CHAPTER SIX

SUMMARY OF RESULTS
Summarizing, we have studied first of all the effect of surface deformations and orientations of the colliding nuclei on the relative excitation energy of the compound nucleus formed, by including these effects in Coulomb interaction alone. We notice that whereas the location of the potential energy minima with respect to mass asymmetry, which characterize the target-projectile combinations, remains the same, their relative depths show a strong dependence on both deformation and orientation of the colliding nuclei. Cool compound nuclei formed in central collisions for the nose-to-nose configuration and its vicinity ($\theta \lesssim 30^\circ$) must have both their reaction partners (symmetric as well as asymmetric) as spherical nuclei. However, for largely oriented nuclei, the potential minima for the case with one reaction partner deformed becomes as deep as that given by the symmetric reaction partners and the excitation energy of the systems corresponding to the potential energy minima is shown to increase with their asymmetry.

The role of proximity force potential, extended to include the collisions between deformed and oriented nuclei is studied. The proximity effects, which are shown to be rather small for spherical colliding nuclei, are found to be strongly attractive for deformed reaction partners. Once the deformed colliding nuclei become oriented in space, the proximity contribution becomes gradually weaker, as the orientation increases. This result is shown to have an important
consequence that the surface separation can not be the same for the spherical-spherical and spherical-deformed (or deformed-deformed) colliding nuclei, and it is a strong function of the mass asymmetry $\eta$. The significance of the proximity forces in the fragmentation potentials is clearly shown in making the cool compound nucleus formed with large mass asymmetry to be more excited.

Next, a model for the fusion of two colliding nuclei is proposed. It is shown that fusion of two heavy ions can take place only if they overcome the adiabatic interaction barrier. The fusion is shown to start already at the first barrier, which appears at a much larger length (or separation) of the colliding system, at a point just past the saddle shape formation. However, this barrier is, too low such that only a "conditional saddle" can be said to be formed and the deep-inelastic collision process occurs. Another barrier at a smaller length of the composite nucleus is also observed which is found to be high enough to hold the system together. Provided the incident energy is good enough, complete fusion of the colliding nuclei occurs by crossing over of this inner barrier. Then, depending on the excitation energy of the fused system formed (given by the barrier height), it will either go to the ground state (after evaporating a few neutrons) forming a cool compound nucleus or fission back resulting in a fusion-fission process. This study gave two further interesting results:
(i) the excitation energies of the cool compound system increases as the mass asymmetry of the incoming nuclei increases; and

(ii) the use of a constant value of relative separation in the calculations of the fragmentation potential is a reasonable approximation for locating the target-projectile combinations corresponding to cool compound systems.

Our calculations for the above mentioned results are made for the composite systems with 102 ≤ Z ≤ 114.

The result that the excitation energies of the cool compound nucleus increases linearly with mass asymmetry leads, apparently, to a preference for the symmetric, spherical target-projectile combinations for forming the cool compound nuclei. This led to a suggestion of the possible use of 134-136 Xe isotopes and oriented heavy nuclei like Dy, Er, Yb, Hf, W, Os and Pt in combination with the isotopes of Kr nuclei for synthesizing new heavy elements.

As an application of this fusion model, we have shown that in the reactions of 4.8-8 MeV/nucleon Pb on Ti, Cr, Fe and Ni, the colliding systems overcome the adiabatic interaction (or fusion) barriers and get captured in the pockets behind the barriers and form composite systems 208, 258, 260, 266, 272, 104, 106, 108 and 110, respectively. Being strongly asymmetric systems, the excitation energies of the
composite systems formed are large so that they fission back
adiabatically. Hence, in these reactions a two step process
of "symmetric fragmentation following capture" given by the
dynamical fragmentation theory is shown to be clearly
prevalent.

The fusion (or capture) cross sections are shown to
compare reasonably well with experiments upto 8 MeV/nucleon
and the gross features of the mass yields, i.e. the symmetric
mass fragmentation is reproduced systematically, independent
of the choice of relative separation distance $R$ and the
detailed structure in the cranking mass parameters. The
symmetric fission is shown to be the (dynamical) liquid drop
effect and the other detailed structure in the mass
distributions including the shoulders, are found to depend on
(i) how the temperature would affect the variation of masses
with mass symmetry and
(ii) the dynamical coupling of mass asymmetry with the
relative motion of the separating systems in these reactions.
This led to the suggestion of refined measurements of the
present data for larger mass asymmetry ($\eta > 0.4$). Also, the
calculations of the critical angular momentum for vanishing of
the fusion barrier suggest to extend the present experiments
to still higher energies.

A fully dynamical calculation of mass (or charge)
fragmentation in nuclear fission and heavy ion collisions
requires solving the time-dependent Schrödinger equation in mass (or charge) asymmetry coordinates, either numerically or analytically. We have shown that, by using the parameterized forms of charge dispersion and scattering potentials, the time-dependent Schrödinger equation is solvable analytically for charge dispersion in nuclear fission. The model is applied to the fission of $^{236}$U for the heavy mass chain $A = 141$ (mass asymmetry $\eta = 0.195$). The scission time, calculated using Newton's classical equation of motion, is $T = 17.44 \times 10^{-22}$ sec, which is typical of the adiabatic fission process. Furthermore, the model gives an explicit Gaussian functional form for the charge distribution yields, which explains the gross structure of the data, with the most probable charge containing the UCD and MPE hypothesis as limiting cases. For the example of $^{236}$U fission studied here, both the hypotheses of UCD and MPE are found to be equally satisfactory.