A Thesis on

NUCLEAR REACTIONS AT HIGH ENERGIES

Submitted by

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B.Sc. 1991

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Women's University College for Arts, Science and Education
Ain Shams University

In Partial Fulfilment of the Requirements for the Award of the M.Sc. Degree in Applied Mathematics

1995

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

قَالَ سَنَشُدُّ عَضُدَكَ بِأَخِيكَ وَنَجْعَلُ

لَكُمَا سُلْطَانًا فَلَا يَصِلُونَ إِلَيْكُمَا

بِآيَاتِنَا أَنْتُمَا وَمَنِ اتَّبَعَكُمَا الْغَالِبُونَ

صَدَقَ اللَّهُ الْعَظِيمُ

بسم الله الرحمن الرحيم

with gratitude
I dedicate this work
to the memory of
my dear father

M.T.

Acknowledgement

Thank God for graciously granting
me the privilege of working
under the supervision of
Prof. Dr. M. G. El Mohandis
and Prof. Dr. A. Y. Abul-Magd,
who were very patient, gentle and
understanding in their guidance.

Thank God for mercifully supporting
me with the encouragement of all the
staff of the Mathematics Department,
Women's University College for
Arts, Science and Education.

Thank God for generously offering
me all benefits, a wise mother and
a magnanimous brother always
busy caring for me presenting
all facilities and help.

NOTE

In addition to the research work covered in this thesis, the candidate has passed written examinations in the following postgraduate courses:

- Quantum Mechanics.
- Group Theory.
- Theory of Atomic Collisions.
- German Language.

with grade "Excellent" in each.

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Abstract

High energy nuclear reactions are treated by Glauber's multiple scattering theory. Within the framework of this theory, a major part of this thesis is devoted for the study of the total reaction cross section, σ_R, and its modifications. As a primary goal, the reaction cross section for proton-nucleus collisions is calculated. The following target nuclear density distributions are adopted during calculations: the Gaussian distribution, the uniform distribution, and finally, the two-parameter Fermi distribution (Wood-Saxon). For the Gaussian and the uniform nuclear shapes, the reaction cross section is analytically derived. Applying the Wood-Saxon distribution, the problem is intractable analytically and thus σ_R is numerically evaluated. The following targets are considered ^{9}Be, ^{12}C, ^{16}O, ^{27}Al, ^{65}Cu and ^{208}Pb, where the projectile energy varied from 100 to 2200 MeV. Also, a compiled comparison of the reaction cross section experimental results with the present calculations is presented for a variety of targets at different proton energies.

In nucleus-nucleus collisions, firstly, the reaction cross section is analytically calculated for interactions between nuclei with Gaussian nuclear density distributions. Another case is considered in which the projectile density distribution is Gaussian while the target density is assumed to be uniform. The following reactions are considered: ^{12}C + ^{12}C at energies 50 - 1000 MeV/nucleon. ^{20}Ne + ^{12}C, ^{12}C + ^{27}Al. ^{12}C + ^{57}Fe, ^{12}C + ^{66}Zn at energies 50 - 350 MeV/nucleon, and ^{12}C + ^{56}Cu at energies 50 - 1500 MeV/nucleon. in addition to a tabulated comparison of the reaction cross section predictions with the corresponding experimental results for several nucleus-nucleus reactions at

different energies. The present calculations of the reaction cross section are shown to be in close agreement with experiment.

In the second stage of this work, the Glauber description of the reaction cross section is modified to describe low energy reactions. This modification diminishes some deviations that occur at low energies.

In the low energy region, where the Coulomb effects are significant, an expression that relates the reaction cross section in the presence of the Coulomb effects to the reaction cross section in the absence of these effects is established.

Finally, the thesis is ended by the discussion of high energy proton induced spallation reactions which are viewed as two step processes. In the first step, and for a Gaussian target nucleus, an analytical expression is derived for the cross section σ_n for the incident proton to collide with n of the target constituents. The following targets are considered: ^{12}C, ^{27}Al, ^{64}Cu and ^{208}Pb to estimate the dependence of σ_n on n. In the same step of the reaction, the cross section $\frac{d\sigma}{dE^*}$ to deposit an energy E^*, after n proton-nucleon collisions, is calculated for the p+^{159}Tb collision at Ep=600MeV. In the second step of the reaction -the decay of the struck target- the mass yield distribution is predicted for the following reactions: p + Cu, p + Ag at Ep = 3 GeV, p + Au at Ep = 1 GeV, 3 GeV and 6 GeV, p + Ta at Ep = 5.7 GeV and p + Ag at Ep = 300 GeV. The predictions provide a reasonable representation of the available experimental data.

INTRODUCTION