*IN THE NAME OF GOD*

# STUDY OF FISSION FRAGMENTS ANGULAR DISTRIBUTION WITH HEAVY-ION REACTION

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To:

*My Dear Parents*

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# ABSTRACT

Study Of Fission Fragments Angular Distribution With Heavy- Ion Reaction
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Fission fragments angular distribution with heavy-ion reaction has been studied for six reactions $^{10}B$ , $^{12}C$ , $^{16}O$ on $^{232}Th$ and $^{237}Np$.In this tesis we used statistical scission model (SSM) to analoge the experimental data.In this model is assumed to be analogous to complex particl evaporation, governed entirely by the phase space available at scission. we used $S_0^2$ values computed from (SSM) and values about from fitting procedure.we understand for level density parameter , $a=\frac{A}{4}$ , have a good agreement with experiment.

TABLE OF CONTENTS


| CONTENT | PAGE |
|---|---|
| *LIST OF FIGURES* | VII |
| *CHAPTER ONE: INTRODUCTION* | 1 |
| *CHAPTER TWO: NUCLEAR MODELS* | 4 |
| 2-1.INTRODUCTION | 4 |
| 2-2. SHELL MODEL | 4 |
| 2-3.LIQUIDE DROP MODEL | 11 |
| 2-4.CLASSICAL THEORY OF COLLECTIVE SHAPE OSCILLATIONS | 15 |
| 2-5.THE UNIFIED MODEL IN THE REGION OF DEFORMED NUCLEI | 17 |
| *CHAPTER THREE: NUCLEAR FISSION* | 21 |
| 3-1. INTRODUCTION | 21 |
| 3-2.FISSION ENERGY | 24 |
| 3-3. FISSION WITH THE VIEW OF BOTH LIQUID DROPAND UNIFIED MODEL | 27 |
| 3-4. SHELL EFFECTS IN NUCLEAR MASSES AND DEFORMATION ENERGIES | 33 |

3-5. CHARACTERISTIC OF FISSION 36

3-5.1 FISSION CROSS SECTION 36

3-5.2 FISSION AND NUCLEAR STUCTURE 38

*CHAPTER FOUR: STATISTICAL SISSION MODEL* 43

4-1. FORMAILISM OF THE STATISTICAL SCISSION MODEL 43

4-2. SPHERICAL FISSION FRAGMENTS 46

4-3. DEFORMED FISSIONM FRAGMENTS 48

4-4. MICROSCOPIC CALCULATION OF THE STATISTICAL SCISSION MODEL 52

4-5. PARAMETRIZATION OF THE STATISTICAL SCISSION MODEL 53

*CHAPTER FIVE: CACULATION AND CONCLUTION* 55

*REFERENCES* 66

*ABSTRACT AND TITLE PAGE IN PERSIAN*

LIST OF FIGURES

FIGURE PAGE

FIGURE(2-1) .LEVEL SYSTEM OF THE OSCILLATOR AND THE SQUARE WELL 8

FIGURE(2-2) .THE POTENTIAL USED BY ROSS , 11

FIGURE(2-3) .A SCHEMATIC REPRESENTATION OF Z VERSUS N CHART 19

FIGURE(3-1) .ABOUT THE CALCULATION OF ENERGY POTENTIAL OF A CHARGED SPHERE 31

FIGURE (3-2) .ABOUT MASS DISTRIBUTION OF FISSION FRAGMENTS THERMAL NEUTRON FISSION 40

FIGURE(3-3) .SCHEMATIC OF THE NUCLEAR ENERGY IN THE ABSENCE OR PRESENT SHELL EFFECTS 41

FIGURE(4-1) . SCHEMATIC ILLUSRATION OF THE RELASTIONSHIP BETWEEN $\vec{I}, \vec{l}, \vec{s}$ AND FOR STATISTICAL MODEL 44

FIGURE(5-1). FISSION ANGULAR ANISOTROPY FOR THE REACTION OF $^{10}B + ^{232}TH$ ($E_{LAB}$ = 64 MeV) 60

FIGURE(5-2) .FISSION ANGULAR ANISOTROPY FOR THE REACTION OF $^{10}B + ^{237}NP$ ($E_{LAB}$ = 64 MeV) 61

FIGURE(5-3) .FISSION ANGULAR ANISOTROPY FOR THE REACTION OF $^{12}C + ^{232}TH$ ($E_{LAB}$ = 79 MeV) 62

FIGURE(5-4) .FISSION ANGULAR ANISOTROPY FOR THE REACTION OF $^{12}C + ^{237}NP$ ($E_{LAB}$ = 72 MeV ) 63

FIGURE(5-5) .FISSION ANGULAR ANISOTROPY FOR THE REACTION OF $^{16}O + ^{232}TH$ ($E_{LAB}$ =88 MeV ) 64

FIGURE(5-6) .FISSION ANGULAR ANISOTROPY FOR THE REACTION OF $^{16}O + ^{237}NP$ ($E_{LAB}$ = 94 MeV ) 65

# *CHAPTER ONE*

## *INTRODUCTION*

Recently, there has been considerable interest in the angular distribution of fragments produced by heavy- ion [7,3] for the first time, Winheld , Demos and Halpern [4] observed non-isotropic fission fragment in photo fission of $^{232}Th$ and $^{238}U$. Such anisotropies were soon reported for fission induced by neutron and other charged particles [1,23] .

Aage Bohr [2] then sketched out an extension of the transition-state model (TSM) [25] to address angular distributions. He suggested that when a heavy nucleus captures a neutron or absorbs a high energy photon, a compound nucleus is formed in which the excitation energy is distributed among a large number of degrees of freedom of the nucleus.

The complex state of motion there by initiated may be described in terms of collective nuclear vibrations and rotations coupled to the motion of individual nucleons. The compound nucleus lives for a relatively very long period, usually of the order of a million times longer than the fundamental nuclear period, after which it decays by emission of radiation or of neutrons , or by fission . The latter process occurs if a sufficient amount of deformation to enable nucleus to pass over the saddle point shape , at which the repulsive coulomb force balanced the cohesive nuclear interactions.

For excitation energies not too far above the fission threshold,the nucleus , in passing over the saddle point is “cold” since the major part of its energy content is bound in potential energy of deformation. The quantum states available to the nucleus at the saddle point of the “fission channels” are then widely separated and represented relatively simple type of motion of the nucleus. These channels are expected to form a similar spectrum as the observed low-energy excitation of the nuclear ground state.

Considerable experimantal evidence [24 ] has shown that the statistical transition state model(TSM) provides a good representation of experimental angular distributions of fragments from low-energy fission of nuclei with finite barriers and well defined transition state configuration.

But the transition state theory is obviously inapplicable for nuclear spins I in excess of the RLDM (rotation liquid drop model) limit of stability where an equilibrium point in the potential energy no longer exists. It may be inapplicable also when the nuclear temperature exceeds magnitudes equivalent to the height of the fission barrier [20] .

Statistical scission model (SSM) first suggested by Ericson [5].

In SSM , fission is assumed to be analogous to complex-particle evaporation, governed entirely by the phase space available at scission.

In chapter two we review nuclear model and introduce the relevant quantities needed in our analysis of fission anisotropy.
In chapter three we discuss the fission theory and in chapter four present the statistical scission model .
In chapter five we show that the methods of computing the fission fragment angular distributions apply to the measured anisotropics abtained in $^{10}B$ , $^{12}C$ , $^{16}O$ on $^{232}Th$ and $^{237}NP$ reactions[23]. Result of comparison of our calculations with experimental are presented in this chapter and are discussed.

# *CHAPTER TWO*

# *NUCLEAR MODELS*

## *2-1. Introduction*

Nuclear models were introduced historically after Chadwick discovered neutron and Ratherfold suggested localized form of nucleus for atom .

It must be stated at the start , that no complete theory of nuclear structure exists. Any complete theory for a complex nucleus has to start form a detailed knowledge of the forces exerted between free nucleons. Our present knowledge of such forces is detailed but there is still considerable doubt. We choose a deliberately oversimplified theory, but one that is mathematically tractable and rich in physical insight. If that theory is fairly successful in accounting for at least a few nuclear properties, we can then improve it by adding additional terms. Through such operations we construct a nuclear model , a simplified view of nuclear structure that still contains the essentials of nuclear physics.

## *2-2. Shell Model*

Atomic theory based on the shell model has provided remarkable clarification of the complicated details of atomic structure . Nuclear Physicist therefore attempted to use a similar theory to attack the problem of nuclear structure, in the hope of similar success in clarifying to properties of nuclei.

The basic assumption of the shell model of the nucleus is that a single nucleon travels within a complex nucleus in a smoothly varing average field of force generate by all the other nucleons in the nucleus and that each particle moves essentially undistributed in its own close orbit. This assumption leads to a theory with many analogies to the theory of the atom which describes the motion of electrons in the centeral coulomb field of force generated by the atomic nucleus.

We consider the motion of a single nucleons in a central nuclear field, V(r) . We wish to solve the schrodinger equation.

$$[\frac{-h^2}{2M}\nabla^2 + V(r)]\psi = E\psi \qquad (2\text{-}1)$$

Before we can proceed we have to make some decision about the form of V(r) . It is conveniet to adopt a static spherically-symmetric potential with the form either of a three-dimensional harmonic oscillator or of a square well:

Harmonic osillator potential

$$V_r = \frac{1}{2} MW_0^2 . r^2$$

Square well potential (2-2)

$$V(r) = -V_0 = constant \qquad For \quad r \le R$$

$$V_r = \infty \qquad For \quad r \rangle R$$

This choices have the virtue that they lead to easy solution of the schrodinger equation and that the true nuclear potential may lie between them these potentials are inserted in the schrodinger equation and the equation is solved leading to a complete orthonormal set of single particle wave function $\psi^{nlm}_{(r_i)}$ where the $r_i$ indicate position variable of the ith nucleon and n,l,m denote the quantum number of the states.

For the harmonic oscillator the eigenvalues of the equation are given by the expression.

$$E = (N + 3/2)\hbar w_0 \qquad (2\text{-}3)$$

$$N = q + r + s$$

It is readily verify that for a given value of N, and hence energy $E_N$ , N can be partitiond among the integer q , r and s with a total $D_N = \frac{1}{2}(N+1)(N+2)$ different ways and hence oscillator is $D_N$-fold degenerate therefore , the pauli principle will allow an accupation number $2D_N = (N+1)(N+2)$ for a level $E_N$ for each nucleon type of nucleon up to including energy $E_N$ is

$$M_N = 2\sum_{N=0} D_N = \frac{1}{3}(N+1)(N+2)(N+3) \qquad (2\text{-}4)$$

Accordingly, closed shells corresponding to $M_N$ are generated for a total number of each type of nucleon given loy

$$M_N = 2,8,20,40,70,112,168,...$$

The level for the isotropic harmonic oscillator are also shown $\sigma_n$ the left side of fig(2-1) , on the right hand side of the same figure are shown the corresponding levels for a square well with infinite walls. In the center of figure the corresponding levels are shown as the average of the two treatment this average is expected to fall closer to the situation in real nuclei we note that the square well gives the same numbers of particles in the major shells but some sub-shell structure appears.