MASS ASYMMETRY IN THERMAL NEUTRON FISSION WITH MODIFIED POTENTIAL

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ABSTRACT

A modified potential of the sudden approximation, modified to include interactions among nuclei of different radii, is applied to explain the mass asymmetry of fission fragments in the thermal fission of Uranium-235. The results are encouraging in that the asymmetry feature in the fission yield is displayed. It appears that the mass asymmetry is a feature that can be explained without incorporating other effects. However, close correspondence requires addition of extra features.

ABSTRAK

Suatu keupayaan terubah bagi penganggaran tiba-tiba, diubah suai bagi merangkumi interaksi di antara nukeus berlainan jejari, digunakan untuk menerangkan ketaksimetrian jisim terhadap fragmen pembelahan di dalam pembelahan terma Uranium-235. Keputusan adalah menggalakkan bahawa terpamernya ciri ketaksimetrian dalam hasil pembelahan. Ianya memperlihatkan bahawa ketaksimetrian jisim adalah suatu ciri yang dapat dijelaskan tanpa menggabungkan kesan-kesan lain. Bagaimanapun, Kecocokan yang rapat memerlukan penjumlahan ciri-ciri tambahan

Keywords: Fission, Mass asymmetry, Quasimolecular potential, Imaginary potential.

INTRODUCTION

The theories of Bethe [1] and Brueckner et. al. [2] presented the basic theories on the nuclear matter for finite nuclei. Scheid and Greiner [3] developed a phenomenological theory on nuclear matter along the lines of [1] and [2] to calculate the properties of nucleus and the potential energy between the two interacting nuclei. The authors then applied to the ^{16}O-^{16}O system and the experimental results were very well explained up to the energy range of 30 MeV. In their formulation the two interacting nuclei were identical which limits the applicability. We have modified the potential between the nuclei so that they can be applied to non-identical nuclei. Also our imaginary potential is obtained in a way different than of Ref. [3]. An application to the ^{16}O-^{28}Si system by us explained the scattering very well for a range of energies with no adjustments of nuclear parameters for different energies. The paper will be published in IJMPE, [4]. In the following we apply the potential developed to a range of interacting nuclei by applying it to the fission of Uranium-235 by thermal neutrons. Rather we take the reverse picture and apply the potential to the fusion of various nuclear fission fragments that then join to form the Uranium-236 nucleus. This is compared with the experimental results [5] obtained for the mass asymmetry observed in the pre-neutron emission. Though other models for the calculation of potential energy exist ours is a simple extension to the model in Ref. [1].

METHODS

The starting point in the derivation of the nuclear potential are a set of equations that for a given density distribution of the nucleus give the binding energy, the nuclear radius and some other properties that can be compared to experiment. The binding energy is given by,

$$B(\rho) = W_0 A + \frac{C}{2\rho_0}\int(\rho-\rho_0)^2 d\tau + \frac{V_0}{8\pi}\int\rho(\mathbf{r}_1)\frac{\exp(-|\mathbf{r}_1-\mathbf{r}_2|/\mu)}{|\mathbf{r}_1-\mathbf{r}_2|}[\rho(\mathbf{r}_2)-\rho(\mathbf{r}_1)]d\tau_1 d\tau_2$$
$$+\frac{1}{2}\left[\frac{eZ}{A}\right]^2\int\rho(\mathbf{r}_1)\frac{1}{|\mathbf{r}_1-\mathbf{r}_2|}\rho(\mathbf{r}_2)d\tau_1 d\tau_2 + \frac{G}{2\rho_0}\left[\frac{2Z}{A}-1\right]^2\int\rho^2 d\tau \tag{1}$$

The density distribution , in turn is obtained by fixing the values for a set of parameters such as the compressibility *C*, the nuclear binding energy per unit volume of infinite nuclear matter W_0, the asymmetry energy parameter *G*, the strength of Yukawa interaction V_0 and the density of infinite nuclear matter $_0$. The values for some of these quantities are known from earlier work [2]. The other are fixed by requiring the binding energy and nuclear radii be reproduced. The values we used for the parameters are as follows:

W_0=-15.3 MeV, . = 0.124 fm^{-3}, *C*=88./9 MeV, *G*=70, V_0=-4880 MeV-fm and =0.45 fm.

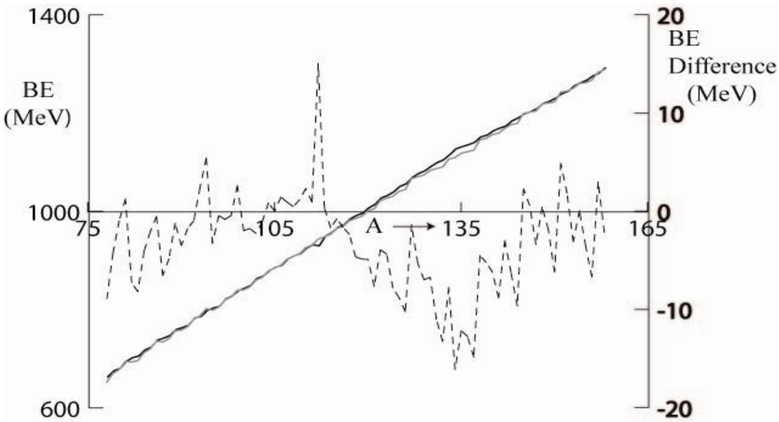

Fig.1 The difference in binding energies from experimental curve (black) and the theoretical (grey) using Eq. (1), is given by the broken curve.

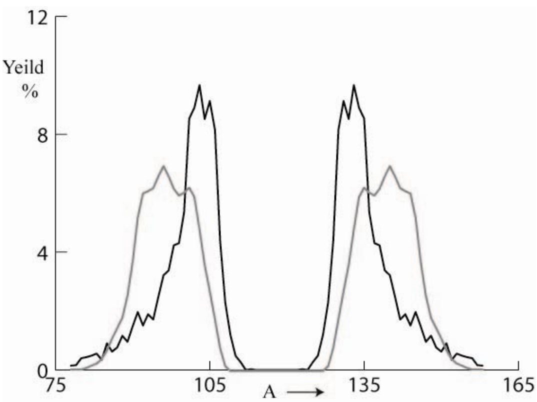

Fig.2 Experimental yield of fission fragments from U-235 fission by thermal neutrons(grey) and the percent fusion of the same fragments into U-236 (black curve). The asymmetry is obvious.

The range of nuclei under investigation was from A =78 to A = 158. These are the nuclei involved in the fission of uranium 235 by thermal neutrons. The values of binding energies from (1) and experiment is displayed in Fig.1 The figure also shows the difference between experiment and theory. At most the binding energies differ by ±20 MeV.

Using the potential that we have worked out for asymmetrical nuclei, we show in Fig.2 the percent of fragments that can fuse to form the Uranium-236. Head on collision is assumed. The kinetic energies of pre-neutron emission fragments have been used in obtaining the curve. On the same figure is displayed the fission yield obtained from experiment as in Ref. [5].

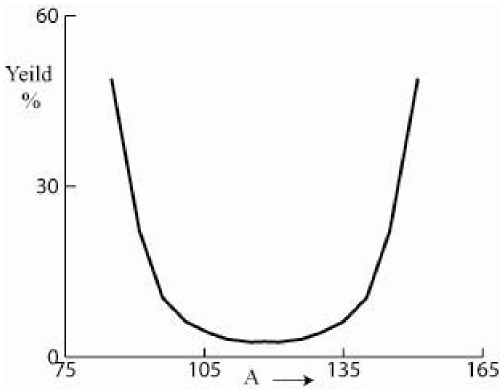

Fig.3 The fusion to U-236 with mass number for constant c.m energy of 180 MeV.

DISCUSSION

It is interesting to note that our potential, which is an extension of Ref. [3] is able to display the asymmetry feature as should be clear from Fig.2. In obtaining the result an imaginary potential similar to that used in [4] is used without any change for all the nuclei. Our potential differs from [3] that was used to explain the ^{16}O-^{16}O scattering. It has its origin in the nuclear part of the ion-ion potential more specifically the Yukawa interaction of the ion-ion potential. The imaginary potential in the interior is taken to be constant. We believe that the interior region is not so important as the nuclei on collision loose their identity. This is the same form adopted in Ref.[4]. A proper potential to explain fusion would be the adiabatic potential rather than the sudden potential we have used. However since the surface region is important the distinction between the two near the surface is not much and this is therefore the reason for using this potential. The fact that the fission yield is low for symmetric fission can be attributed to the high Coulomb barrier for the interacting nuclei as compared to the nuclei involved in asymmetric fission. This reasoning alone would give a higher fission yield for highly asymmetric nuclei such as the pair A = 85 and 151. However this is not what is experimentally observed and this is also shown by our black curve in Fig.2. To gain an understanding as to why the fission drops for higher asymmetric fragments we have recalculated the percent yield for fifteen pairs of interacting nuclei keeping the energy constant at 180 MeV. The result is displayed in Fig.3. From the graph it is obvious that the drop in the yield can be attributed to the fall in the pre-neutron emission fragments energy for highly asymmetric nuclei. These are the energies used in obtaining the theoretical curve of Fig.2 and taken from Ref.[5].

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