Comparative analysis of IQMD model and one-body type models towards balance energy

Rajni Bansal[1], Sakshi Gautam[2], and Rajeev K. Puri[1*]
[1]*Department of Physics, Panjab University, Chandigarh - 160 014, India*
[2]*Department of Physics, Dev Samaj College for Women, Sector 45 B, Chandigarh -160 047, India*

Introduction

A large number of experimental as well as theoretical efforts have been reported in the literature to understand balance energy (E_{bal}). Here we compare the system size dependence of E_{bal} as predicted by one-body type models like the Boltzmann Uehling Uhlenbeck (BUU) [1–3] and its improved version, namely, IBUU [4], Relativistic Valsov Uehling Uhlenbeck Relativistic Valsov Uehling Uhlenbeck (RVUU) [5] and Landau Valsov (LV) approach [6] models along with our calculations carried out using Isospin-dependent Quantum Molecular (IQMD) model [7].

Results and discussion

In Fig. 1, squares represent our present calculations (using soft momentum-dependent equation of state (EOS) along with reduce cross-section ($0.8\sigma_{free}$) [8] and circles correspond to earlier calculations using the above mentioned one-body type models. Lines represent the power law fit $\propto A^{-\tau}$. Let us now analyze each of these results. Fig. 1(a) displays the calculations by Krofchek *et al.* [1] where BUU model was used. From the figure, we find good agreement of E_{bal} for lighter system $^{40}Ar+^{51}V$ whereas a clear deviation is visible for heavier systems. Except for the difference in the basic theoretical approach (BUU by Krofchek *et al.* and IQMD in present calculations), the other differences in two attempts are of Coulomb potential, nn cross-section and equation of state. The calculations by Krofchek *et al.* have been carried

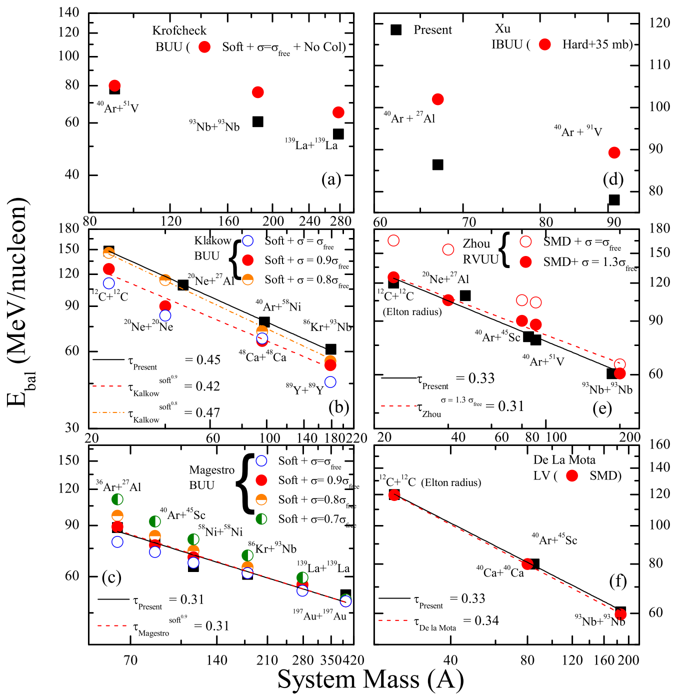

FIG. 1: The balance energy as function of system mass for various theoretical approaches. Elton radius is used for $^{12}C+^{12}C$ reaction [9].

out without Coulomb potential and momentum dependence of mean field and also with free nn cross-section. The momentum dependence of mean field lowers the balance energy (due to its repulsive nature) and reduction of nn cross-section will enhance the balance energy, these two factors thus oppose each other and therefore will get cancel out. The only remaining difference is that of Coulomb potential. To check this point, we also cal-

*Electronic address: `rkpuri@pu.ac.in`

culated the E_{bal} by neglecting the Coulomb potential in the present IQMD calculations (results not shown) and now E_{bal} calculated with IQMD model becomes almost same to that calculated by Krofcheck *et al.* using the BUU model. Fig. 1 (b) displays the calculations of Klakow *et al.* [2] using BUU model having Coulomb potential. Circles represent different parameters sets for different reduction factors of the cross-section. From the figure, we see that calculations of Klakow *et al.* (with 20% reduced cross-section) matches well with the present calculations. We have stated earlier that the Coulomb potential is responsible for the difference in system size effects between BUU and IQMD model. Since the calculations of Klakow *et al.* include Coulomb potential, therefore, agreement with the present results goes better. Moreover, we see that the various reductions in cross-section only alter the magnitude of E_{bal}, the mass dependence is still preserved and approximately same as that of the present calculations, the best being obtained with 10% reduction of cross-section. It is worth mentioning that for the present calculations we employed constant reduction in the nucleon nucleon (nn) cross-section, whereas the calculations of Ref. [2] use density-dependent reduction. To see the relative behavior of density-dependent reduction with respect to constant reduction of cross-section, we have also calculated the mass dependence of the E_{bal} with density-dependent reduced cross-section (20% reduction) and found the power law factor to be almost the same as that with the constant reduction (results not shown). Fig. 1 (c) displays the calculations of Magestro *et al.* [3] using BUU model which covers a wider mass range over Klakow *et al.* [2]. These calculations also show best agreement with 10% reduction of nn cross-section as obtained for earlier attempts by Klakow *et al.* [2]. Another attempt to study the system size effects in balance energy was done using improved version of BUU model (labeled as IBUU). Fig. 1 (d) displays the calculations of Xu [4] using IBUU model. From the figure, we notice that our calculations predict lower balance energy than that predicted by Xu. This is because of difference in equation of state in two cases (SMD in present and hard in Ref. [4]). To verify this, we have calculated the balance energy with hard EOS along with 20% reduction in cross-section (which is equivalent to 32 mb in the present case, and this approximately equals 35 mb, the cross-section as used by Xu). We have found almost same E_{bal} for both the systems (results not shown). Fig. 1 (e) displays the results of relativistic VUU approach by Zhou *et al.* [5]. From the figure we find that our calculations show better agreement with enhanced cross-section results of Zhou *et al.* In the last part of the comparison, we display the results of LV calculations by De la Mota *et al.* [6]. The calculations show good agreement with the present results as the power law factor is almost the same in both cases. This is because of the similar treatment of potentials and cross-section in both the approaches. In summary, our findings revealed that once physical parameters are kept the same, almost all one-body models yield nearly same balance energy as that of IQMD calculations. This work is funded by University Grant Commission (UGC) of India.

References

[1] D. Krofcheck *et al.*, Phys. Rev. Lett. **63**, 2028 (1989); *ibid.* Phys. Rev. C **43**, 350 (1991); *ibid.* C **46**, 1416 (1992).

[2] D. Klakow, G. Welke and W. Bauer, Phys. Rev. C **48**, 1982 (1993).

[3] D. J. Magestro *et al.*, Phys. Rev. C **62**, 041603(R) (2000).

[4] H. M. Xu, Phys. Rev. Lett. **67**, 2769 (1991); *ibid.* Phys. Rev. C **46**, R389 (1992).

[5] H. Zhou *et al.*, Phys. Rev. C **50**, R2664 (1994).

[6] V. De La Mota *et al.*, Phys. Rev. C **46**, 677 (1992).

[7] S. Gautam *et al.*, Phys. Rev. C **83**, 034606 (2011); *ibid.* C **83**, 014603 (2011).

[8] R. Bansal, S. Gautam and R. K. Puri Phys. Rev. C (submitted).

[9] R. Bansal *et al.*, Phys. Rev. C **87**, 061602(R) (2013).