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Effect of Excitation Energy and Mass number on Most probable exciton number

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Abstract

Exciton model describes the excitation of particles in pre-equilibrium region of nuclear reaction by exciton. In pre-equilibrium region there is a small probability for occurring emission and the number of excitons be the probability of the emission of it possible more is called most probable exciton number MPEN. In this paper the MPEN formula was derived for protons and neutrons separately and so MPEN formula derived with taking into account the non equidistant spacing between the energy states. The MPEN was studied with the mass number where it is noticed the MPEN increases with increasing the mass number. Also, MPEN studied for different isotopes of Al, the MPEN increases with increasing mass number of isotopes. MPEN for neutron is compared with that of protons and found that the MPEN for neutrons is larger than that of protons. MPEN in case of one component is compared with MPEN of proton and neutron it is found that the MPEN of one-component is greater than the MPEN for both protons and neutrons. Finally the MPEN in case of equidistant spacing model ESM is compared with that of non equidistant spacing model non-ESM where it is noticed the MPEN of ESM is greater than that of non-ESM.

Keywords: exciton model, pre-equilibrium nuclear reaction.

تاثير طاقة الاثارة والعدد الكتلي على عدد الاكسايتونات الاكثر احتمالا

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الخلاصة

يصف نموذج الاكسايتون اثارة الجسيمات النووية لمرحلة قبل التوازن باستخدام فرضية الاكسايتون. في منطقة قبل التوازن هناك احتمالية صغيرة لحدوث الانبعاث وعدد الاكسايتونات الذي تكون احتمالية الانبعاث منه عالية يدعى بعدد الاكسايتونات الاكثر احتمالا MPEN most probable exciton number. في هذا البحث اشتقت صيغة الـ MPEN للبروتونات والنيترونات بشكل مستقل. كما تم اشتقاقها مع الاخذ بالاعتبار حالة الفسح غير المتساوية بين مستويات الطاقة. درست الـ MPEN مع العدد الكتلي حيث لوحظ انها تزداد بزيادة العدد الكتلي. كذلك درست الـ MPEN لنظائر مختلفة لعنصر Al حيث لوحظ زيادة الـ MPEN بزيادة العدد الكتلي للنظائر. اما بالنسبة للـ MPEN للنيترونات فقد قورنت مع تلك الخاصة بالبروتونات ووجد ان الـ MPEN لحالة النيترونات اكبر منها للبروتونات. كما قورنت الـ MPEN للمركبة الواحدة مع الـ MPEN لكل من البروتونات والنيترونات كل على انفراد حيث لوحظ ان قيمها للمركبة الواحدة تكون اكبر منها مما لو اخذت للبروتونات او النيترونات بشكل منفصل. واخيرا، قورنت الـ MPEN في حالة كون الفسح متساوية بين مستويات الطاقة مع قيم الـ MPEN عندما تكون الفسح غير متساوية ووجد انه لحالة الفسح المتساوية تكون قيم الـ MPEN اكبر منها لحالة الفسح غير المتساوية.

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1. Introduction:

As a result of the lack of a comprehensive theory of nuclear physics so was replaced by the nuclear models and that every one of these models has been successful interpretation of a particular phenomenon and failed to explain other phenomen. One of these models is the exciton model; this model was supposed by J. J. Griffin in 1966 [1] to explain the emission occurring in pre-equilibrium nuclear reaction stage PE i.e. before energy distribution of all nucleon is complete). This model assumes that when the nucleon hits the nucleus, it shares energy with one of the target nucleons and excites it above the Fermi energy level, a virtual level is taken as a reference to measure energy. This excited nucleon will collide with other nucleon and give part of its energy and so energy is transferred to the other particles this process called two body collision process [2].

2. Theory:

The excited particle (p) above the Fermi level leaves behind it a hole (h) remains under the Fermi level and the pair of the particle and the hole is called exciton. The exciton number is the sum of particles and holes $n = p + h$ [3,4]. Griffin used Ericson's formula [5] to calculate the exciton level density , this formula does not distinguish between the proton and neutron but takes all as particles, therefore called one-component Ericson' formula.

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

Where p, h and n are particle number hole number and exciton number respectively. E is the excitation energy and g is the single particle level density and it is given by

$$\boldsymbol{g = \frac{A}{d}} \qquad (2)$$

The symbol A is the mass number and d is the space between the energy levels. The space is equal therefore the model is called equidistant spacing model ESM.

If the protons and neutrons are considered as a distinguishing particles Ericson's formula becomes [5].

$$\boldsymbol{\omega_2(n,E) = \frac{g_\pi^{n_\pi} g_\upsilon^{n_\upsilon} E^{n-1}}{p_\pi!\, h_\pi!\, p_\upsilon!\, h_\upsilon!\,(n-1)!}} \qquad (3)$$

The symbol n_π is the exciton number of protons, n_υ is the exciton number of neutrons, p_π is the proton particle, h_π is the proton hole, p_υ is the neutron particle, h_υ is the neutron hole, g_π is the single particle level density of proton, g_υ is the single particle level density of neutron and n is the total exciton number $(n = n_\pi + n_\upsilon)$.

$$\boldsymbol{g_\pi = \frac{Z}{A}\, g} \qquad (4)$$

$$\boldsymbol{g_\upsilon = \frac{N}{A}\, g} \qquad (5)$$

For more accuracy the spaces between the levels have been taken not equal therefore, the single particle level density will be [6,7]

$$\boldsymbol{g = g_o \sqrt{\frac{\varepsilon}{F}}} \qquad (6)$$

Where the symbol ε is the excitation energy divided on exciton number $\varepsilon = \frac{E}{n}$ and F is the Fermi energy level.

$$\boldsymbol{g_o = \frac{3A}{2F}} \qquad (7)$$

The emission of particle may occur during pre-equilibrium in small probability. And there is exciton number which represents the number that the probability of emission of it be more likely. This number is called *most probable exciton number* $\bar{n}$ which is given by [8, 9].

$$\boldsymbol{\bar{n} = \sqrt{gE}} \qquad (8)$$

Since the most probable exciton number depends on g then from equation (2) and (8) we can get

$$\boldsymbol{\bar{n} = \sqrt{\frac{AE}{d}}} \qquad (9)$$

The equation (9) shows that $\bar{n}$ depends on the mass number A.

In case of two-component, from equations (2), (4) and (8) one can get on most probable exciton number for protons

$$\bar{n}_\pi = \sqrt{\frac{ZE}{d}} \tag{10}$$

Also the most probable exciton number for neutron can get from (3), (4) and (8)

$$\bar{n}_\upsilon = \sqrt{\frac{NE}{d}} \tag{11}$$

If the most probable exciton number is investigated with non-ESM, g from (6) must be used. The quantity ε is modified to $\varepsilon = \frac{E}{\bar{n}}$ and then substitute in (6) then becomes

$$g = g_o \sqrt{\frac{E}{F\bar{n}}} \tag{12}$$

Now from equation (7), (8) and (12) the quantity g for non ESM will be

$$\bar{n} = (\frac{3A}{2})^{1/3}\,\frac{E}{F} \tag{13}$$

Equation (13) shows that the parameter $\bar{n}$ is proportional to E and $A^{1/3}$.

3. Results and Discussion:

This section includes the discussion of results. The above equations were programmed by Mat. Lab. Figure-1 shows that the MPEN increases with increasing the mass number. That's mean increasing emission probability with mass number, because the increasing in nucleons gives a higher chance of emission as seen in equation (8).

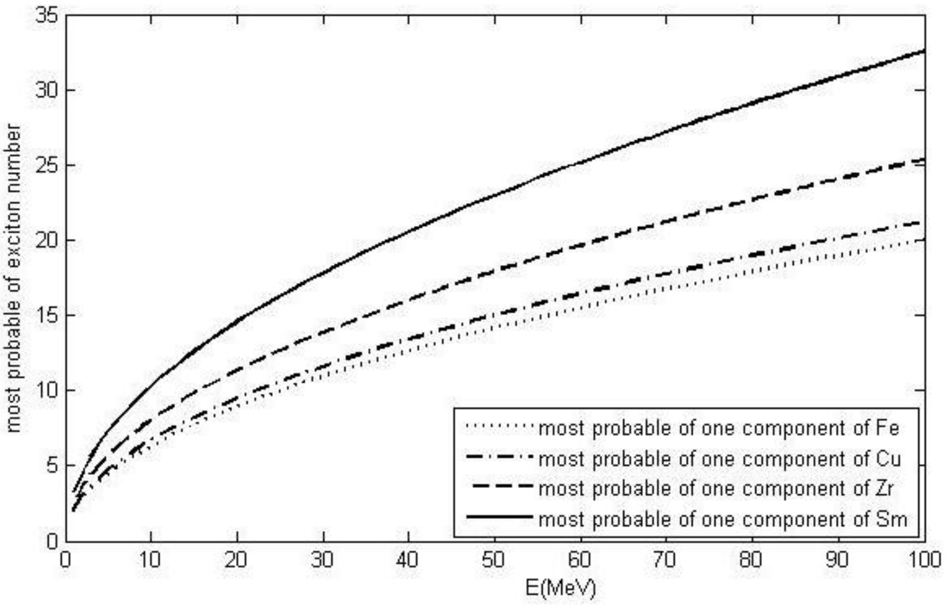

Figure 1- Shows the MPEN values with different mass numbers

Figure-2 gives MPEN for different isotopes of Al. one can see that the MPEN increases with increasing isotope mass number, i.e. the probability of emission will also increase with increasing the nucleons.

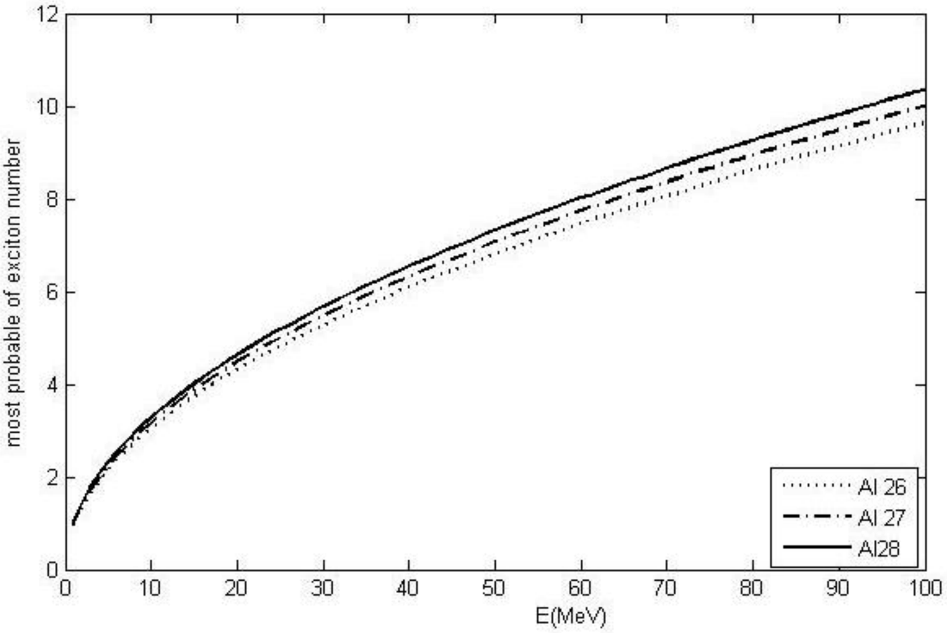

Figure 2- Shows MPEN values of different isotopes for Al**.**

In Figure-3 an analogy has been made between MPEN for proton (eq 10) with that for neutron (eq 11). It is noticed that the MPEN of neutrons is greater than that of protons. This is because the numbers of neutrons in nuclei are often greater than numbers of protons. Therefore the probability emission from neutrons is most probable.

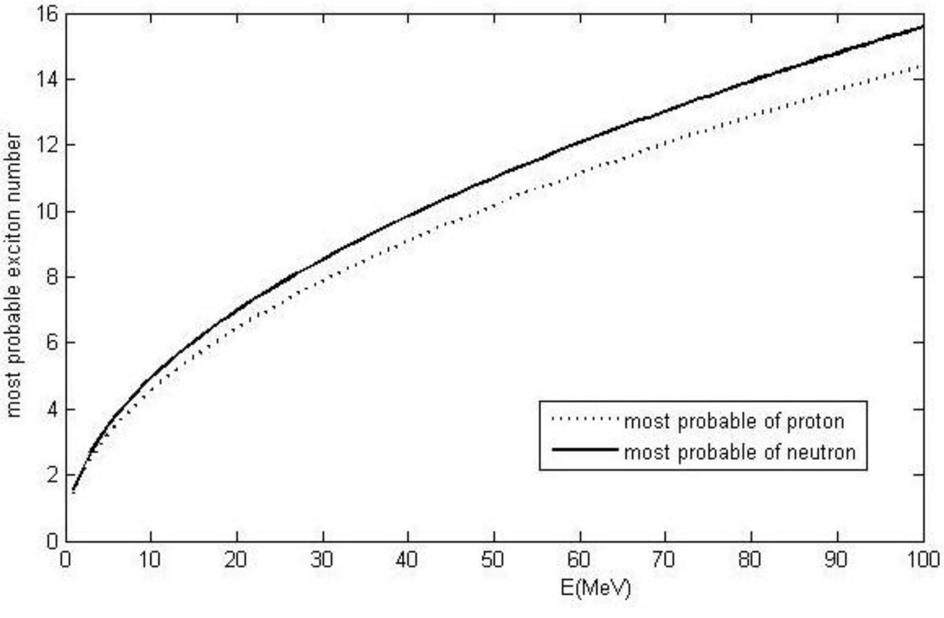

Figure 3- Gives a comparison between MPEN for protons and these for neutrons.

In Figure-4 the MPEN of one-component equation (9) is compared with MPEN of proton equation (10). One can see that MPEN of one-component is greater than that of protons. This is as in case of one-component the emission occurs from all nucleons while in case of protons the emission occurs only from protons. So MPEN for one-component is greater than that of protons.

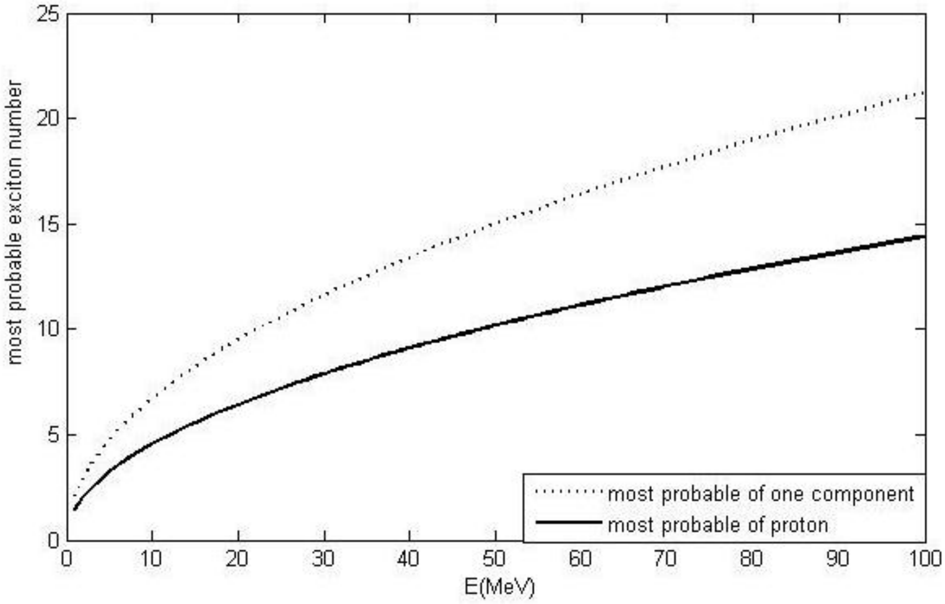

Figure 4- shows comparison between MPEN for protons and these for one-component **.**

Also MPEN for one-component is compared with that for neutron number in Figure-5. The MPEN for one-component is greater than that of neutron because in case of one-component the emission occurs from all nucleons while in case of neutrons the emission occurs only from neutrons. So MPEN for one-component is greater than that of neutrons.

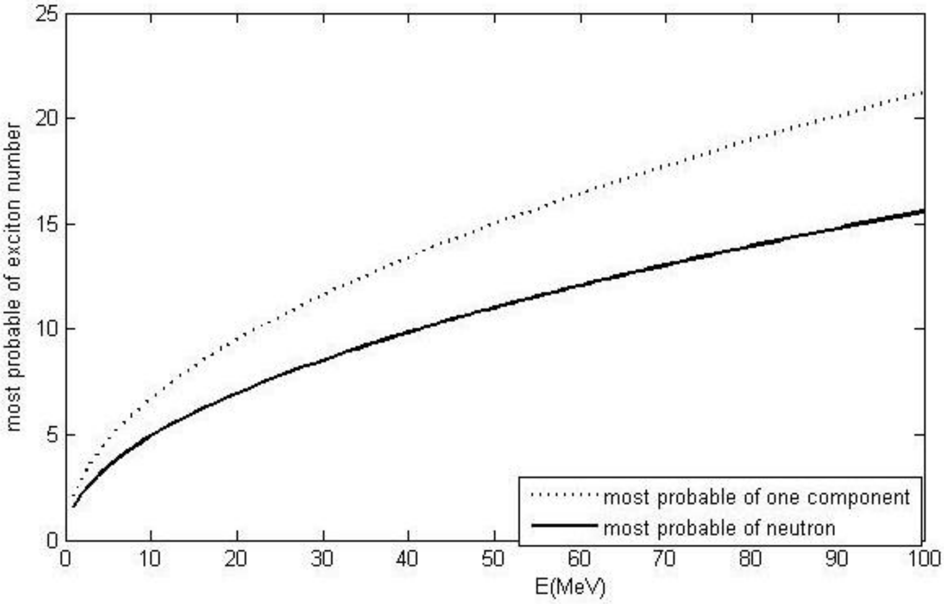

Figure 5- Shows comparison between MPEN for neutron and these for one-component.

Finally Figure-6 shows a comparison between MPEN in case of ESM and MPEN in case of non-ESM. It is noted the MPEN in ESM is greater than non-ESM. This is interpreted as the states of non-ESM are more than the states of ESM, therefore, the energy distributes on a larger number of states and the probability of emission will be small

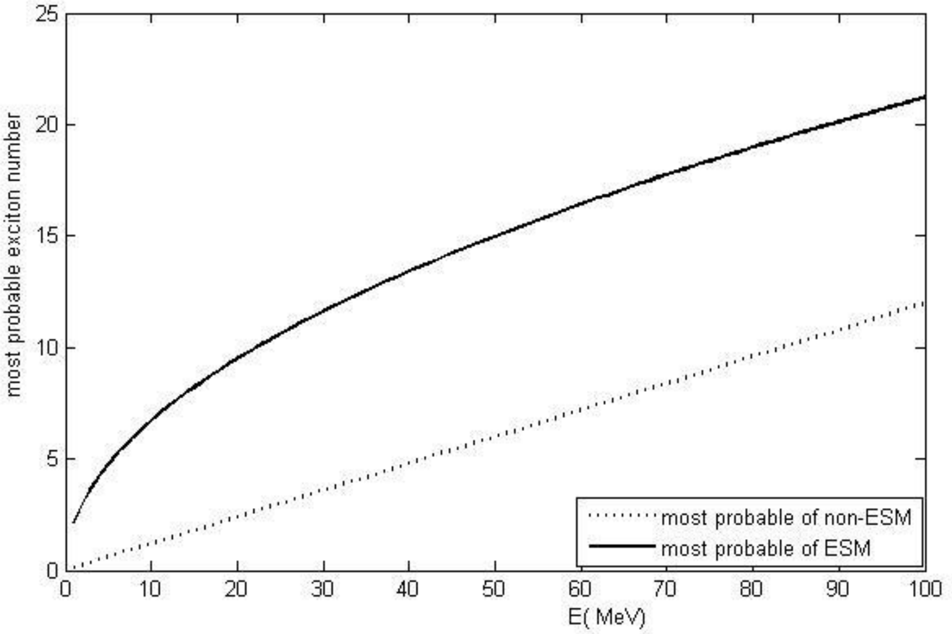

Figure 6- Gives a comparison between MPEN in case of ESM and this of non-ESM**.**

4. Conclusion

The MPEN increases with the energy and the mass number. MPEN for neutron is greater than that of protons and for one-component is greater than that of protons and neutrons separately. MPEN in case of one-component exciton number is greater than that in case of non-ESM.

References

1. Blann, M. **1971**. Extensions of Griffin's statistical model for medium-energy nuclear reaction. *Physical Review Letter*, 18(21), pp: 1357-1360.
2. Weisskopf, V. **1937**. Statistics and Nuclear Reactions. *Physical Review*, 52, pp: 295-303.
3. Ericson, T. 1960. The statistical Model and Nuclear Level Densities. *Advanced Physics*, 9, pp: 425-511.
4. Selman, A. A. **2009**. Neutron Induced Pre-equilibrium Nuclear Reactions Using the Exciton Model. Ph.D. Thesis. Department of Physics, College of Science, University of Baghdad. Baghdad, Iraq.
5. Avirgeano, M. and Avirgeano, V. **1998**. Partial Level Densities for Nuclear Data Calculations. *Journal of Computational Physics. Phys. Comm*. 112, pp: 191-226. Also available from: Cornell university online publications, ref. arXiv:physics/9805002v1.
6. Bĕták, E. and Hodgson, P. **1998**. Particle-Hole State Density in Pre-Equilibrium Nuclear Reactions. University of Oxford, available from *CERN Libraries, Geneva, report ref. OUNP-98-02*, pp: 483-524.
7. Kalbach, C. **1985**. Surface Effect in The Exciton Model of Pre-equilibrium Nuclear Reactions. *Physical Review C32*, pp: 1157-1168.
8. Kalbach, C. **2005**. Isospin Conservation in Pre-equilibrium Reactions. *Physical Review*, C72, pp: 1-15.
9. Watanabe, Y. and Kodaka, K. **1990**. Incident Energy Dependence of Preequilibrium (p, p') Spectra. *Journal of Z. Physics*, A33, pp: 63-69.