ON ELEMENTARY PARTICLES

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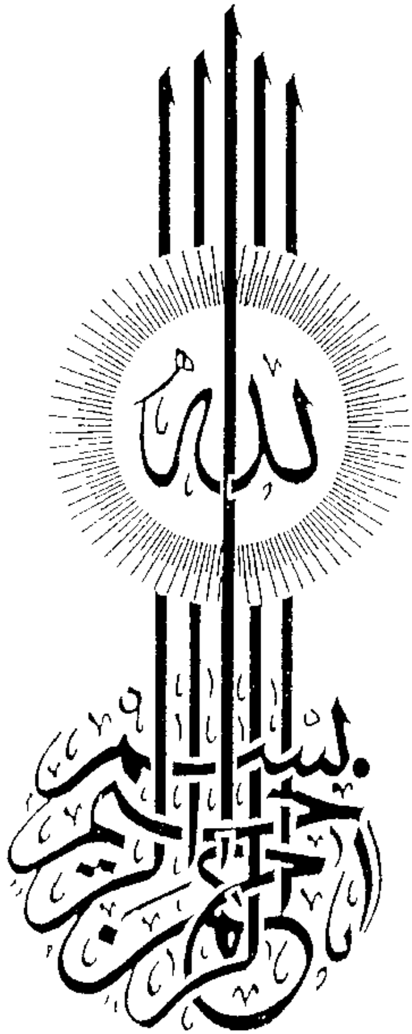
بسم الله الرحمن الرحيم

C O N T E N T S

S U M M A R Y

The study of single particle transition in bound states for both protons and neutrons has been done, on the basis of Shell model calculations. A Saxon - wood potential with spin orbit coupling and Coulomb potential in case of protons has been used. Study of isolated resonance states in case of neutrons has been discussed. The single particle half width and the spectroscopic factor in case of stripping reaction due to the capture of single neutron has been also given.

Two fortran programms SPUBS and TOK have been written for IBM 1130 Ain Shams University and they have been used to obtain the following results.

1- The programm SPUBS calculates for both protons and neutrons the energy and the normalized wave function for a certain bound state if the potential depth is given. Also it calculates the potential depth and the normalized wave function if the energy of the single particle in the given bound state is known.

2- The normalized wave function of bound states could be used as a form factor for DWBA calculations.

3- The change of energy levels with mass number between $A = 20, 40, 60, 80, 100$ for both single proton and neutron for bound states is given and shows the magic number property of nuclei.

4- The effect of spin-orbit couppling is also studied for $A = 100$ and $V_{s.o} = 0, 4.825, 9.65, 14.475, 19.3$ MeV. The interference between levels increases by decreasing the binding energy.

5- As the binding energy decreases the wave function decreases slowly with the nucler radius R. Therefore one must increase the range of integration for weakly bound state in order to obtain reasonable form factor.

6- It was possible to prove that, one cannot calculate the required energy of the unbound or resonance state, if the potential depth is given while the opposite result is possible. SPUBS is also used to calculate the potential depth and also the normali ed wave function required for the known resonance state with phase shift $\delta = \frac{\pi}{2}$

7- Compound elastic scattering cross section is calculated and by comparing with the elastic scattering cross section, one can find the single particle half width $\Gamma_{s.p}$. The programm TOK is used to calculate $\Gamma_{s.p}$ for the $1d^{+}_{3/2}$ resonance state with E_{res} = 0.93 MeV in O^{16}+ n reaction. It has the value 110 KeV using the same parameters which are given from SPUBS.

8- The shape of wave functions at resonance energy and at E_n = 0.83 MeV, E_n = 1.3 MeV show the resonance maximum amplitude at E_n = 0.93 MeV.

9- The spectroscopic factor S for the state $1d^{+}_{3/2}$ in O^{17} is found to be $\sim$ 0.8 by taking Γ_{el} from experimental result, which is in a good agreement with that calculated using DWBA method for O^{16} (d,p) O^{17} reaction.

CHAPTER I

INTRODUCTION

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I N T R O D U C T I O N

The fundamental types of elementary particles are both protons and neutrons. They are the strong stones in the structure of each material, since they are the main parts in each nucleus. But according to the short range property of nuclear forces, there is many assumptions which have been used to discuss the nuclear forces. These assumptions had led to the so called nuclear models. One of them is the shell model. In this model, one considers the nucleons to move independently in an average potential. This model is successfully used to account for various regularities in nuclear properties.

However, there is two ways to study the nuclear structure. One is the use of nuclear models by assuming a certain form for nuclear potential and try to solve Schrödinger's equation to obtain the energies and wave functions. The other way is to use the nuclear reactions method. This means that from the knowledge of energy levels and angular distributions for the outgoing particles, one can obtain theoretically the required nuclear parameters for experimental results.

In the present work, one has used the last two methods for the study of structure of some nuclei using the shell model for the first case and the elastic scattering in the second method.

Now assuming that the target to be consists of a closed core plus one particle, then the nuclear properties of that nucleus depends mainly on the energy and wave function of the single particle. This condition is also similar to the capture of a single nucleon by a target which is assumed to be always in the ground state. Actually if that particle is found in a bound state then, it is necessary to know its energy and wave function in a certain state, if the average potential depth through which it moves is given. Also if the energy of that bound state is known, one can get the required potential depth and also the normalized wave function.

It is interesting to show the required changes, if the single particle is excited to unbound or resonance states. It is proved that one can not calculate the required energy of the resonance state if the potential depth is known while if the energy is known, one can calculate the potential. This will be given in more details in chapter II. The method of calculation and the numerical technique is also given in chapter III.

Moreover, by considering a neutron in resonance states due to the formation of a compound nucleus, then after a certain time τ it decays into different modes, one can obtain the elastic scattering cross section and the inelastic or reaction cross section in terms of the el astic or inelastic half width respectively. Actually from the structure point of view, and by considering only the elastic channel to be opend, then the compound half width will reduce to the elastic scattering half width. Consequently the relation between the elastic half width and the single particle half width calculated from shell model gives the spectroscopic factor for isolated resonance states. The last problems have been discussed in the present work in chapter IV.

Two Fortran programs have been written for IBM 1130 Ain Shams University to make the available calculations for single particle in bound and resonance states. In chapter V the results of calculations on both bound and unbound states introducing different effects such as spin-orbit couppling, nuclear radius, potential depth etc . are given. Also applications on the single particle in $1d^{+}_{3/2}$ - resonance state in O^{17} and on N^{15}+ n for $(1\ p_{1/2})^{-1}\ 2s_{1/2}$ and $(1\ p_{1/2})^{-1}\ 1\ d_{5/2}$ is also given.

CHAPTER II

SINGLE PARTICLE STATES

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The success of shell model in satisfying the magic numbers 2, 8, 20, 28, 50, ... for both protons and neutrons, gives the possibility to assume that the structure of nuclei could be discussed by using the single particle model.[7),13]

These particles could be found inside the nucleus under the Fermi energy i.e. in bound states or above the binding energy region i.e. in the unbound or resonance states.

To study these different types of states, one should solve Schrödinger's equation to find either the energy or the potential and also the wave function corresponding to these types.

Now since Schrödinger's equation of the nucleus with energy E is given by[(6),(7)]

$$H \Psi = E \Psi$$

where $H = \left(\sum_i - \frac{\hbar^2}{2\mu} \nabla_i^2 \right) + \frac{1}{2}\left(\sum_{i \neq j} V(r_{ij}) \right)$

where the summation is taken over all number of particles.
Also the potential is

$$\frac{1}{2}\sum V_{ij} = \sum_{i} V_i + \frac{1}{2}\sum_{i \neq j} V_{ij} - \sum_{i} V_i$$

$$\therefore \quad H = \sum_{i}\left(-\frac{h^2}{2\mu}\nabla_i^2 + V_i\right) + \left(\frac{1}{2}\sum_{i \neq j} V_{ij} - \sum_{i} V_i\right)$$

The residual interaction

$$V_R = \frac{1}{2}\sum_{i \neq j} V_{ij} - \sum_{i} V_i$$

Taking $\sum_{i}\left(-\frac{h^2}{2\mu}\nabla_i^2 + V_i\right) = H_o$

$$\therefore \quad H = H_o + V_R$$

where $H_o \psi = E_o \psi$ (1)

neglecting the effect of the residual interaction i.e. taking $V_R \longrightarrow o$ for single particle model, then equation (1) represnts the equation to be solved by assuming that the single particle moving in an average potential $V(r) = \sum_{i} V_i$ with energy $E_o = E$.

The wave function ψ_o is actually related to the wave function of that single particle $\psi_s(\bar{r})$ in the residual nucleus (A-1) is

$$\psi_o(\bar{r}, \xi) = \psi_s(\bar{r})\, \psi_{(A-1)}(\xi)$$