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Analysis of Edge Irregularity in the Close Barrier Elastic Scattering of 7li on 116sn

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Abstract* – *In past work we have examined the flexible dispersing of the 6Li + 116,112Sn frameworks. A reasonable BTA conduct was watched, with the fanciful potential expanding when the assaulting vitality diminishes towards the obstruction. This conduct was observed to be reliable with the deliberate gotten from the flexible dispersing of 6Li on various focuses, from 27Al to 209Bi. For the disseminating of 7Li the circumstance isn't so clear. The 7Li core has separation limit vitality of 2.47 MeV and one bound energized state at 0.48 MeV. As pointed out by Lubian et al., since 7Li has one bound energized state and the depriving of one neutron may have expansive positive Q-values for a few target cores, the alluring part of the dynamic polarization potential in the scrambling of this shot might be tantamount or even prevails over the shocking unique polarization potential because of the separation. The net outcome may shift subjectively for various focuses, since the qualities and the impedance between the distinctive polarization possibilities might be unique.

Keywords: Edge Irregularity, Barrier, Elastic Scattering, 7li on 116sn.

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INTRODUCTION

Amid the most recent couple of years, the dissipating of pitifully bound cores crashing at energies close and beneath the Coulomb obstruction has been a subject of extraordinary intrigue. The vitality reliance of the optical potential (OP) of the flexible dissipating of firmly bound cores, at close obstruction energies, demonstrate a quick variety of both the genuine and fanciful parts of the potential. This vitality reliance is created by polarization possibilities started from the coupling between the flexible scrambling and distinctive response channels, for example, inelastic excitations, exchange of nucleons, separation and so forth. Dynamic polarization potential, or essentially polarization potential, is to such an extent that when it is added to the uncovered vitality autonomous potential, it creates a similar flexible disseminating cross segment as the one got with coupled channel computations. The net impact on the vitality reliance of the optical potential relies upon the significance and quality of the diverse particular polarization possibilities. For frameworks containing just firmly bound cores, couplings to bound energized states or exchange channels create an alluring polarization potential. This extra fascination of the genuine potential abatements the Coulomb obstruction, thusly upgrading the combination cross segment, when contrasted and no-coupling counts. This marvel has been named edge abnormality (TA) [1-3]. The vitality conditions of the genuine and fanciful possibilities are identified with one another and are steady with a scattering connection [1-3]. The fundamental portrayal of the TA is the perception of a confined top in the genuine piece of the potential going with a sharp diminishing of the fanciful part as the shelling vitality diminishes towards the Coulomb obstruction. The conduct of the nonexistent piece of the potential is connected with the end of response channels when the vitality approaches or is littler than the Coulomb hindrance.

At the point when something like one of the impacting cores is feebly bound, the circumstance changes in light of the fact that the separation channel may wind up essential and this channel has excitation work that does not drop strongly at energies beneath the Coulomb hindrance. Moreover, the separation direct feeds states in the continuum, that just under some spatial confinements returns to combination. In this way, the net polarization potential in the dispersing of feebly bound cores has two segments: one appealing, because of the couplings of the versatile channel with inelastic excitations and other direct responses and one loathsome, because of the separation. On the off chance that the alluring potential prevails, the conduct of the net polarization potential is with the end goal that TA is as yet watched. In any case, if the horrendous polarization potential prevails, one says that the framework shows the Breakup Threshold Anomaly (BTA) [4,5]. In the first paper depicting this marvel [5], it was referenced that the BTA is described by the expansion of the fanciful potential as the vitality diminishes towards the boundary. By and by, BTA may likewise be deciphered as the nonappearance of the TA because of the separation channel [6], and thus vitality autonomous genuine and nonexistent possibilities.

The examination of the nearness of TA, BTA or vitality free optical possibilities through the investigation of flexible disseminating rakish appropriations is an extremely troublesome assignment, since the coveted sign of the optical potential conduct must be surveyed at close and beneath obstruction energies, where the versatile scrambling is prevalently of the Rutherford type, and little deviations from it might just be gotten from exceptionally exact estimations. All things being equal, the low sensibility of the atomic collaborating potential at such low energies with the relating flexible scrambling information prompts expansive mistake bars in the assurance of such possibilities. Satchler [2] has officially tended to this trouble and as of late reciprocal estimations on that course were embraced by Zerva et al. [7,8] by the backscattering system.

As a matter of fact, a methodical conduct for the vitality reliance of the optical potential in the dissipating of 7Li has not been come to up until this point, since the couple of frameworks explored in the writing (27Al, 28Si, 59Co, 138Ba, 144Sm, 208Pb) [4, 15, 16, 19-24] show diverse practices. Especially for medium-substantial focuses, there is just a single work on the 144Sm target [15], where almost vitality free genuine and fanciful possibilities were watched. For the 138Ba target, distinctive examinations prompt diverse ends [4, 23, 24]. With the end goal to add to get an all the more clear image of a conceivable orderly conduct for the optical potential in the close hindrance disseminating of 7Li [25], we performed estimations of flexible dissipating for the 7Li + 116Sn framework, likewise filling the hole between A = 59 and 144 for the objective mass. The vitality scope of the estimations is from 20% underneath the Coulomb boundary to 70% over the hindrance. The aggregate response cross areas have additionally been removed by the optical model fitting of the test information and they are contrasted and those from the 6Li + 116Sn framework.

In this part we give test points of interest of this work. Further, an optical model investigation of the deliberate flexible disseminating precise conveyances is displayed with the end goal to think about the vitality reliance of the collaboration potential at close hindrance energies. The inferred response cross areas are contrasted and the ones for the 6Li+ 116Sn framework and furthermore with different pitifully and firmly bound frameworks.

Experimental Design

The present theory reports the test examination on response instrument did at the 14 UD Pelletron Accelerator set up as a community oriented venture between the Bhabha Atomic Research Center (BARC) and the Tata Institute of Fundamental Research (TIFR), has been filling in as a noteworthy office for substantial particle quickening agent based research in India since its dispatching in December 1988. The exact portrayal, with the exception of vitality misfortune estimations, of quickening agent offices is depicted before in Chapter - 3, Section 3.2.

1. Energy Loss Calculations

At the point when a vivacious shaft cooperates with the objective there is flashing electrostatic connection among it and the molecules of the objective by which it is passing. Because of which it loses some vitality in continuation with the versatile pieces, which loses incomplete or full vitality in the AE indicator. This vitality misfortune is additionally of prime significance for the kinematical estimations and information investigation. The vitality misfortune for the 7Li in the objectives and versatile pieces in the AE indicator were figured by utilizing the program halting influence and scope of particles in issue (SRIM) [26]. The measure of vitality lost (AE) is conversely corresponding to the pillar vitality and is given by the connection, The separate vitality loss of the 7Li bar in 430 p,g/cm2 116Sn target was 68 KeV.

Experiment Details

The trial was performed at Bhabha Atomic Research Center - Tata Institute of Fundamental Research (BARC-TIFR) pelletron office, Mumbai, India. The light emission was conveyed by the 14UD Pelletron quickening agent. The versatile scrambling rakish circulations were estimated for 7Li pillar at ten diverse shelling energies beginning from beneath the Coulomb boundary, to be specific, 18, 19, 20, 21, 22, 23, 24, 26, 30 and 35 MeV. The ostensible Coulomb obstruction for this framework is around 23 MeV in the research center edge. The bar was barraged on a 430 |ig/cm2 self-upheld advanced 116Sn (> 98%) target and the flexibly scattered 7Li particles were identified by a four strong state silicon surface boundary AE + E adjustable course of action. The telescopes utilized were of various thicknesses. One screen of thickness 600 p,m was utilized for the outright standardization. The telescopes were set on a pivoting arm inside a 1 meter distance across dissipating chamber at precise division of 10° between back to back telescopes. The screen was settled at the forward edge 30°. Shaft flows were running somewhere in the range of 7 and 40 nA. The rakish dispersions were estimated in ventures of 2.5° to 5° at edges from 20° to 173° at lower energies and from 20° to 105° for higher energies. The vulnerability in the indicator rakish position is 0.1 degrees

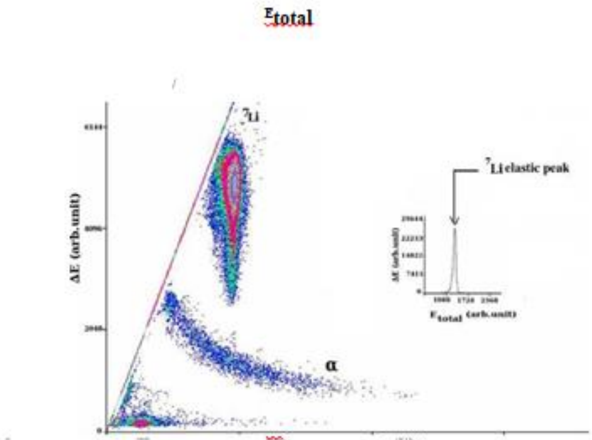


Figure 4.2 A typical bi-parametric E-ΔE spectrum for the 7Li + 116Sn system at Elab = 35 MeV and θ = 40. The Projection of the 7Li elastic peak of the bi-parametric E-ΔE spectrum is shown in the inset.

The factual blunder in this framework was discovered to be under 5% on account of forward points and a most extreme of 30% on account of in reverse edges. From the known plenitudes of the Sn focus on the commitment from the contaminants of the objective was assessed to 1%. The finders strong points vulnerability is 2%. When one includes the vulnerabilities in the precise position, in the pillar point and in the shaft spot position one gauges the by and large deliberate vulnerability in the standardization as ± 6.0%. Along these lines, the general mistakes in the cross segments are from 8.0% and 31%. A Photograph of the partners is posted underneath while setting up the investigation. Fig. 4.2 demonstrates a normal bi-parametric E-AE range for the 7Li + 116Sn framework at Elab = 35 MeV and 9 = 400.

Electronics and information obtaining

The hardware setup is the equivalent as we did it for 6Li try different things with a distinction of, an extra fourth locator, and the use of just a single screen.

1. Optical model examination of the flexible disseminating

2. Analysis Using Phenomenological Woods-Saxon Potential

The phenomenological Woods - Saxon potential has been utilized to fit the versatile scrambling precise circulation information by utilizing the ECIS code [29]. The optical model potential used to remove the versatile scrambling differential cross areas is given by the accompanying condition.

$$U(r) = V_{coul}(r) - V_r f(r, R_r, a_r) - iW_i f(r, R_i, a_i) \qquad (4.2),$$

whereVcoul is the Coulomb capability of a consistently charged circle of range Rc = 1.25 fm, Ap and At being the mass quantities of the shot and target separately; f speaks to the Woods-Saxon frame work which is given by f (r, R, a) = [1 + exp (r-R/a)]1, where R is the span and an is the diffuseness; ri is the diminished sweep, characterized as Ri = ri (Ap1/3 + A13). As needs be, the third term in condition (4.2) speaks to the volume fanciful capability of the optical potential U and Wi symbolizes its profundity. The second term is the genuine piece of the potential U, where Vr symbolizes its profundity.

As we didn't partition the fanciful piece of the optical potential into two sections (volume + surface), the entire assimilation because of the inelastic disseminating, exchange channels, separation and combination forms is taken consideration by the volume nonexistent capability of the optical potential U. This phenomenological system contains six parameters i.e., Vr and Wi, in particular, the two profundities, Rr and Ri, to be specific, the two radii, ar and ai, in particular, the two diffusenesses. These amounts might be free parameters to fit the exploratory differential cross areas. Be that as it may, by changing such countless one may get impossible physically values. In this way, it is normal to keep some settled parameters in the fit strategy.

The fitting system of the information was performed by changing just the genuine and fanciful profundities of the potential and by keeping the genuine and nonexistent lessened radii as 1.06 and 0.53 fm, individually. After the main fit was gotten, we by and by kept the radii settled and shifted the diffusivity of the possibilities from 0.49 to 0.57 fm in ventures of 0.02 fm and the profundities of the genuine and fanciful possibilities were fitted. For the most minimal three energies, the diffuseness of the possibilities was decreased to 0.45 fm with the end goal to get alluring genuine atomic potential and retention of motion. As it more often than not occurs in this sort of examination, albeit great fits were gotten, a few groups of optical potential parameters that portray the rakish dispersions fitted similarly well the information. These ambiguities are evacuated by assessing the potential at the affectability radii RSr and RSi [2], comparing to the genuine and nonexistent potential, characterized as the estimation of the radii for which distinctive possibilities with comparative great fits have a similar esteem. The inferred mean affectability radii were 10.42 and 8.95 fm without a doubt and nonexistent potential, separately. Fig. 4.3 (an) and (b) appear, for the vitality of 23 MeV, groups of possibilities that give comparative fits, and the intersection directs relating toward the affectability radii for the genuine and nonexistent parts, individually.

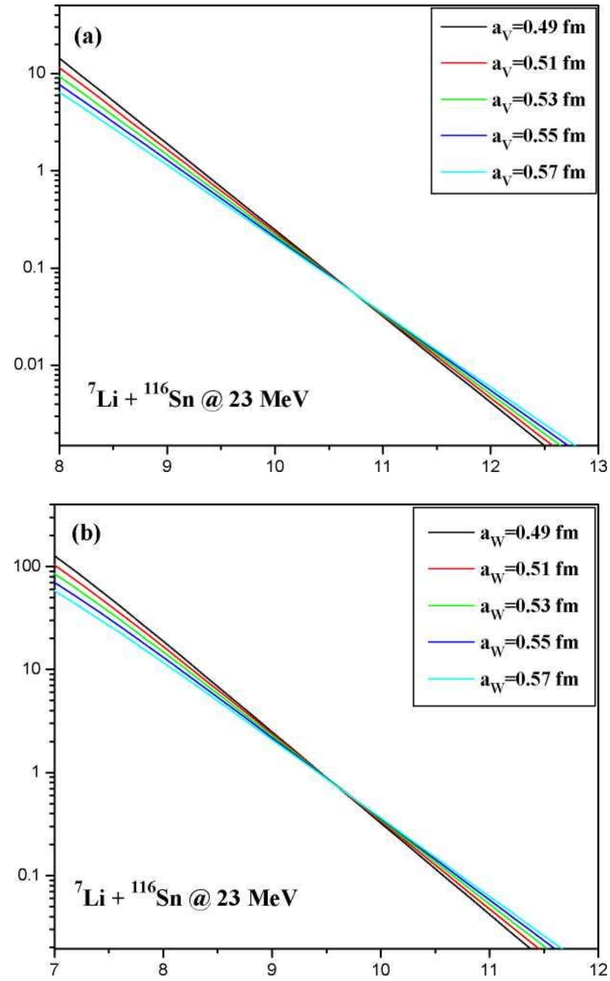


Figure 4.3 Different families of potential parameters that produce similar fits of the data, at 23 MeV. The real and imaginary sensitivity radii are the values where they intersect each other, respectively in Fig. (a) and (b).

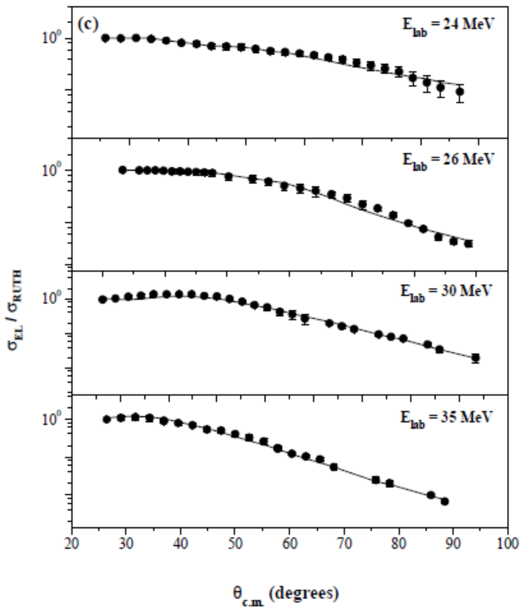


Figure 4.4 (c) Same as Fig. 4.4 (a) but for energies E_{lab} = 24 – 35 MeV.

Table 4.1 Parameters used with Woods - Saxon potential calculations for 7Li + 116Sn System and the derived total reaction cross sections.

Elab (MeV)	Vr (MeV)	Vi (MeV)	R_v&Ri (fm)	a_r&a_i (fm)	$x^{2/n}$	OR (mb)
18	2500	3850	7.20	0.45	0.30	21
19	2550	3450	7.20	0.45	2.32	55
20	2580	3500	7.20	0.45	0.88	128
21	757	901	7.20	0.53	3.10	257
22	550	616	7.20	0. 53	1.33	327
23	349	552	7.20	0. 53	0.67	405
24	855	600	7.20	0. 53	4.00	635
26	498	255	7.20	0. 53	1.71	730
30	565	61	7.20	0. 53	0.81	1059
35	789	31.5	7.20	0. 53	6.83	1444

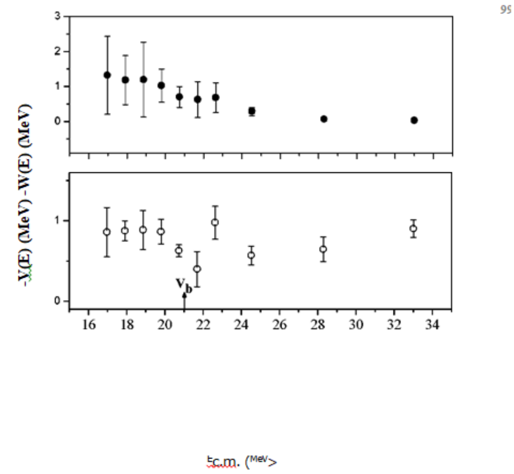


Figure 4.5 Energy dependence of the real and imaginary parts of the optical potential obtained for the ^{7}Li + ^{116}Sn system at an average radius R_s = 9.685 fm. The energy V_b of the Coulomb barrier is shown by the arrow.

From Fig. 4.5 it very well may be seen that genuine and fanciful parts of the cooperating possibilities are very vitality free at energies higher than the Coulomb vitality. Anyway it very well may be seen that at energies underneath the Coulomb boundary the nonexistent piece of the OP does not drop to zero, but instead there is a little augmentation showing the nonappearance of the TA. One can likewise observe a relatively steady pattern of the genuine potential at lower energies, rather than the trademark ringer shape that compares to the TA. This conduct is fundamentally the same as the one watched for the 7Li + Sm framework [15]. For the a lot lighter Li + Al framework [21], both the genuine and nonexistent possibilities indicate nearly vitality autonomous practices. For any of those frameworks, there is no proof of the nearness of the TA. The BTA conduct, with a sharp increment of the fanciful potential is additionally not watched. The clarification for that ought to be that the alluring polarization potential because of the 7Li bound energized state and exchange channels is of comparative quality as the loathsome polarization potential because of the separation for these frameworks. Likewise, as of late it has been demonstrated [30, 31] that a vital portion of the 7Li separation is certifiably not an immediate system, yet rather a successive procedure where the depriving of one neutron and the pickup of one proton happen before the separation. These initial step exchange responses may diminish the quality of the unpleasant separation polarization potential, as contrasted and unadulterated direct separation of 7Li.

3. Examination Using the Double-Folding Sao Paulo Potential

The Sao Paulo potential has been utilized for fitting of the versatile scrambling rakish dissemination information by utilizing the ECIS code [29]. The Sao Paulo potential [27, 28] is a model for the substantial particle atomic association. The minor vitality reliance of the uncovered cooperation emerges from the utilization of a nearby proportional model dependent on the nonlocal idea of the association. Over a restricted scope of vitality, as in the present work, it very well may be viewed as the typical twofold collapsing potential dependent on a broad systematization of atomic densities extricated from flexible scrambling information. The nonexistent piece of the communication is expected to have indistinguishable shape from the genuine part, with one single movable parameter NI identified with its quality. At close boundary energies, because of the solid vitality reliance of the optical potential, the information fit method is performed with two free parameters, the standardization factors for the genuine and nonexistent parts, NR and NI. Fig. 4.6 demonstrates the trial versatile diffusing rakish disseminations and the best fit acquired.

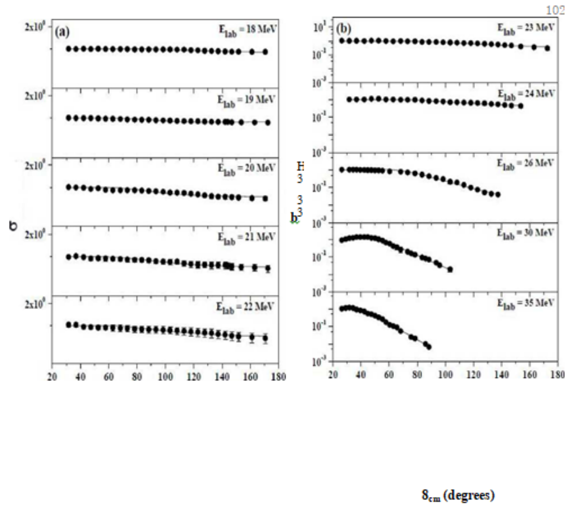


Figure 4.6 Experimental elastic scattering cross sections normalized to Rutherford cross sections for the ^{7}Li + ^{116}Sn system and their best fits from optical model calculations. The curves correspond to best fits were obtained using the Sao Paulo potential (SPP).

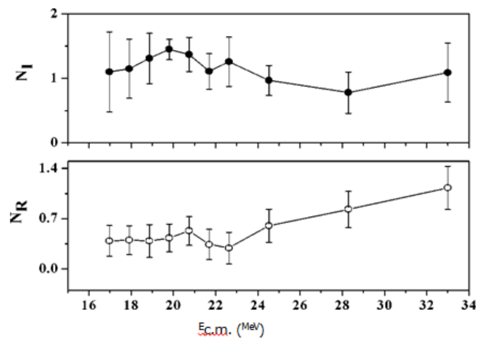


Figure 4.7 Best fits for N_R and Ni as a function of the bombarding energy obtained from fits with the Sao Paulo potential for the ^{7}Li + ^{116}Sn system. The energy V_c of the Coulomb barrier is around 21.2 MeV in the centre of mass frame calculated using the Bass formula. The solid line is just a trend line to show the dependence of interacting potential on energy.

Table 4.2 Parameters used with the Sao Paulo potential calculations for 7Li + 116Sn System and the derived total reaction cross sections.

ELab (MeV)	N_R	N_I	$c^{2/n}$	OR (mb)
18	0.39	1.10	0.31	22
19	0.40	1.15	0.35	52
20	0.39	1.31	0.51	131
21	0.43	1.45	0.42	256
22	0.53	1.37	1.20	346
23	0.34	1.11	0.50	412
24	0.29	1.26	0.40	611
26	0.60	0.97	1.22	770
30	0.83	0.78	1.01	1130
35	1.13	1.09	6.18	1556

Total Reaction Cross Sections

The aggregate response cross segments acquired for the 7Li + 116Sn framework, which is gotten from the optical model fitting of the test information is appeared in the last section of the table 4.1. In our ongoing work [9] on the diffusing of 6Li on 112, 116Sn, we have thought about the inferred aggregate response cross areas for those frameworks with some other feebly and firmly bound frameworks. In the present paper we look at the aggregate response cross areas between the 6Li + 116Sn and 7Li + 116Sn frameworks. Figs. 4.8 (an) and 4.8 (b) demonstrate the examination by the two decrease strategies generally used to think about cross segments of various frameworks in a similar plot. Fig. 4.8 (an) utilizes the technique proposed by Gomes et al. [34] and Fig. 4.8 (b) utilizes the technique proposed by Canto et al. [35,36] for combination cross segments and later reached out by Shorto et al. [37] for aggregate response cross areas. A concise depiction of the two techniques can be found in ref [9] and in section - 3. One can see that by the two strategies the aggregate response cross area for the 6Li + 116Sn framework is bigger than for the 7Li + 116Sn framework. Along these lines, the diverse conduct of the vitality reliance of the optical potential for these two frameworks is reflected in the aggregate response cross area esteems. In the 6Li diffusing, the separation assumes a more vital job than in the 7Li dispersing. The separation cross segment for 6Li ought to be bigger than for 7Li, and therefore, the aggregate response cross segment is bigger for responses prompted by 6Li than by 7Li. Further to underscore the significance of separation impact on the aggregate response cross area, that is, to analyze the reliance of the separation and aggregate response cross segment in the region of Coulomb hindrance, we have additionally look at [38] our frameworks utilizing the over two decrease strategies with the accessible frameworks.

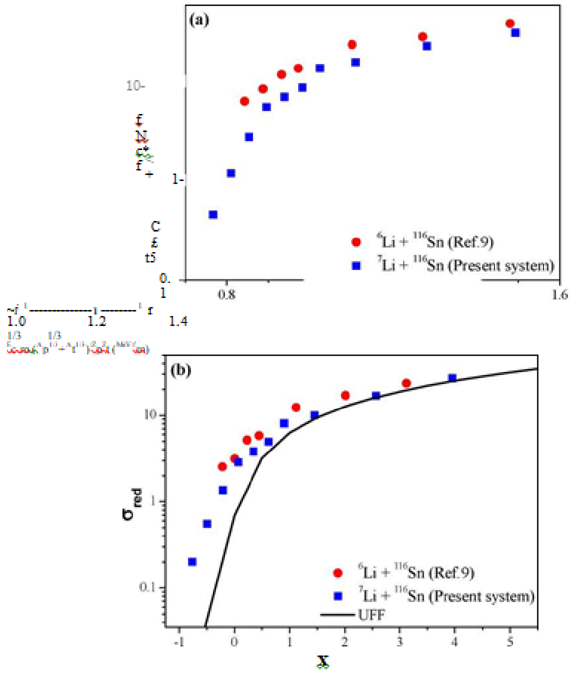


Figure 4.8 Total reaction cross sections for the 6, 7 Li + 116Sn systems. On the upper panel (a) the reduction method is proposed in Ref. [34] and on the lower panel (b), the reduction method is proposed in ref [35 - 37].

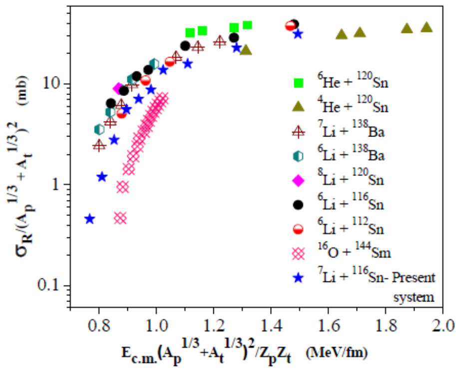
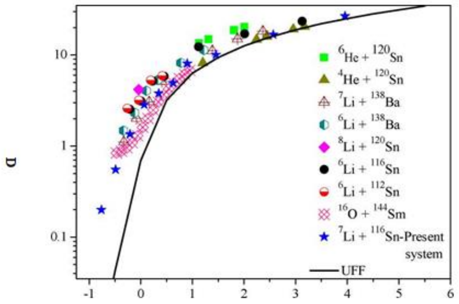


Figure 4.9 Reduced reaction cross section vs reduced projectile energy for the ^{7}Li + ^{116}Sn reaction using the prescription given in Ref. [34]. The reaction cross sections were obtained from optical model fits of the experimental angular distributions.

Figure 4.10 Reduced reaction cross section vs reduced projectile energy for the $^{7}Li + ^{116}Sn$ reaction using the prescription given in Ref. [35 - 37]. The reaction cross sections were obtained from optical model fits of the



experimental angular distributions.

Separation limit peculiarity in , Li + 116Sn framework

The vitality reliance of the optical potential close to the boundary indicates predictable conduct in the optical model and twofold collapsing structure and it tends to be tried utilizing scattering relations [43,44]. The flexible dispersing cross segment can be duplicated by presenting a powerful cooperation/optical potential that represents all coupling impacts and in this way the many-body issue can be lessened to a one-body issue with a comparable potential.

$$U(r,E) = V(r,E) + iW(r,E), \quad (4.3)$$

where V and W are the genuine and nonexistent parts of the potential and are associated through the scattering connection:

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$$V(r,E) = V_0(r,E) + \Delta V(r,E),$$
$$\Delta V(r,E) = \frac{P}{\pi}\int_0^{\infty}\frac{W(r,E')}{E'-E}dE',$$

(4.4)

whereAVis an alluring polarization potential. The nonexistent potential Whas little impact on AV at low vitality; in this manner V0 can be standardized at some vitality Es,

$$V(r,E) = V_0(r,E_s) + \frac{P}{\pi}(E-E_s) \times \int_0^{\infty}\frac{W(r,E')}{(E'-E_s)(E'-E)}dE'.$$

(4.5)

We have utilized [45] the direct section display proposed in Ref. [43] for W(r,E) and endeavored to get the genuine part. These scattering relations for phenomenological Woods - Saxon model is given in Figs. 4.11 and 4.12, separately. The examination recommends the nonattendance of the edge oddity (TA) in 6Li + 116Sn framework [9] due to the nearly vitality freedom of the genuine piece of the optical potential. The presence of non - zero nonexistent potential even beneath the Coulomb hindrance infers the presence of open response direct in this vitality area. This outcome is in concurrence with those gotten for the diffusing of 6Li by heavier and lighter targets and it demonstrate a reasonable conduct run of the mill of the separation limit oddity (BTA). We clarify these practices by the way that the scrambling of feebly bound cores are influenced by the unpleasant polarization potential created by the separation procedure, critical even at energies underneath the Coulomb obstruction. Be that as it may, for 7Li + 116Sn [25] diffusing the vitality reliance conduct of the fanciful potential appears to contrast from those in the writing for a few different frameworks including 7Li as a shot. For this situation there is a solid rivalry between this shocking polarization potential and the alluring polarization potential created by the bound 7Li energized state and exchange responses. These two segments of the genuine polarization potential may have comparable qualities and the net outcome could offer ascent to a nearly vitality free genuine part. Also, the non - zero fanciful part at the sub - boundary energies may have come about because of the overwhelming separation channel like 6Li

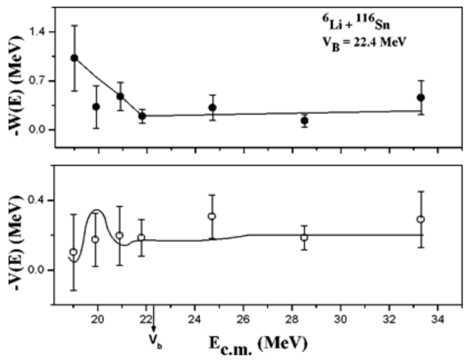

Figure 4.11 Values of the imaginary and real parts of the optical potential at the average sensitive radius, equal to 9.40 fm, for the system $^{6}Li + ^{116}Sn$. The solid line corresponds to the dispersion relation calculations.

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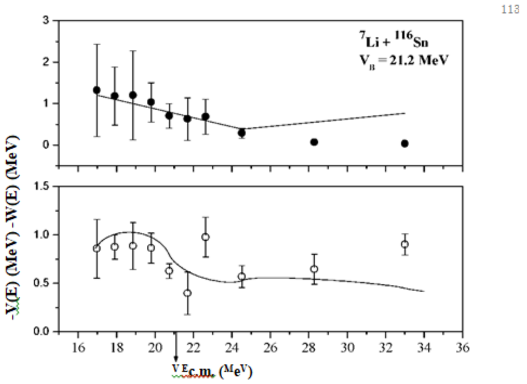

Figure 4.12 Values of the imaginary and real parts of the optical potential at the average sensitive radius, equal to 9.685 fm, for the system ^{7}Li + ^{116}Sn. The solid line corresponds to the dispersion relation calculations.

CONCLUSIONS

With the end goal to add to the examination of the nearness of the limit inconsistency or separation edge abnormality in the optical capability of the disseminating of pitifully bound frameworks, versatile dispersing precise circulations have been estimated for the 7Li + 116Sn framework at energies around and beneath the Coulomb hindrance. The present examination recommends the nonappearance of the edge inconsistency (TA) due to the nearly vitality freedom of the genuine and fanciful parts of the optical potential. This outcome is in concurrence with those acquired for the diffusing of 7Li by heavier and lighter targets. Then again, a few frameworks with 6Li as shot demonstrate a reasonable conduct run of the mill of the edge separation abnormality (BTA), incorporating the one with the equivalent 116Sn target. We clarify these practices by the way that the diffusing of feebly bound cores are influenced by the shocking polarization potential delivered by the separation procedure, imperative even at energies underneath the Coulomb boundary, however for the explicit instance of 7Li there is a solid rivalry between this appalling polarization potential and the alluring polarization potential created by the bound 7Li energized state and exchange responses. For 7Li, these two segments of the polarization potential have comparable qualities and the net outcome is a nearly vitality free optical potential. This outcome can't be extrapolated for each objective, in light of the fact that the general significance of the polarization potential created by the distinctive response instruments may shift with the objective structure. The aggregate response cross area for the 6Li + 116Sn framework is bigger than for 7Li + 116Sn framework, relating to bigger separation cross segment for the previous than for the later. This work likewise reports the examination of our framework with the few different frameworks utilizing the two decrease strategies. The aggregate response cross-segments for all frameworks, and by the two decreasing techniques utilized, were observed to be comparable, regardless of the shot being firmly or pitifully bound, steady or radioactive, aside from when corona cores were available. In this circumstance, the aggregate response areas were bigger than for the others. Scattering connection examination for the two frameworks, that is, 6Li + 116Sn and 7Li + 116Sn, has been likewise done to check the vitality reliance of the optical potential close to the boundary. From this examination as well, the reasonable - cut nearness of BTA could be watched for both the frameworks.

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