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An Investigation about The Deuterium-Deuterium Nuclear Fusion differential cross section.

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Abstract

Differential cross section for the D-D fusion reaction represents an important parameter in calculating the neutron or proton yield and this calculation need to study the changes of the differential cross section with both deuteron energy and reaction angle .We see that the differential cross section are strongly effected with a range of reaction angle between [0-100] degree , and it seems that it has a maximum value when the reaction angle equal to zero because the present of the parameter cos θ in there calculated equation .From the figures we notice a good agreement between our calculated results and the experimentally results. This lead to the ability for using this model in the future for different calculations and the ability for modifying it's to construction a like formulas for another fusion reactions by depending on their physical characteristics.

Key words: cross section, d-d reaction, neutron yield.

Introduction

The D(d,n)3He and D(d,p)3H reaction is of interest for nuclear processes in the early solar system and early universe and for fusion energy applications. This reaction belongs to the network of processes which will be used to fuel the first inertial-confinement fusion reactors [1]. The knowledge of D(d,n)3He and D(d,p)3H fusion cross sections at low energies is of interest in pure and applied physics. Both reactions are crucial for the Standard Big Bang Nucleosynthesis (SBBN) network calculations, as they are involved in the synthesis of D, 3He, 4He and 7Li in the early universe.[2].

Theory

For nuclear reactions in which the reactant must penetrate a barrier, which is the case with thermonuclear reactions, the cross section can be expressed in the form [3].

σDD = 288/Ed (-45.8/Ed)……………(1)

Where Ed is the deuteron bombarding energy in KeV, and σDD is the total cross section in barns.

Also there is another relation to compute total cross sections for D-D reactions as follows [4].

σDD = exp(4.727-0.03154Ed)………………(2)

Where Ed is the deuteron bombarding energy in MeV, and σDD is the total cross section in mille barns.

Also The interaction cross-section σ(D- D) is given by

σ DD= (π/k2) exp(- e2 / ħVd)……………….(3)

k2 = (2 m Ed /ħ2) Where Ed is the deuteron bombarding energy in keV, and σDD is the total cross section in barns.

By Using mr ~ 1.67 x 10-24 gms, Vd (impact) = ~ 6.5 x 106 cm sec-1, e = 4.8x10-10 cgs units, and ħ2= 10-27 erg sec, we have σ(D-D) = (π/3.68x1020) exp(-35.5) cm2 = ~ 3x10-36 cm2. From a D-D calculation, at Vd(impact) = 5 x 105 cm sec-1, the value for σ(D-D) is Vanishingly small. Thus, the increase in impact velocity, in the range of interest from 5x 105 cm/sec to 6.5 +/- 2 x 106 cm/sec as shown in Figure (1) [5].

Calculation of differential cross section

The differential cross sections dσ/dΩ are calculated as a function of reaction angle θ for deuteron energies Ed for wide range from (18-26) MeV by using the relation

$$\frac{d\sigma}{d\Omega} = \frac{\sigma_T}{4\pi}\,\frac{(1+A\cos^2\theta+B\cos^4\theta)}{(1+1/3A+1/5B)} \times \frac{(1+2\tau\cos\theta_1+\tau^2)^{3/2}}{(1+\tau\cos\theta_1)}$$

…………..(4)

The results of calculations of dσ/dΩ and θ are presented for all bombarding energy in table (2) , (3) and figures (2) , (3).

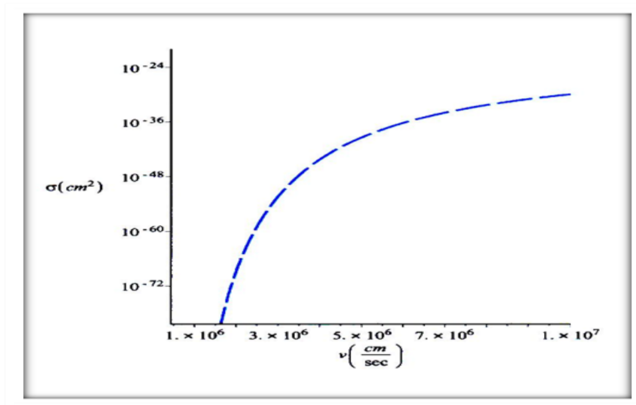

Fig (1) cross section as a function of deuteron impact velocity.

Table (1). Legendre polynomial coefficients for least squares fit to c.m. angular distributions from D-D fusion reaction ref.[7].

coefficient	18 Mev	20 Mev	22 Mev	24 Mev	26 Mev
A_0	6.12	5.87	5.54	5.73	5.30
A_2/A_0	1.78	1.72	1.65	1.59	1.63
$\frac{A_4}{A_0}$	2.26	2.14	2.00	1.85	1.80

Table (2): Differential cross sections results at deuteron energy range from (18-26)MeV. By using eq. (1).

Reaction angle (degree)	Differential cross section at18 Mev	Differential cross section at 20 MeV	Differential cross section at 22 MeV	Differential cross section at 24 MeV	Differential cross section at 26 MeV
0	495.39	458.35	422.58	388.79	363.57
10	382.09	353.7	326.28	300.42	281.02
20	120.85	112.04	103.55	95.55	89.47
30	122.91	114.25	105.95	98.16	92.05
40	232.93	217.44	202.7	188.93	177.5
50	208.2	195.5	183.58	172.48	162.31
60	118.54	112.13	106.23	100.73	94.84
70	26.74	25.48	24.35	23.29	21.9
80	42.36	40.57	39.01	37.52	35.2
90	85.83	82.36	79.36	76.47	71.67
100	102.8	98.46	94.67	91.05	85.43

Table (3): Differential cross section results reaction at deuteron energy range from (18-26) KeV.by using eq.(2).

Reaction angle (degree)	Differential cross section at 18MeV	Differential cross section at 20 MeV	Differential cross section at 22MeV	ifferential cross sectio at 24MeV	Differential cross section at 26MeV
0	87.99	79.42	71.98	65.51	60.93
10	67.87	61.29	55.57	50.62	47.10
20	21.46	19.41	17.63	16.1	14.99
30	21.83	19.79	18.04	16.54	15.42
40	41.37	37.67	34.52	31.83	29.75
50	36.98	33.87	31.27	29.06	27.20
60	21.05	19.43	18.09	16.97	15.89
70	4.75	4.41	4.17	3.92	3.67
80	7.52	7.03	6.64	6.32	5.9
90	15.24	14.27	13.51	12.88	12.01
100	18.26	17.06	16.12	15.34	14.31

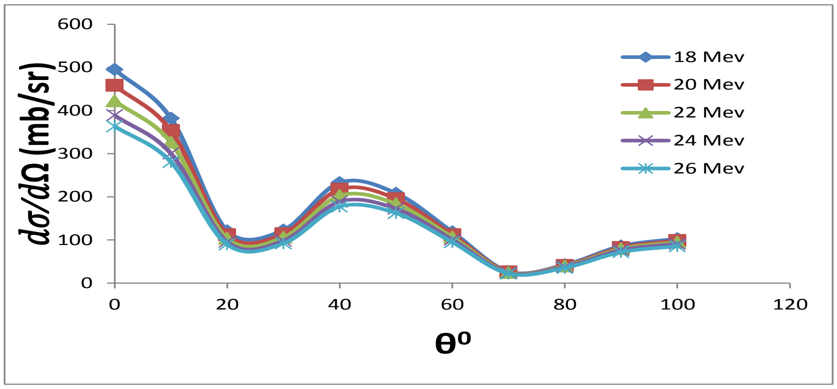

Figure (2) :The c.m. differential cross section dσ/dΩ for the D-D reaction at deuteron bombarding energy of 18 to 26 MeV by using eq.(1).

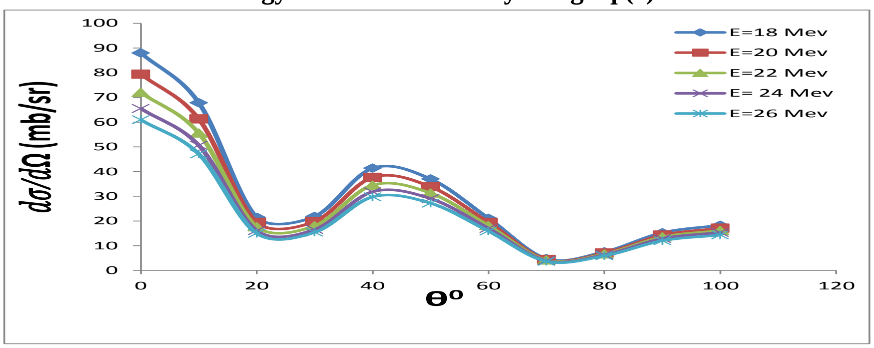

Figure (3) :The c.m. differential cross section dσ/dΩ for the D-D reaction at deuteron bombarding energy of 18 to 26 MeV by using eq.(2).

Discussion and conclusion

Firstly, we have made a theoretical study about the differential cross section for the D-D reaction From the calculations deals with the differential cross section in the centre of mass system that represented in Figure (2)and(3) and Tables (2)and(3) we conclude that there are a good agreement between our results and the published results in ref. [7].For wide range of incident deuteron energy that represented in keV unites and Mev unites, we concentrate on the energy range from [18-26 MeV] since there is an published result present which explained in below.

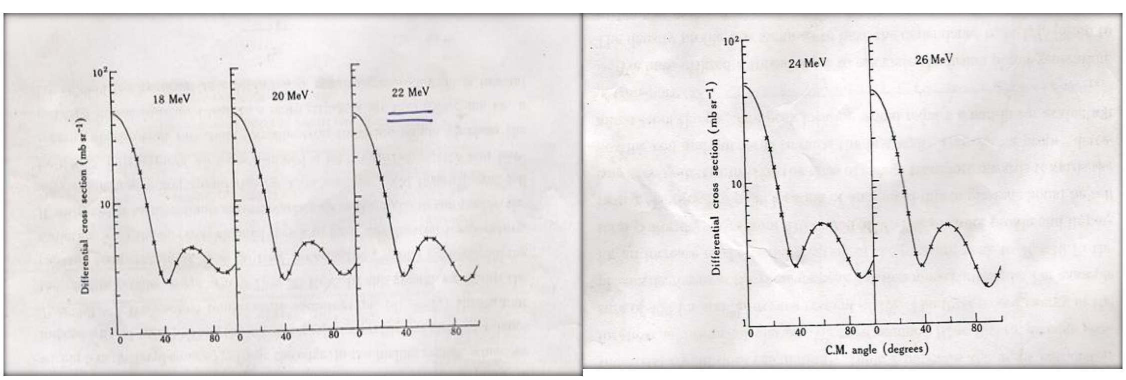

Figure (4): Differential cross section in c.m.system of Jones. (ref.7) for deuterons energy from 18 to 26 MeV.

Through the study the change of the total cross sections for D-D reaction with deuteron velocities we see that the probability of interaction increased when deuteron velocities increasing in the range of velocities between (1.E+6-1.E+8). From figure (1) We see that our calculated results about the total reaction cross section are more compatible with the published results ref.[5]. we concentrate on the velocity range from(1.E+6-1.E+8) since there is published result present From the comparison between our calculated results and the experimentally published result we have obtained the same behavior . From the comparison between our calculated results and the experimentally result we have obtained the same behavior but it is necessary to note that there are a different values for the differential cross section and this case can be explained by the fact that we use an empirical formulas for calculation the total cross section given by eq.(1)which is especially deals with energy given in KeV and another empirical formulas for calculation the total cross section given in eq.(2)which is especially deals with energy given in MeV .

References

[1] A. Tumino "Low-energy d+d fusion reactions via the Trojan Horse Method " Physics Letters B ,700,p. 111–115,(2011).

[2] Atzeni, Stefano. The Physics of Inertial Fusion. N.p.: Oxford University Press, May 2009.

[3] David J .Rose, Melville clark, JR "Plasmas And Controlled Fusion", John Wiley and sons Inc., NewYork, London, 1961.

[4] M.Drosg ,″ On The Energy Dependence Of The Total Cross Section Of The Reaction D(d,n)3He ″ Nucl.Sci.Eng.″ , vol.65, 1978.

[5] Sinha, K.P. and A. Meulenberg. A model for enhanced fusion reaction in a solid matrix of metal deuterides. in ICCF-14 International Conference on Condensed Matter Nuclear Science. 2008.

[6] R.B. Theus , W.L. Mcgarry , and L.A.Beach, "Angular Distribution And Cross-Section Ratios For The Reactions D(d,n)3He and D(d,p)3H Below 500 Kev", Nuclear Physics,vol.80, 1966.

[7] A.B.Jones, " D(d,n)3He Differential Cross Sections from18 To26 Mev".,Aust.J.phys., vol.33 , 1980.Washington, DC.

تحقيقات للمقاطع العرضية التفاضلية للتفاعلات النووية الاندماجية نوع ديتريوم– ديتريوم.

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الخلاصة

المقطع العرضي التفاضلي للتفاعل الأندماجي D-D يمثل عامل مهم في حساب النتاج النيوتروني او البروتوني وهذه الحسابات نحتاج لها لدراسة التغيرات في المقاطع العرضية التفاضلية مع طاقة الديوترون وزاوية التفاعل ، لاحظنا ان المقاطع العرضية التفاضلية تتأثر وبشدة لمدى طاقي يتراوح بين MeV (18-26) ولزوايا تفاعل من(0-100) درجة ويتبين ان اعظم قيمة لهذه المقاطع العرضية التفاضلية عند الزاوية $\theta = 0$ وذلك لوجودالعامل $\cos\theta$ في معادلة الحساب, من الاشكال الموضحة بالرسم لوحظ وجود توافق جيد و مناسب مع النتائج التجريبية المحسوبة عالميا مما يقود الى امكانية اعتماد العلاقات المثبتة في بحثنا الحالي في الحسابات المستقبلية وامكانية تعديلها للتفاعلات الاندماجية الاخرى بالاعتماد على خصائص التفاعل الماخوذ بنظر الاعتبار.