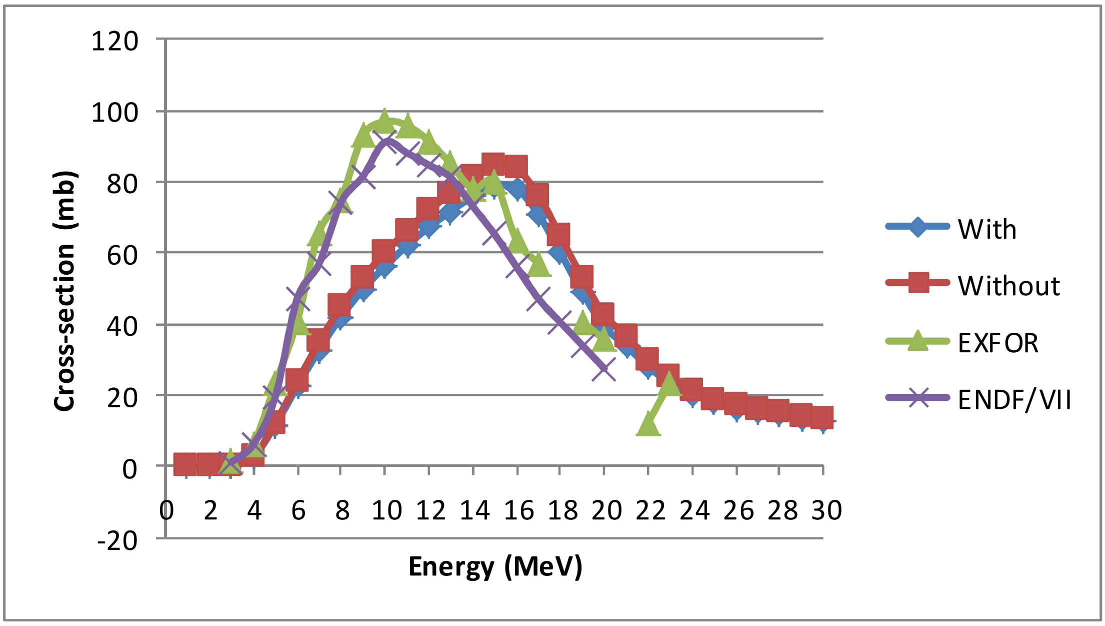

Fig. 7: Cross-section against energy for the ^{27}Al (n, p) ^{27}Mg reaction.

The ^{27}Al (n, α) ^{24}Na reaction cross-section starts to show values at 6 MeV (Table 3). Experimental and evaluated data are available up to 20 MeV. In the 5 – 21 MeV region, the EXIFON code results fairly reproduce evaluated data and the experimental data of Tewes et al (1960), Bayhurst and Prestwood (1961), Grundl (1967), Ferguson and Albergotti (1967), Mostafa (1976), Kornilov et al (1989) and Ikeda et al (1991). This is shown in Fig. 8.

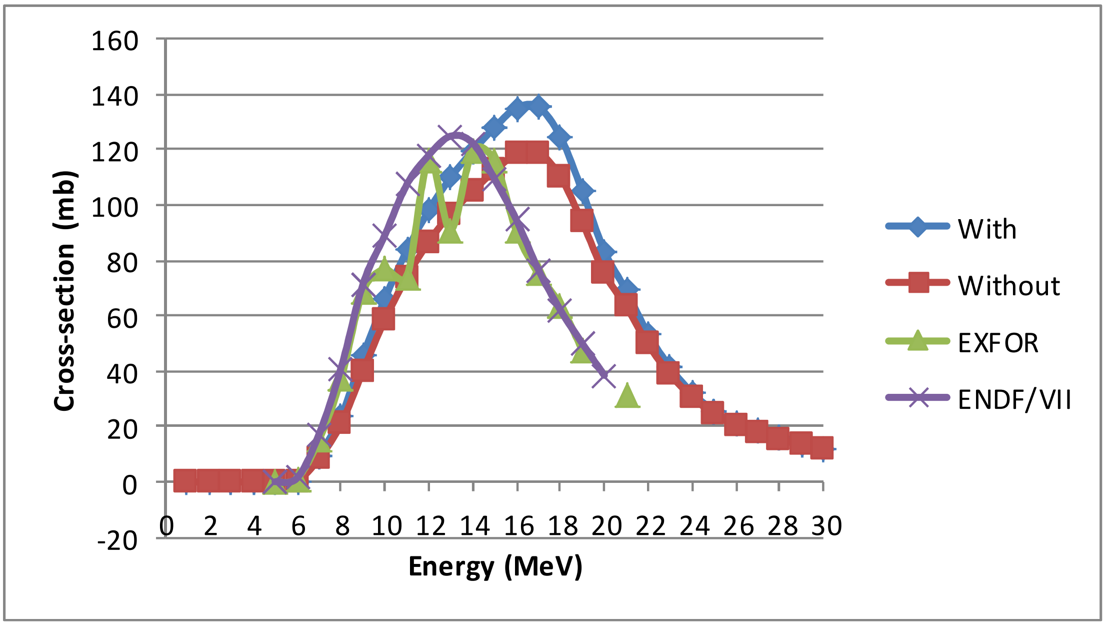

Fig. 8: Cross-section against energy for the ^{27}Al (n, α) ^{24}Na reaction.

The ^{27}Al (n, $2n$) ^{26}Al cross-section begins to show value at 14 MeV as seen in Table 3. There is a dearth of both experimental and evaluated data for this reaction. Figure 9 shows that the calculations from EXIFON over predict the experimental data of Janczyszyn and Gorski (1973), Nakamura et al (1991) and Wallner et al (2003). The same over prediction is reported beyond 15 MeV in Saran et al (2012) for the ALICE code calculation. The

EXIFON calculation agrees with values from the Chinese Evaluated Nuclear Data Library (CENDL) at 15 MeV but over predicts the data from 16 – 20 MeV.

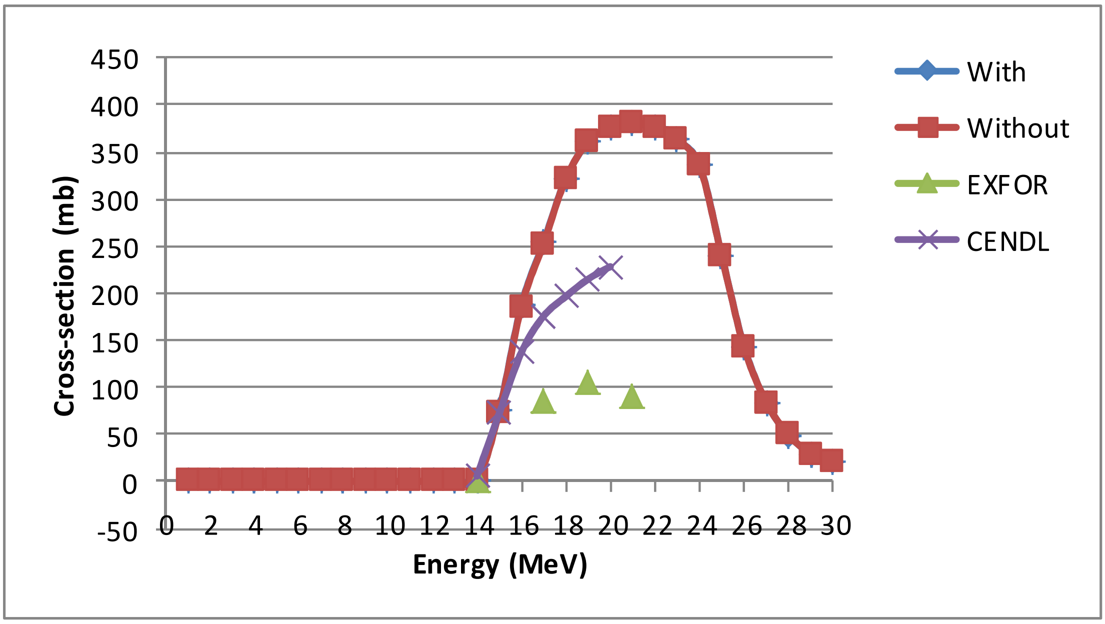

Fig. 9: Cross-section against energy for the ^{27}Al (*n*, *2n*) ^{26}Alreaction.

Conclusions
Theoretical calculations of cross-section for neutron induced reactions in sodium, magnesium and aluminium have been performed using the statistical multistep reaction code EXIFON. Calculated values have also been compared with experimental data from other authors and evaluated data from the IAEA Nuclear Data Section library. The code accounted for the neutron – nucleus interaction in the energy region of interest, which is 1 – 30 MeV. Where there are no experimental and evaluated data, and where existing data are scarce or discrepant, the code was able to predict cross-section.

Unlike the (*n*, *2n*) reaction which dominates the reaction channel in heavy nuclides (Muhammed et al, 2010), charged particle emission is the most dominant reaction channel in the light and intermediate mass nuclei considered in this work. This is attributed to lower nuclear charge, which enhances the emission of charged particle due to decreasing coulomb barrier.

The most dominant reaction channel is the (*n*, *p*) reaction in the odd-even nucleus $^{23}_{11}Na$(proton-11, neutron-12) and $^{27}_{13}Al$(proton-13, neutron-14). This cross-section increases with mass of the target in these odd-even nuclides. This can be explained in terms of increased dominant competition between proton and neutron emission as the total number of nucleons increases. In addition, the threshold of the reaction decreases in the heavier nuclide (^{27}Al) due to the Q-value effect. This trend is in contrast to the decrease in the (*n*, *p*) cross-sections with increasing neutron numbers observed in isotopes of titanium, germanium, nickel and chromium (Molla et al, 1992; Galanopoulos et al, 2007; Lalremruata et al, 2009; and Lalremruata et al, 2012). The (*n*, *α*) reaction is the most dominant reaction channel in the even-odd nucleus ($^{25}_{12}Mg$ (proton-12, neutron-13)).

The cross-section is higher when the shell correction is considered in the Na (*n*, *2n*), Mg (*n*, *p*) and Al (*n*, *α*) reactions. The cross-section is higher when the shell correction is not considered in the Na (*n*, *p*), Mg (*n*, *2n*) and Al (*n*, *p*) reactions.

The disagreements between evaluated (*n*, *α*) and (*n*, *p*) cross-sections for ^{25}Mg and the results from the EXIFON code has been explained on the basis of lack of experimental data for these reactions. Lack of experimental data for the neutron-induced reactions in^{25}Mg makes it difficult to adjust some nuclear parameters and refine the nuclear model for this nuclide in the development of the theoretical code. This lack of experimental data may be attributed to the fact that magnox reactors are no longer being designed and built, thus no new studies are carried out on the use of magnesium as cladding materials as there are no new magnox reactors, since they are a Generation 1 reactor, all of which are no longer in use except one. The presence of other pre equilibrium multi-particle emissions, competing for emission probability has been given as the reason for the discrepancies between experimental (*n*, *2n*) reaction cross-sections of sodium and aluminium and those of the EXIFON data.

The results of present calculation provide new data between 20 – 30 MeV where experimental results are non-existent. This can be used to generate evaluated nuclear data when combined with calculations from other codes and measurements from other authors. Due to the lack of measured cross-sections beyond 20 MeV, more experimental data are needed in the 20 – 30 MeV range in order to further test the reliability of the theoretical calculations.

Nigerian Evaluated Nuclear Data Library (NENDL) should be established under the auspices of the Nigeria Atomic Energy Commission (NAEC) in collaboration with the Nuclear Data Section of the International Atomic Energy Agency (IAEA-NDS). This can serve the nuclear data needs of Nigeria and Africa at large.

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