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RESEARCH ARTICLE

Effect of Exciton Number on One-Component and Two-Component Partial Level Density Formulae

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ABSTRACT

In this paper we made a comparison between the theoretical results of one and two components of partial level density Ericson's formulae with the experimental results. In the frame work of equidistant spacing model. It is noticed that the values of one-component partial level density formula increases with increasing the exciton number. the excitons numbers is taken 3, 5, 7 and 9. The same excitons number is substituted in two-component partial level density formula, but the increase in partial level density values in case of two components with the excitons numbers is slight and this change is so small that it cannot be seen. Therefore one can say that the increase in exciton number effects on the one-component partial level density value and lead to an increase them. But in the case of two-components the partial level density value doesn't affect by the change in exciton number values because the energy distributed on particles more than in case of one-component and this makes partial level density less than in case of one-component and the effect of change in exciton number doesn't appear. In case of one-component when the exciton numbers is n = 3 the theoretical partial level density curve lies below the experimental curve and when n = 5 the theoretical curve become more close to the experimental curve. And at n = 7 the theoretical curve intersect with the experimental curve at E = 5 MeV, So when n = 9 the theoretical curve intersect with the experimental curve at 4 MeV.

Keywords: Level density, Nuclear level density, Nuclear reaction, Pre-compound nucleus, Pre-equilibrium

Introduction

The level density (L-D) is a parameter that has importance in theoretical calculations like cross section, transition rates, and nuclear reactors and medical physics.[1–3] The cross-section in compound nucleus reactions and pre-equilibrium reactions also depend on the level density.[4,5] Pre-equilibrium reactions mean the nuclear reaction that leads to the emission of particles before the completeness of energy distribution on all nucleon in the target nucleus, the age of this stage is about 10^{-18} sec.[6,7] Since not all the nucleons are excited during the pre-equilibrium region as it is mentioned above, i.e. during the pre-equilibrium reactions some of the nuclei are excited,therefore, the level density called partial level density PLD because it represents excitation of a part of nucleons.[8–10] The first use of PLD in pre-equilibrium was by J.J. Griffin in 1966 using Ericson's formula which is considered a crude formula.[10] After that many corrections were added to the Ericson's formula in order to make an enhancement to the theoretical results. The corrections are two-component formula, Williams's correction, spin correction, surface correction and isospin correction.[10]

In this paper a study was made on $^{56}_{26}Fe$ to investigate the change in PLD with a change of parameter called exciton number n. for both Ericson's one-component and two-component formulae in order to show, are these formulae affected by the exciton number which represent the increase in excited particles number?

The reason behind choosing $^{56}_{26}Fe$ nucleus is because the mass number of $^{56}_{26}Fe$ is in intermediate values so

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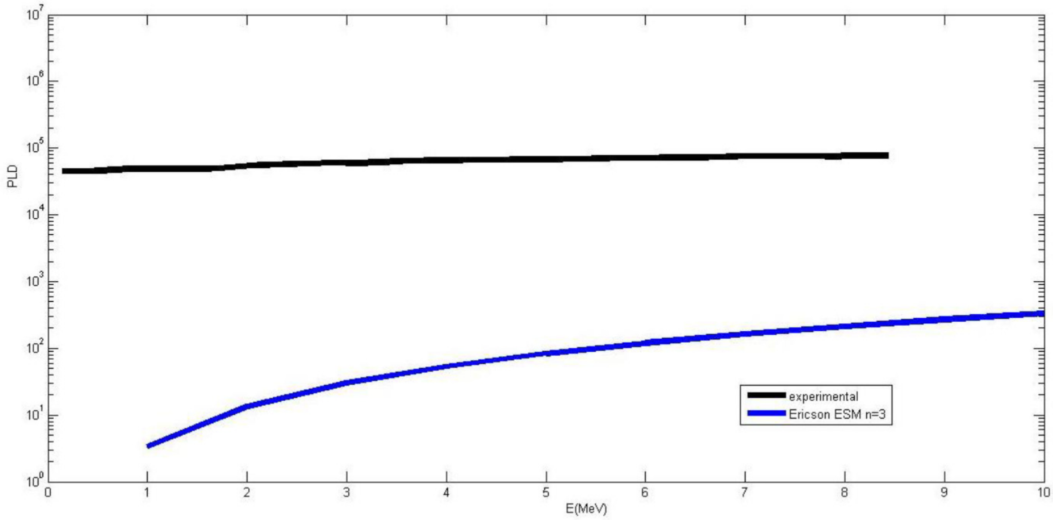

Fig. 1. Comparison between one-component with n = 3 and experimental curve for ${}^{56}_{26}Fe$.

that the pre-equilibrium reactions appear clearly in this region.

Theory

The first description of PLD in 1966 by J.J. Griffin using the Ericson's formula or accurately called one-component Ericson's formula, because it doesn't distinguishes the protons and the neutrons but consider all as a same type of the particles called nucleons the one-component Ericson's formula is.[10]

$$\omega_1\,(n.E) = \frac{g^n E^{n-1}}{p!h!\,(n-1)} \tag{1}$$

The symbols are p is the particle number, h is the hole number, n is the exciton number which is n = p + h, E is the excitation energy and g is the single particle level density which is given by

$$g = \frac{A}{d} \tag{2}$$

In frame work of equidistant spacing model which is consider the spacing between the levels are equal.

The parameter A is the mass number and d = $13(MeV)^{-1}$

When the protons and the neutrons are considered as two types of particles or distinguishable particles the Ericson's formula is modified to two components Ericson's formula.[10]

$$\omega_{2(n.E)} = \frac{g_\pi^{n_\pi} g_\nu^{n_\nu} E^{n-1}}{P_\pi!h_\pi!P_\nu!h_\nu!\,(n-1)!} \tag{3}$$

The symbols p_π is the proton particle, h_π proton holes, $p\gamma$ neutron particle, h_ν neutron holes, n_π is the exciton number of proton $n_\pi = p_\pi + h_\pi$, n_ν is the exciton number of neutrons $n_\nu = p_\nu + h_\nu$ and the total $n = n_\pi + n_\nu$

E is the excitation energy, g_π is the single particle level density for protons and g_ν is the single particle level density for neutrons.[10]

$$\left.\begin{array}{l} g_\pi = \frac{Z}{A} \\ g_\nu = \frac{N}{A} g \end{array}\right\} \tag{4}$$

Results and discussion

In this section a comparison between the one-component and two-component theoretical curves of PLD with the exciton number. The results for the ${}^{56}_{26}Fe$ isotopes and the figures were plotted by Mat. Lap program. Fig. 1 shows a comparison between the one-component theoretical curve when n = 3 with the experimental data.[10] One can notice that the one-component theoretical curve starts from 1 Mev and increases with increasing energy and the theoretical curve lies below the experimental curve[10] because when the exciton number is taken n = 3 the number of excited levels is low, therefore, the theoretical curve below the experimental one.

In Fig. 2 comparison was made between two-component PLD theoretical curve for n = 3 with the experimental data. The theoretical curve starts from 1 MeV and increases with increasing energy and the theoretical curve lies below the experimental data[10] for the same reason in Fig. 1, so in case of two components the energy distributed on a number of

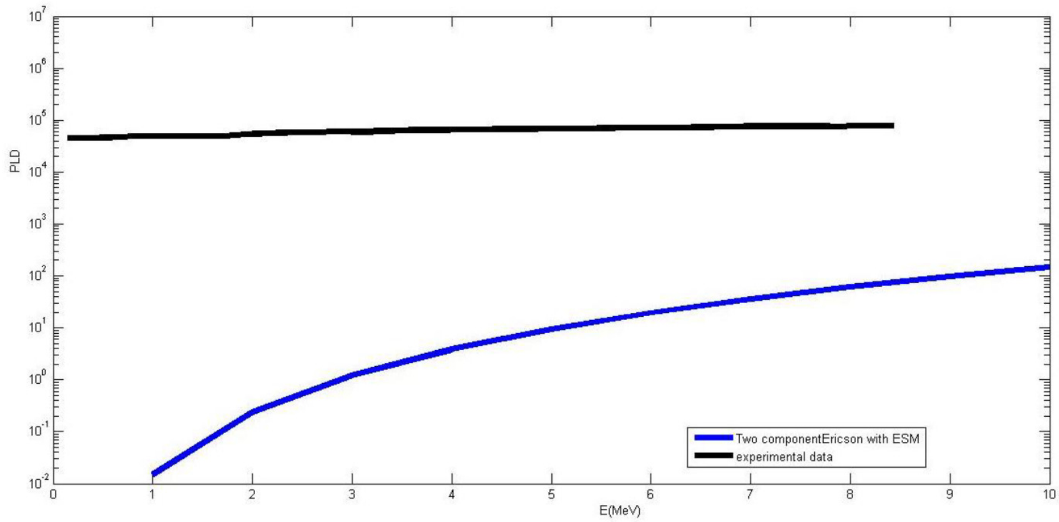

Fig. 2. Comparison between two-component with n = 3 and experimental curve.

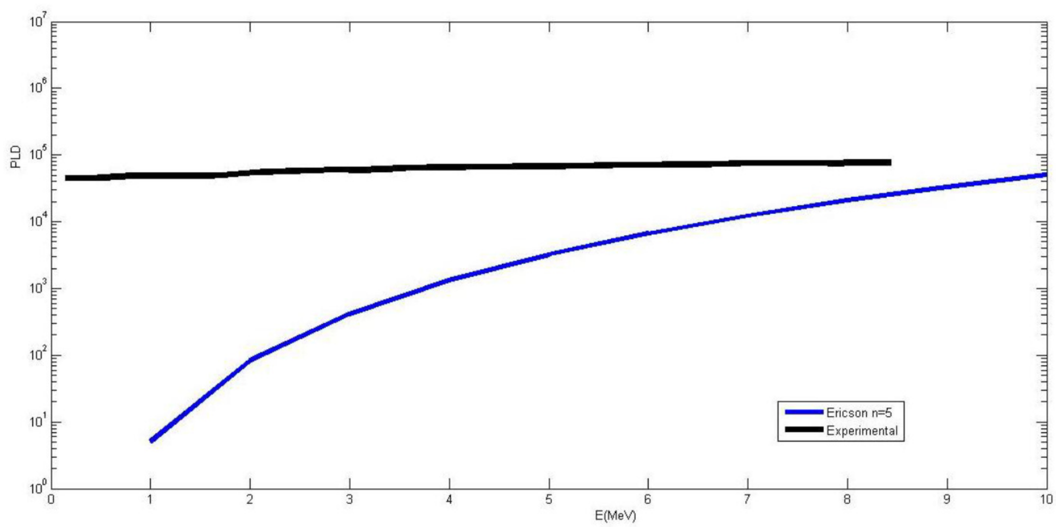

Fig. 3. Comparison between one-component with n = 5 and experimental curve.

particles is bigger than in case of one-component this decreases the number of excited state or PLD hence the theoretical curve is below the experimental curve.

Fig. 3 shows a comparison between one-component theoretical curve and the experimental data when n = 5. It is noticed that the theoretical curve starts from 1 MeV and increases with the energy and it is closer to the experimental curve than in case of n = 3.

But in Fig. 4 the comparison was made between two-component theoretical curve and the experimental data when n = 5. It is noticed there is no noticeable change between n = 3 and n = 5 because the values of theoretical energy levels stay less than the experimental values when n = 5 for two reasons the first is the theoretical values of PLD stay less than the experimental values when n = 5 and the second in case of two component the excitation energy distribute on the large number of protons and neutrons and this decreases the PLD.

In Fig. 5 a comparison between one-component theoretical curve and the experimental data was made when n = 7. The theoretical curve starts from an excitation energy (E) equal to 1 MeV and increases rapidly with increasing (E). it lies below the experimental curve up to 5 MeV and between 5 MeV and 6 MeV an agreement between the theoretical and the experimental curves then the theoretical curve becomes above experimental curve because the theoretical curve is dependent on the excitation

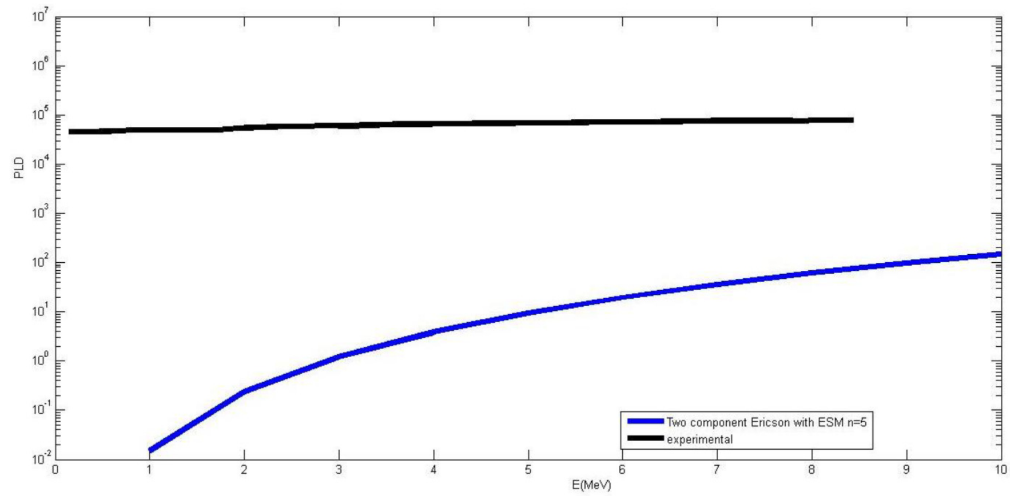

Fig. 4. Comparison between one-component with n = 5 and experimental curve.

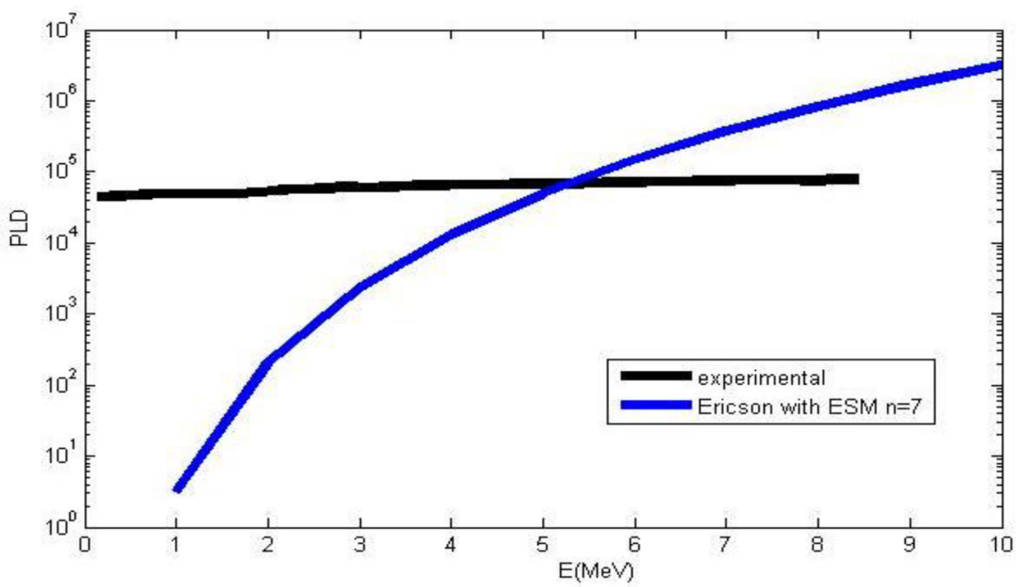

Fig. 5. Comparison between one-component with n = 7 and experimental curve.

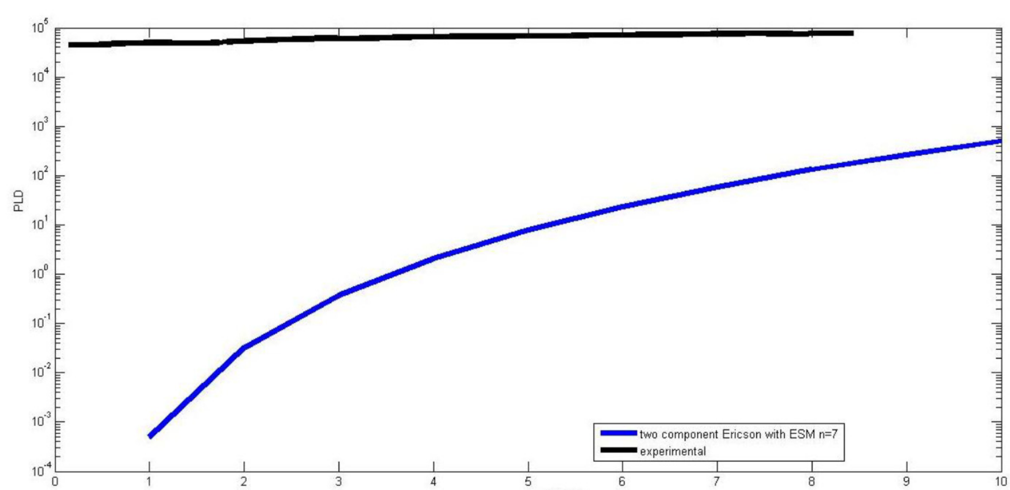

Fig. 6. Comparison between two-component with n = 7 and experimental curve.

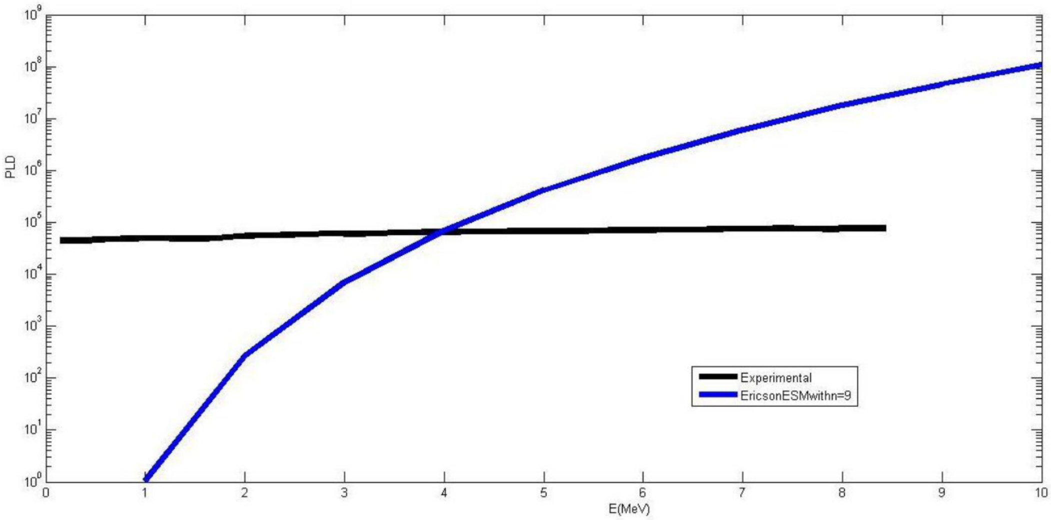

Fig. 7. Comparison between one-component with n = 9 and experimental curve.

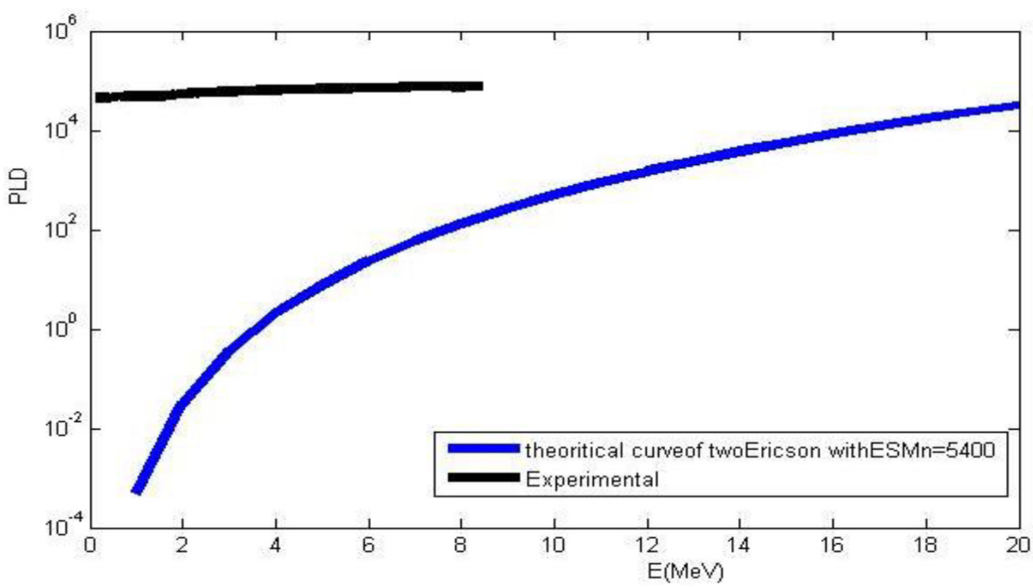

Fig. 8. Comparison between two-component with n = 9 and experimental curve.

energy and the increase in the energy led to increase the theoretical curve above the experimental curve.

In case of two-component theoretical curve at n = 7. In the Fig. 6 the theoretical curve lies below the experimental curve. It starts from 1 MeV and increases with increasing the energy (E) but stay below the experimental values because in case of two components the energy is distributed on a number of nucleons bigger than in case of one-component and this leads to excited level less than as in one component hence the PLD values are less than in one-component.

Fig. 7 shows the one-component theoretical curve when n = 9. The curve starts from 1 MeV and increases with E and intersects with the experimental curve at E = 4 MeV then after that becomes above the experimental curve.[10]

Fig. 8 shows the two-component curve. It starts from excitation energy (E) equal to 1 MeV and increases with increasing (E) but it lies below the experimental data because in case of two components the energy distribute on a number of nucleons bigger than in case of one-component and this lead to excited level less than as in one component hence the PLD values are less than in one-component.

Conclusion

The theoretical curves of both one and two components increase rapidly with increasing the excitation energy where it is noticed they all start from 1 MeV and increase with increasing the energy on x-axis. However, the effect of increasing the value of the exciton number on the theoretical curves was noticed in case of one component where the theoretical curve intersects with the experimental curve at $n = 7$ and $n = 9$. In case of two-components there is no noticeable increase with increasing the exciton number because the energy distributed on two-types of particles results in decrease in the excitation of the particles so this will decrease the level density in case of two components.

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Authors' declaration

- Conflicts of Interest: None.
- We hereby confirm that all the Figures in the manuscript are ours. Furthermore, any Figures and images, that are not ours, have been included with the necessary permission for re-publication, which is attached to the manuscript.
- No animal studies are present in the manuscript.
- No human studies are present in the manuscript.
- The author has signed a partial level density in pre-equilibrium nuclear reactions with different exciton numbers in pre-equilibrium region.
- Ethical clearance the project was approved by the local ethical committee in University of Baghdad

Authors' contribution statement

A. D. S proposed the topic of research and guidance and supervised on the student and review and proofreading the research S. A. N wrote the paper and made the calculations then discuss the results.

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تاثير عدد الاكسايتونات على صيغتي كثافة الحالات الجزئية ذات المركبة والمركبتين

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الخلاصة

عملنا في هذا البحث مقارنة بين النتائج النظرية لصيغة اركسون للمركبة والمركبتين لكثافة الحالات الجزئية مع نتائج العملية في اطار نموذج الفسح المتساوية. يلاحظ ان صيغة كثافة الحالات الجزئية لمركبة واحدة تزداد مع زيادة قيمة عدد الاكسايتونات حيث اخذ عدد الاكسايتونات (9,7,5,3). نفس عدد الاكسايتونات عوض في صيغة كثافة الحالات الجزئية بمركبتين ولكن الزيادة في قيم كثافة الحالات الجزئية للمركبتين صغيرة جدا بحيث لا يمكن ملاحظتها لذلك يمكن القول ان الزيادة بعدد الاكسايتونات يؤثر على قيم كثافة الحالات الجزئية للمركبة الواحدة ولكن في حالة المركبتين فان قيم كثافة الحالات الجزئية لمركبة واحدة لا تتاثر بعدد الاكسايتونات وذلك لان الطاقة تتوزع على عدد اكبر من الجسيمات في حالة المركبتين عما هو علية في حالة المركبة الواحدة وهذا يجعل كثافة الحالات اقل مما هي عليه في حالة المركبة الواحدة ولا يضهر تاثير عدد الاكسايتونات. في حالة المركبتين عندما عدد الاكسايتونات (3) فان المنحني النظري يقع اسفل المستوى العملي وعندما عدد الاكسايتونات يساوي (5) يقترب المنحني النظري من المنحني العملي وعندما عدد الاكسايتونات يساوي (7) فان المنحني النظري يتقاطع مع العملي عند قيمة الطاقة ($E = 5$ MeV) وعندما عدد الاكسايتونات يساوي (9) يتقاطع المنحني النظري مع العملي عند قيمة الطاقة ($E = 4$ MeV).

الكلمات المفتاحية: حساب كثافة الحالات، كثافة الحالات النووية، التفاعل النووي، تفاعلات قبل التوازن، مرحلة النواة قبل المركبة.