

## Isospin dependence of the microscopic proton potential

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Lane [1] has suggested the isobaric spin dependence of the optical potential and has shown that it gives rise to a (N-Z)/ A dependence of the depth of the Optical Potential.

The depth of the real nucleon-nucleus optical potential can be written as

$$V = V_0 \pm V_1 (N-Z/A) + \overline{V}_c$$

$V_1$  is the strength of isospin potential.

+ (-) sign applies to proton (neutron) Optical potential respectively. As Lane pointed out knowledge of  $V_1$  is important for several distinct classes of phenomena including nuclear symmetry energies, nuclear scattering data and exchange scattering to the isobaric analogue states. Assuming the linear energy dependence of the real part of the optical potential  $V_0(E) = V_0(0) + \beta E$  where E is the incident kinetic energy of the proton and  $\beta = -0.3$  Perey [2] estimated the magnitude of the Coulomb correction term  $\overline{V}_c$  to be  $0.4Z/A^{1/3}$ .

Hodgson [3], Rook [4], Sood [5], Koning and Delaroche [6], Nadasen [7] and J.Ball [8] *et al.* independently studied the dependence of real nuclear potential well depth on nuclear symmetry parameter (N-Z)/A using empirical analysis.

In present work, to investigate the isospin term microscopically, we have followed the procedure outlined below.

We have calculated the volume integral per nucleon  $J_v/A$  from our microscopic potential for a range of isotopes of Zr and Sn at two different energies. Since the radial form of the calculated potential is not necessarily Saxon-Wood's we would have to study (N-Z)/ A dependence of the volume integrals. From the calculated volume integrals we would have to subtract the contribution coming from volume integrals of the isoscalar term  $V_0$  and the Coulomb term  $V_c$ . To estimate the contribution in the volume integrals of Coulomb correction term we use the approximation of a Saxon-Woods form factors.

We define Volume integral  $J_v$  as

$$J_v = \int_0^\infty 4\pi V(r) r^2 dr$$

$V(r)$  is the real part of Optical Model Potential.

If we assume a Saxon-Woods radial form, the Real Volume Integral  $J_v$  can be evaluated (approximately to order  $a/R^2$ ) as:

$$J_v = \frac{4}{3} A \pi r_0^3 V_0 \left[ 1 + (\pi a_0 / R_0)^2 \right]$$

If we take

$$V(r) = \left[ V_0 + 0.4Z / A^{1/3} + V_1 \frac{(N-Z)}{A} \right] f(r)$$

where  $f(r)$  is the Saxon-Woods form factor.

$$4\pi \int V(r) r^2 dr = \left[ V_0 + 0.4Z / A^{1/3} + V_1 \frac{(N-Z)}{A} \right] 4\pi \int f(r) r^2 dr$$

$$J_v - 0.4Z / A^{1/3} \int f(r) d^3 r = \left[ V_0 + V_1 \frac{(N-Z)}{A} \right] \int f(r) d^3 r$$

$$\int f(r) d^3 r = \frac{4}{3} \pi r_0 A \left[ 1 + (\pi a_0 / R_0)^2 \right]$$

$$J_v / A - \left[ 0.4 \frac{Z}{A^{1/3}} \frac{4}{3} \pi r_0^3 \left\{ 1 + (\pi a_0 / R_0)^2 \right\} \right] =$$

$$V_0 \frac{4}{3} \pi r_0^3 \left\{ 1 + (\pi a_0 / R_0)^2 \right\} + V_1 \frac{(N-Z)}{A} \left\{ 1 + (\pi a_0 / R_0)^2 \right\}$$

This equation can be written as:

$$J_v / A - J_c = J_0 + J_1 \left( \frac{N-Z}{A} \right)$$

We calculate  $J_c$  (volume integral of the coulomb correction term) for each isotope of Zr and Sn. Now the left hand side of the equation is known for each isotope as  $J_v / A$  has been calculated microscopically using first order Brueckner theory. The right hand side of this equation can be treated as a straight line equation with (N-Z)/A as the independent variable. The straight line fit gives the value of  $J_0$  and  $J_1$  and thus we

get the estimate of potentials  $V_0$  and  $V_1$ . The variation of  $J_v/A - J_c$  with  $(N-Z)/A$  is shown in the figures below.

In estimating  $V_0$  and  $V_1$  from their Volume integrals  $J_0$  and  $J_1$  we have assumed the Saxon-Woods behavior of their form factors. The radius and diffuseness parameters  $r_0, a_0$  from the recently obtained Global optical potential of Koning & Deloroche [6] have been used.

We also compare our results with the values obtained by different people using empirical analysis.

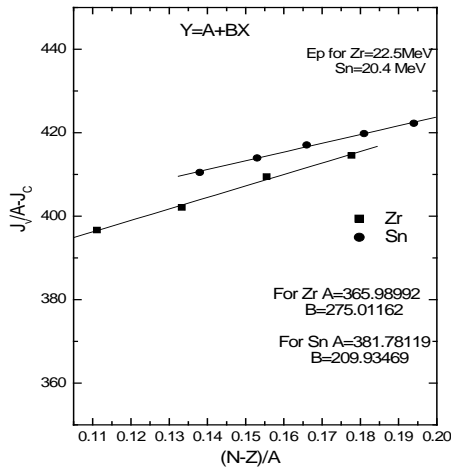
Empirical analysis by Perry and Buck [9] concluded that the average value of  $V_1$  is 20 MeV. Hodgson and Rook [4] obtained 35MeV. Another independent determination of magnitude of  $V_1$  by Sood [5] led to the value 28.5MeV. Analysis by J.B.Ball *et al* [8] yielded a value of  $27 \pm 6.0$ MeV for  $V_1$ .

Using our analysis we conclude that the average values for all the isotopes of Zr and Sn are:

For Zr at 22.5MeV

$$V_0=42.65\text{MeV}$$

$$V_1=32.05\text{MeV}$$



Sn at 20.4MeV

$$V_0=44.69\text{MeV}$$

$$V_1=24.58\text{MeV}$$

For Zr at 50MeV

$$V_0=32.93\text{MeV}$$

$$V_1=19.21\text{MeV}$$

For Sn at 50 MeV

$$V_0=33.25\text{MeV}$$

$$V_1=12.95\text{MeV}$$

We observe an energy dependence of the value of  $V_0$  as well as  $V_1$ . Value of  $\beta$  comes out to be -0.35 which is close to the value calculated by Perey[2].

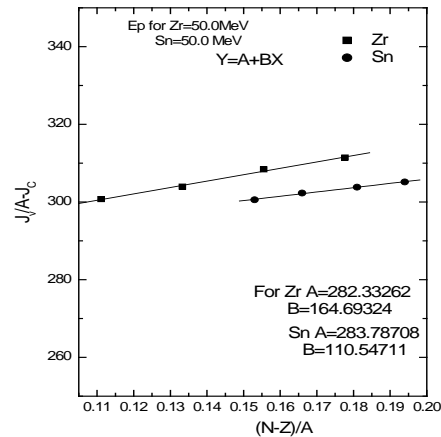
This energy dependence of  $V_1$  and  $V_0$  was also predicted by A. Nadasen *et.al* [7] and Koning *et.al* [6] independently. They found the following variation

$$V_1(E)= 59(1-0.18\ln E)$$

and  $V_1(E)= 21-0.15E$

respectively

We observe that our results for the calculation of both  $V_0$  and  $V_1$  are in agreement with the results from above approximations and both decrease with energy as also found in [10]. The values of  $V_1$  are smaller than empirical results as is found by Hodgson [11] also.



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