Exact calculation of nucleon nucleus Spin orbit Potential in Brueckner theory

Syed Rafi and W.Haider
Department of Physics
Aligarh Muslim University,Aligarh-202002

Introduction

The paper is concerned with the calculation of the direct part of the nucleon nucleus spin orbit potential in the first order Brueckner Hartee Fock approach.The usual method is to calculate internucleon effective interaction,G matrix, in nuclear matter, and then use local density approximation to extract different parts of the nucleon nucleus optical potential.The only inputs required are realistic internucleon potential and nucleon densities of the target nuclei. The nucleon nucleus spin orbit potential has been calculated by several authors as a series expansion [1,2]with various approximations to sum the series.

Therefore it is important to remove these approximations to get the exact expression for the spin orbit potential. The direct part of the nucleon nucleus spin orbit potential in the folding model approach is:

$$U_{SO}^{D}(r_1,E)=\sum_n\int\phi_n^{+}(r_2)t_{SO}^{D}(|r_1-r_2)|,$$
$$\rho_T(|\frac{r_1+r_2}{2}|,E)L.S\,\phi_n(r_2)d^3r_2 \quad (1)$$

where t_{SO}^{D} is the direct part of the nucleon-nucleon spin-orbit t-matrix, L and S are respectively the total orbital and spin angular momentum for the interacting nucleon pair, $\varphi_n(r)$ is the bound state single particle wave function of the target nucleon, ρ_T is the total density and the label n represents all the appropriate quantum numbers representing the bound orbital. The summation in Eq.(1) is over all occupied states of the target nucleus. Further we use label 1 and 2 respectively for the incident and target nucleon. For the scalar product L.S we take

$$L.S=\frac{1}{2}(r_1-r_2)\times(p_1-p_2).(s_1+s_2) \quad (2)$$

where p_i and s_i refer to the momentum and spins of the interacting nucleons. Changing the integration variable $x=(r_2-r_1)$ we obtain

$$U_{SO}^{D}(r_1,E)=-\frac{1}{2}\int\rho(|r_1+x|)t_{SO}^{D}x\times (p_1-p_2).(s_1+s_2)d^3x \quad (3)$$

The integration over p_2 vanishes identically as no direction of nucleons in the target is specified. We consider spin zero targets and hence summation over s_2 is similarly zero. This gives us

$$U_{SO}^{D}(r_1,E)=-\frac{1}{2}\int\rho(|r_1-r_2|)t_{SO}^{D}d^3x\times p_1.s_1$$

This is the expression obtained by Brieva and Rook (BR) [1]. The integration over *x* must be in the direction of r_1 to contribute to the spin orbit potential. Hence we can replace the vector *x* in the above equation by

$$x\approx x\cos(\theta)r_1/|r_1|$$

This finally gives us

$$U_{SO}^{D}(r_1,E)=-\frac{1}{2r_1}\int\rho(|r_1+x|)t_{SO}^{D}x\cos(\theta)d^3xl_1.s_1 \quad (4)$$

This is an exact expression within folding model approach as no approximation has been made. This can be easily used to calculate the spin–orbit potential without making any approximation. This can be easily generalized for incident protons taking into consideration different proton and neutron density distribution in the target nucleus to the following expression.

$$U_{SO}^{D,p}(r_1,E)=-\frac{1}{2r_1}[\int\rho_p(|r_1+x|)t_{SO}^{D,pp}x\cos(\theta)d^3x+\int\rho_n(|r_1,x|)t_{SO}^{D,pn}x\cos\theta d^3x]l_1.s_1$$

where $t_{SO}^{D,pp}$ and $t_{SO}^{D,pn}$ are the proton-proton and proton neutron t-matrices.

Results and discussion

We have calculated the direct part of the spin orbit potential for the scattering of protons from ^{16}O, ^{40}Ca, ^{90}Zr and ^{208}Pb at 65 MeV to make a comparison of the spin orbit obtained by BR and our results obtained after removing the approximations which were assumed by BR. We have calculated the potential for different targets so as to study the mass number dependence of the calculated direct and imaginary parts of the spin orbit potential. We have employed Argonne v18 inter nucleon potential to solve Bethe-Goldstone integral equation to obtain t- matrices which were then folded numerically over the target densities. Effective mass correction has also been taken into account during the calculations[3]. The nucleon densities used for the four targets were calculated using Relativistic mean field theory [4].

Figure 1 shows the Real part of the direct Spin orbit potential. Figure 2 shows imaginary part of Spin orbit potential. From Figures 1 and 2 we note that for all targets considered here the BR approximation overestimates the calculated potential at the peak and underestimate at short distances. For ^{16}O, ^{40}Ca, ^{90}Zr and ^{208}Pb the use of exact expression reduces the peak value by 40%, 36%, 34% and 30% respectively as compared with BR. The percentage reduction decreases as the mass number of the target increases. Further the BR results shifts the peak position slightly outside (by about 0.2fm) in all cases. We note a very sharp decrease of the peak value of the spin-orbit potential with increase in target mass number.

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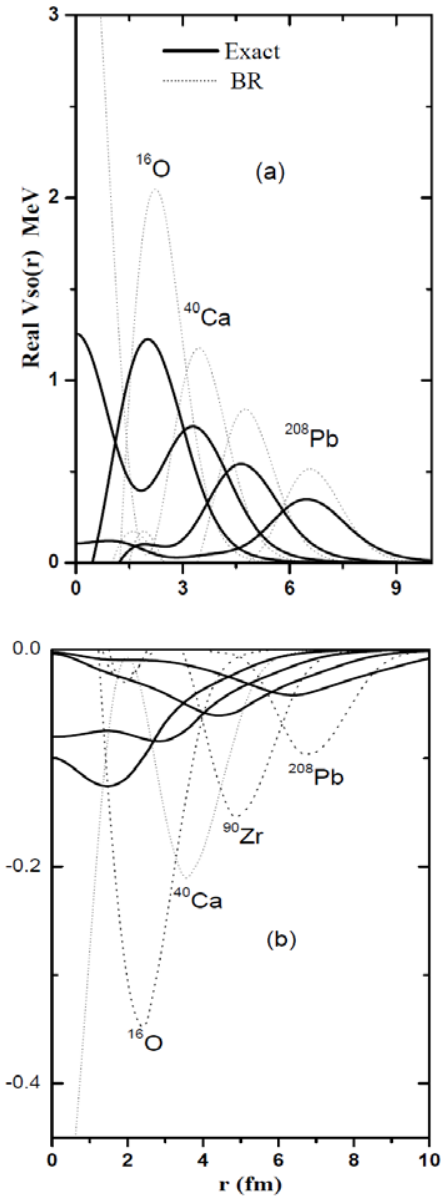
$$V^{so} = V_0 + V_1 e^{-V_2 A^{1/3}}$$

The values of parameters at 65MeV are; V_0= 0.28 ,V_1= 5.654 and V_2=1.4 for the real part and for the imaginary part the corresponding values are: V_0= 0.034 ,V_1= -0.062 and V_2=-1.33.

The calculations for more targets and wider energy range are underway. This may reveal several important properties about nucleon nucleus spin orbit interaction among nuclei.



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