

## CHAPTER V

### DATA AND RESULTS



#### 5.1 Energy Spectra

The necessary parameters required for construction of the potential are obtained from spectroscopy. Because the energy spectra are usually given in  $\text{cm}^{-1}$  (Moore, 1949) while the required unit needed in our construction is the rydberg unit, we divide the quoted energy spectra by the rydberg number ( $109,737 \text{ cm}^{-1}$ ). Normally, the spectra tables give splitting levels of a degenerate state. Because our calculation do not need the various energy levels of the degenerate state, we average the degenerate state by using the splitting factor for each energy level as a weighting factor.

The energy spectra in the rydberg unit,  $E_{nl}(\text{exp})$ , of the alkali series are given in table 5.1. The energy levels with less than seven digits are given for core states (Slater, 1950).

#### 5.2 Na Effective Potentials

##### 5.2.1 The Prokofjew's potential

The Na potential constructed by Prokofjew(1929) is tabulated in table 5.2

##### 5.2.2 The Newly Constructed Na Potential

The quantization condition is quite good for f states when we assume  $Q(\rho) = \rho$ . We have calculated  $\rho_{\text{min}}$  for each state and get the following results.

State	Li	Na	K	Rb	Cs
1s	4.77	79.4	266.2	1120.1	
2s	.3962944	5.2	28.2	152.7	
3s	.1483677	.3777265	3.0	24.3	
4s	.0772330	.1431617	.3190406	2.7	
5s	.0472749	.0751718	.1724254	.3070228	
6s	.0318910	.0462662	.0688855	.1235474	.2862062
7s	.0229580	.0313262	.0431543	.0672491	.1172939
8s			.0295698	.0423219	.0646062
9s			.0215211	.0290880	.0409718
2p	.2604767	2.8	22.2	134.5	
3p	.1144745	.2231020	1.81	18.3	
4p	.0639510	.1018732	.2003574	1.56	
5p	.0407495	.0583927	.0938248	.1909486	
6p	.0282167	.0378395	.0547219	.0904379	.1809736
7p			.0358757	.0531516	.0867583
8p			.0253471	.0350253	.0514193
3d	.1112146	.1118770	.1227911	8.7	
4d	.0625491	.0628870	.0693704	.1306410	
5d	.0400261	.0402139	.0439642	.0728000	.1535402
6d	.0277931	.0279069	.0302017	.0455874	.0801211
7d	.0204191		.0219741	.0310743	.0487200
4f	.0624870	.0625240	.0627157	.0628702	.0631920
5f	.0399390	.0400243	.0401348	.0402191	.0404178
6f		.0277902	.0278561	.0279150	.0280404
7f		.0204169	.0204608	.0204994	.0205817
8f		.0156345	.0156627	.0156886	.0157448

Table 5.1 Energy spectra,  $\epsilon_{nl}(\text{exp})$ , of the alkali series

$\rho = 0$	to	.01	$Q(\rho) =$	$11\rho$
$= .01$		.15	$=$	$-26.4\rho^2 + 11.53\rho - .00264$
$= .15$		1.00	$=$	$-2.84\rho^2 + 4.46\rho + .5275$
$= 1.00$		1.55	$=$	$1.508\rho^2 - 4.236\rho + 4.876$
$= 1.55$		3.30	$=$	$.1196\rho^2 + .2072\rho + 1.319$
$= 3.30$		6.74	$=$	$.0005\rho^2 + .9933\rho + .0222$
$= 6.74$		$\infty$	$=$	$\rho$

Table 5.2 The Prokofjew Na potential

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state	$\rho_{\min}$
4f	8.26
5f	7.14
6f	6.76

We now let

$$Q_0(\rho) = \rho, \quad 6.76 < \rho < \infty \quad (5.2.1)$$

Using the energy spectral data, we get for the d states (eq.(4.3.18))

state	$\alpha_1$	$\rho_{\min}$
3d	.010090	3.89
4d	.008581	3.39
5d	.008385	3.25
6d	.008356	3.16

After averaging the above  $\alpha_1$ 's and computing  $\beta_1$  and  $\delta_1$  (eq.(4.3.21))

we have

$$Q_1(\rho) = .008853\rho^2 + .880307\rho + .404561, \quad 3.16 < \rho < 6.76, \quad (5.2.2)$$

The results of our determination of the parameters of  $Q(\rho)$  for

1s state are

state	$E_{nl}$	$\alpha_5$	$\beta_5$	$\gamma_5$	$\rho_{min}$	$\rho_{max}$
1s	79.4	-26.7606	11.5013	-.003457	.011366	.16

For the new interval, we let

$$Q_6(\rho) = 11\rho, \quad 0 < \rho < .01 \quad (5.2.3)$$

Since  $\rho_{min}$  of 2p state in matching with the 1s state is found to be .157, we get

$$Q_5(\rho) = -26.7606\rho^2 + 11.6083\rho - .003457, \quad .01 < \rho < .16 \quad (5.2.4)$$

By matching the np states with the (n-1)s states, we get

state	$\alpha_4$	$\rho_{min}$
2p	-1.53484	1.06
3p	-4.53031	1.79
4p	-3.19876	2.96
5p	-2.24568	4.56
6p	-1.14699	9.03

Using the same procedure used on the d states, we get

$$Q_4(\rho) = -2.51082\rho^2 + 3.99244\rho + .594502, \quad .16 < \rho < 1.06 \quad (5.2.5)$$

The two matching functions are (see Appendix D)

$$Q_3(\rho) = 1.79219\rho^2 - 5.12992\rho + 5.42936, \quad 1.06 < \rho < 1.70 \quad (5.2.6)$$

$$Q_2(\rho) = -.009933\rho^2 + .995241\rho + .222965, \quad 1.70 < \rho < 3.16 \quad (5.2.7)$$

The total result is tabulated in table 5.5 and is plotted in Fig. 5.1 against the Prokofjew potential.

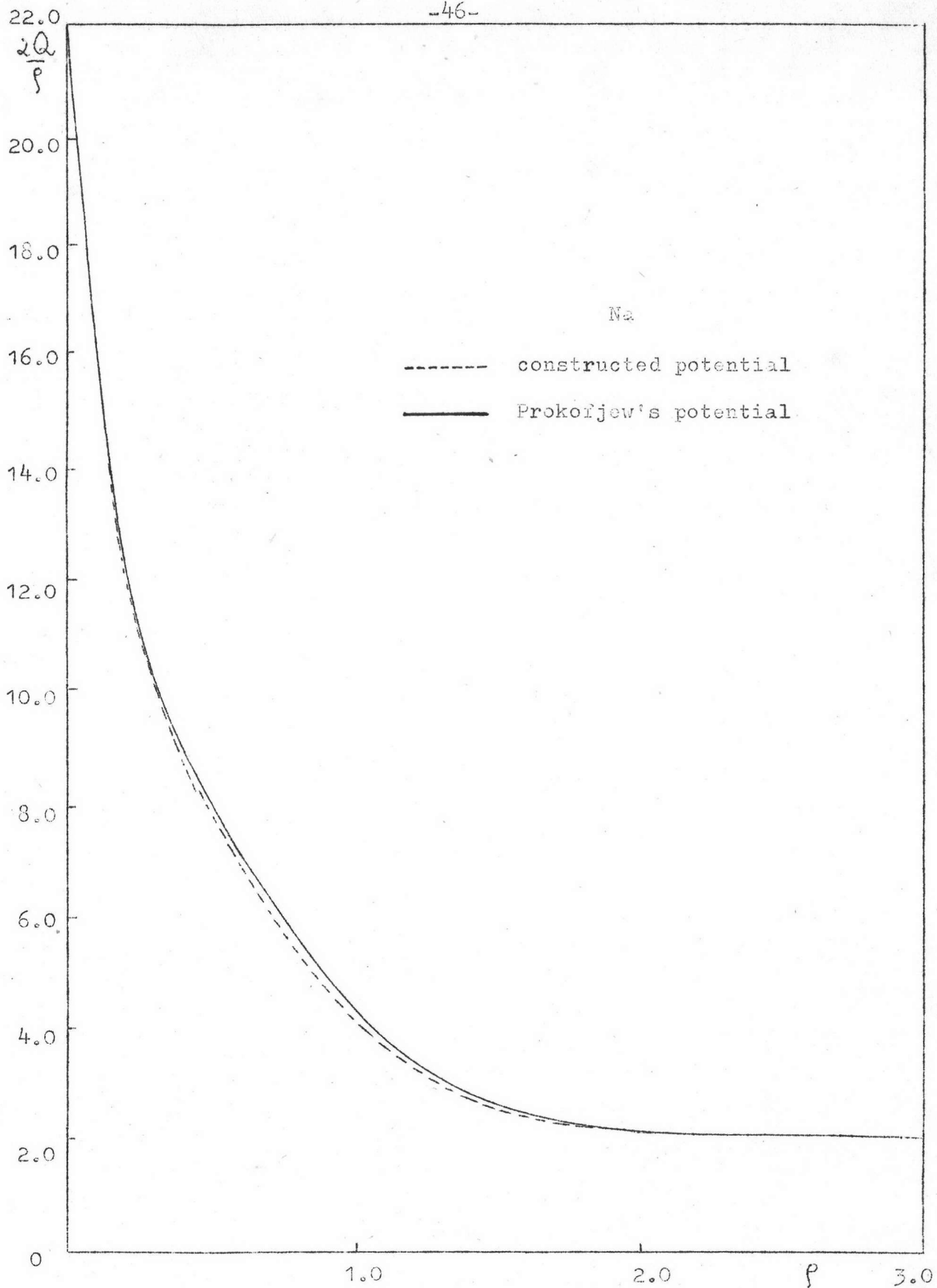


Fig. 5.1 The constructed Na potential against the Prokofjew's potential

$\rho = 0$	to	$.01$	$Q(\rho) =$	$11\rho$
$= .01$		$.16$	$=$	$-26.7606\rho^2 + 11.6083\rho - .003457$
$= .16$		$1.06$	$=$	$-2.51082\rho^2 + 3.99244\rho + .594502$
$= 1.06$		$1.70$	$=$	$1.79219\rho^2 - 5.12992\rho + 5.42936$
$= 1.70$		$3.16$	$=$	$-.009333\rho^2 + .995241\rho + .222965$
$= 3.16$		$6.76$	$=$	$.008853\rho^2 + .880307\rho + .404561$
$= 6.76$		$\infty$	$=$	$\rho$

Table 5.3 The constructed Na potential

### 5.2.3 The Na Potential with Polarization

When the polarization term is inserted, we have to determine the parameter  $\delta$ . The  $\delta$  for 4f state is chosen because it is the lowest state among other f states. This determination gives

$$Q_6(\rho) = \rho + .525262/\rho^2, \quad 8.24 < \rho < \infty \quad (5.2.8)$$

The other steps are the same as those mentioned in section 5.2.2. The result is tabulated in table 5.4.

$\rho = 0$	to	$.01$	$Q(\rho) =$	$11\rho$
$= .01$		$.16$	$=$	$-26.7606\rho^2 + 11.6083\rho - .003457$
$= .16$		$1.06$	$=$	$-2.51082\rho^2 + 3.99244\rho + .594502$
$= 1.06$		$1.70$	$=$	$1.72675\rho^2 - 4.99121\rho + 5.35584$
$= 1.70$		$3.20$	$=$	$.037617\rho^2 + .751858\rho + .474231$
$= 3.20$		$8.24$	$=$	$-.000801\rho^2 + .997732\rho + .080832$
$= 8.24$		$\infty$	$=$	$\rho + .525262/\rho^2$

Table 5.4 The constructed Na potential with polarization

### 5.3 Li Effective Potentials

#### 5.3.1 The Seitz's Potential

The corrected Seitz's potential as published by Kohn and Rostoker (1954) which has been converted to  $Q(\rho)$  by multiplying  $-rV$  with  $\rho/2$  is tabulated in table 5.5. It should be noted that  $Q(\rho)$  for  $\rho$  greater than 3.72 is equal to  $\rho$ .

$\rho$	$Q(\rho)$	$\rho$	$Q(\rho)$	$\rho$	$Q(\rho)$	$\rho$	$Q(\rho)$	$\rho$	$Q(\rho)$
.02	.0573	.20	.4762	.56	.87385	1.24	1.3662	2.44	2.4678
.04	.1109	.24	.5476	.60	.90414	1.32	1.4296	2.60	2.6161
.06	.1635	.28	.6104	.68	.96363	1.40	1.4945	2.76	2.7690
.08	.2140	.32	.66534	.76	1.0215	1.48	1.5607	2.92	2.9245
.10	.2627	.36	.71055	.84	1.0778	1.64	1.6972	3.08	3.0823
.12	.3094	.40	.74720	.92	1.1151	1.80	1.8419	3.24	3.2413
.14	.3541	.44	.77944	1.00	1.1883	1.96	1.9919	3.40	3.4007
.16	.3968	.48	.81113	1.08	1.2451	2.12	2.1505	3.56	3.5604
.18	.4376	.52	.84284	1.16	1.3026	2.28	2.3133	3.72	3.7202

Table 5.5 The Seitz's Li potential

#### 5.3.2 The Newly Constructed Li Potential

By using procedure similar to those applied to Na in section 5.2.2, we obtain

$$Q_0(\rho) = \rho, \quad 7.14 < \rho < \infty \quad (5.3.1)$$

$$Q_1(\rho) = .000915\rho^2 + .986934\rho + .046646, \quad 3.26 < \rho < 7.14 \quad (5.3.2)$$

It is found that  $\rho_{\min}$  for 2p state by matching with  $Q(\rho)$  is 6.31. Thus  $\rho_{\min}$  of  $Q_1(\rho)$  is equal to 6.31. This point is then used in the determination of parameters for  $Q_2(\rho)$ . The result is

$$Q_2(\rho) = .004041\rho^2 + .947620\rho + .170195, \quad 1.21 < \rho < 6.31 \quad (5.3.3)$$

We shall not go into numerical details for the next calculations but will tabulate the total result in table 5.6. The result is plotted in Fig. 5.2 against the Seitz's potential.

$\rho =$	0	to	.04	$Q(\rho) =$	$3\rho$
	.04		.58		$= -2.75058\rho^2 + 3.23736\rho - .005121$
	.58		.90		$= 1.02024\rho^2 - 1.13679\rho + 1.26338$
	.90		1.21		$= .415525\rho^2 - .048308\rho + .773565$
	1.21		6.31		$= .004041\rho^2 + .947484\rho + .171111$
	6.31		7.14		$= .000915\rho^2 + .986934\rho + .046646$
	7.14		$\infty$		$= \rho$

Table 5.6 The constructed Li potential

### 5.3.3 The Li Potential with Polarization

The contribution from polarization is chosen to occur in the nearest f state, 4f, and the total result is tabulated in table 5.7.



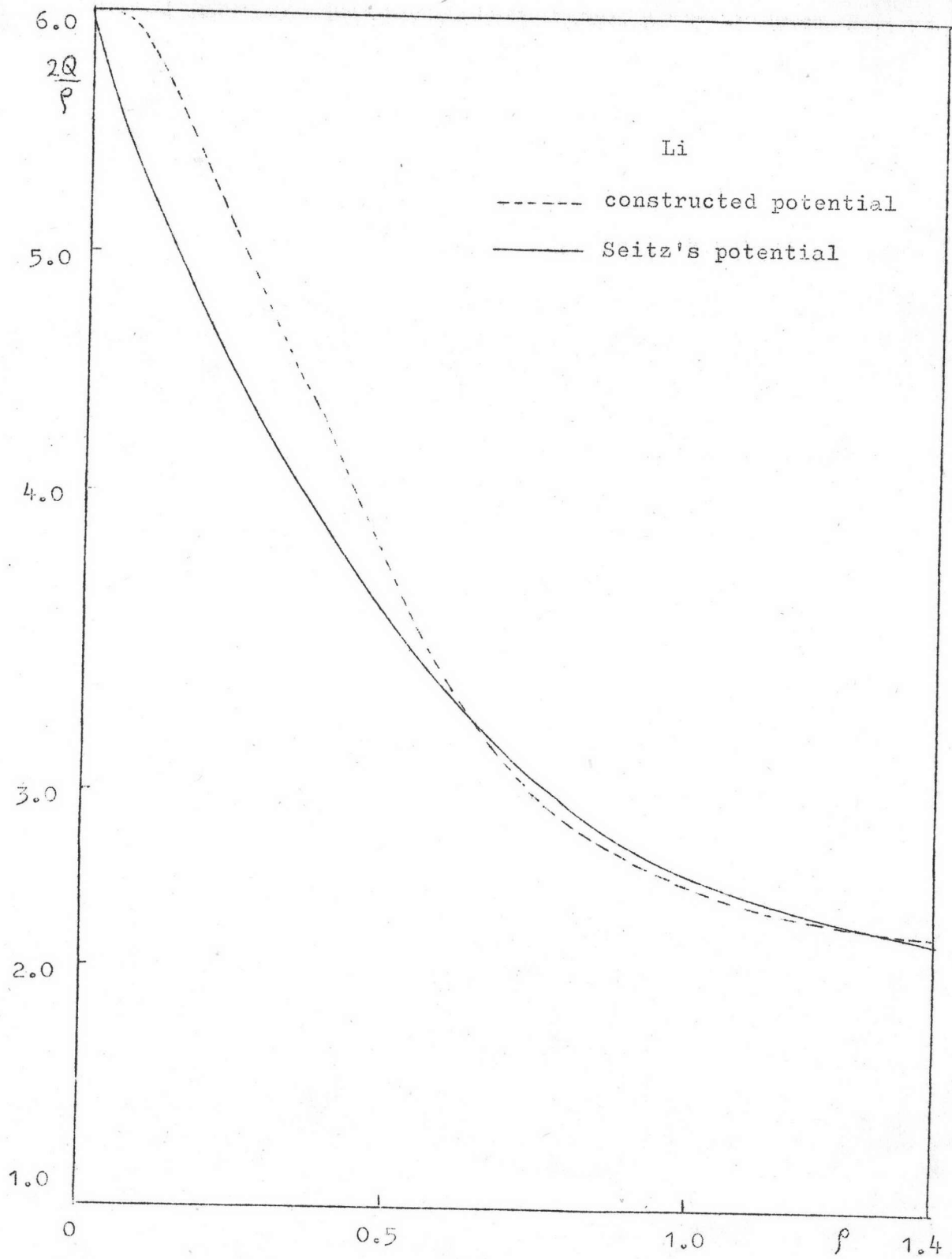


Fig. 5.2 The constructed Li potential against the Seitz's potential

$\rho = 0$	to	$.04$	$q(\rho) =$	$3\rho$
$= .04$		$.50$	$=$	$-2.75058\rho^2 + 3.23736\rho - .005121$
$= .50$		$.90$	$=$	$.972673\rho^2 - 1.08162\rho + 1.24738$
$= .90$		$1.24$	$=$	$.447067\rho^2 - .135523\rho + .821639$
$= 1.24$		$7.47$	$=$	$.001816\rho^2 + .968699\rho + .137022$
$= 7.47$		$0.25$	$=$	$.000593\rho^2 + .986966\rho + .068796$
$= 0.25$		$\infty$	$=$	$\rho + .110593/\rho^2$

Table 5.7 The constructed Li potential with polarization

### 5.4 Potential Testings

#### 5.4.1 By Using the QDM (Semiclassical Method)

We test the constructed potentials by calculating energy levels and then compare them with the experimental data. The calculation is performed by employing the QDM. We may recall the relation between the quantum defect and the potential in chapter III. The relation can be re written as

$$\mu_l(E) = I_1 - I_2 \quad (5.4.1)$$

where  $I_1$  and  $I_2$  stand for the terms in the right hand side of eq. (3.3.28) respectively.

$I_2$ , the coulomb term, can be analytically integrated and is a constant for a given energy level. The energy level can then be determined after we obtain the quantum defect. The results are shown in tables 5.8 and 5.9. It should be noted that the Simpson's integration formula is employed to compute some integral for which the analytical integration formula is not available (Appendix B).

state	$\epsilon_{nl}(\text{exp})$	$I_2$	$\epsilon_{nl}(\text{Prok})$	$\epsilon_{nl}(\text{No.1})$	$\epsilon_{nl}(\text{No.2})$
3s	.3777265	1.127089	.385864	.377282	.374133
4s	.1431617	2.142938	.144658	.142236	.141740
5s	.0751719	3.147306	.075661	.074762	.074573
6s	.0462662	4.149101	.046492	.046057	.045964
3p	.2231020	0.617174	.211206	.204029	.202649
4p	.1018733	1.633068	.098492	.096154	.095737
5p	.0583927	2.638288	.056965	.055932	.055755
6p	.0378396	3.640753	.037103	.036563	.036470
3d	.1118770	0.490169	.111145	.111744	.112049
4d	.0628870	1.488331	.062521	.062900	.062889
5d	.0402139	2.486685	.040012	.040227	.040200
6d	.0279070	3.486093	.027785	.027915	.027892
4f	.0625241	0.499229	.062500	.062500	.062508
5f	.0400243	1.498482	.040000	.040000	.040024
6f	.0277902	2.498659	.027778	.027778	.027795
7f	.0204170	3.498485	.020408	.020408	.020418

Table 5.8. Energy levels reproduced from constructed Na potentials

$\epsilon_{nl}(\text{Prok})$ ,  $\epsilon_{nl}(\text{No.1})$ ,  $\epsilon_{nl}(\text{No.2})$ , and  $\epsilon_{nl}(\text{exp})$  are the energy levels reproduced from the Prokofjew's Na potential, the constructed Na potentials in tables 5.3 and 5.4, and the experimental energy levels respectively.

state	$E_{nl}(\text{exp})$	$I_2$	$E_{nl}(\text{Seitz})$	$E_{nl}(\text{No.3})$	$E_{nl}(\text{No.4})$
2s	.5962944	1.088514	.3844	.418188	.418887
3s	.1485678	2.096152	.1459	.152871	.152949
4s	.0772330	3.098310	.0763	.078888	.078902
5s	.0472749	4.099225	.0468	.048054	.048063
6s	.0318910	5.099713	.0316	.032321	.032328
2p	.2604768	0.459366	.2583	.261604	.261930
3p	.1144745	1.455600	.1145	.114488	.114421
4p	.0639511	2.454358	.0639	.063926	.063890
5p	.0407495	3.453804	.0407	.040729	.040710
6p	.0282167	4.453151	.0282	.028198	.028189
3d	.1112146	0.498604	.1111	.111344	.111616
4d	.0625491	1.498430	.0625	.062645	.062741
5d	.0400262	2.498363	.0400	.040082	.040127
6d	.0277932	3.498333	.0278	.027828	.027855
7d	.0204192	4.498108	.0204	.020440	.020456
4f	.0624871	0.500413	.0625	.062500	.062465
5f	.0399390	1.503817	.0400	.040000	.039893

Table 5.9 Energy levels reproduced from constructed Li potentials

$E_{nl}(\text{Seitz})$ ,  $E_{nl}(\text{No.3})$ ,  $E_{nl}(\text{No.4})$ , and  $E_{nl}(\text{exp})$  are the energy levels reproduced from the Seitz's Li potential, the constructed Li potentials in tables 5.6 and 5.7, and the experimental energy levels respectively.

### 5.4.2 By Using Quantum Mechanical Method

The ground state energy level of Na atom is calculated numerically using the procedure given by Dumrongrak (1976) in order to compare with that reproduced from the Frokofjew's potential. This calculation may be called "integration" because we are able to find the value of wave function at the fourth point after the first three values have been known or determined.

In our calculation, the asymptotic radial wave function ( for  $\rho \rightarrow 0$  ) is needed because we start the calculation at the point  $\rho = 0$  which the radial wave function vanishes. The second and the third points can be obtained from the asymptotic wave function  $\rho e^{-Z\rho}$  which we adapt from the asymptotic s-state radial wave function of Hydrogen-like atom given by Park (1964) instead of  $\rho$  which was used by Dumrongrak. We have performed the outward integration only. If the radial wave function vanishes as  $\rho$  tends to infinity, the energy required for the integration to be possible will be the required energy. We can use larger intervals for larger radial distance because the radial wave function does not fluctuate at the outer region. However, we must reset appropriate first-three points of integration for the new intervals. For example, if we have a table of integration with an interval of .08

$\rho$	U
4.08	.178826
4.16	.172859
4.24	.172502
4.32	.168237
4.40	.156772

and we want to double the interval of integration to be .16 i.e. calculate

the wave function  $U$  at  $\rho = 4.56, 4.72, \dots$ ; we must reset first-three points to be

	$\rho$	$U$
first-three points	4.08	.174996
	4.24	.170602
	4.40	.156775
	4.56	.....
	4.72	.....

We can use new finite differences of the first-three points to determine  $U$  at  $\rho = 4.56, 4.72, \dots$ . Dumrongsak made an error because he used the table

	$\rho$	$U$
first-three points	4.24	.170602
	4.32	.168237
	4.40	.156775
	4.56	.....
	4.72	.....

The calculated value of  $U$  at  $\rho = 4.56$  had an error because of the the misuse of the first-three points which led to an error of the derivative at the point  $\rho = 4.40$ .

We have calculated several wave functions for some assumed ground state energies by using the Prokofjew's potential. The wave function which vanishes at infinity will give the ground state energy predicted by this potential. It is found that the ground state energy is inbetween .3800 and .3815 rydberg which is the same as those shown in the first paper of Wigner and Seitz (1933). The wave functions for those two assumed energies are given in table 5.10 and 5.11 and plotted in Fig.5.3. It should be noted that we have neglected the decimal

decimal point and following zeros in the table. One of them cuts the axis and the other blows up. This implies that the ground state energy should be inbetween those two assumed energies.

When our constructed Na potential is used instead of the Prokofjew's potential, the predicted ground state energy is found to be in the interval .37889 and .37895 rydberg. Our result deviates from the experimental value by about 0.3 % while that reproduced from the Prokofjew's potential gives an error about 0.9 % . The calculated wave functions obtained by using our potential are given in tables 5.12 and 5.13 and also plotted in Fig.5.5.





P	U	P	U	P	U	P	U
.0025	.002432	.32	- 40021		102496		112115
.0050	4732		- 44307		107094		106585
.0075	6906		- 48075		111522		101157
.0100	8953		- 51326		115781		95850
	10876		- 54071	1.34	119872		90678
.015	12680		- 56321		123799		85653
	14368		- 58096	1.92	127561		80785
.020	15944		- 59413		131162		76080
	17412		- 60295	2.00	134604		71542
.025	18775		- 60765				67173
			- 60846	2.08	141022		62974
.030	21203		- 60563		146836		58946
	23254		- 59934		152071		55084
	24955		- 58995		156752		51388
	26331		- 57759		160903		47852
	27407		- 56252		164549		44473
	28205		- 54495		167716		41244
	28746		- 52511		170429	8.56	38160
	29050		- 50318		172710		35215
	29135		- 47938		174585	8.88	32401
	29020	.72	- 45389		176076		29713
.08	28721		- 42687		177205	9.20	27142
	28254	.76	- 39850		177993		24682
.09	27633		- 36894		178461	9.52	20062
	26873	.80	- 33832		178628		15790
.10	25985				178514		11804
		.84	- 27448		178136		8040
.11	23876		- 20797		177512		4431
	21394		- 13964		176658		911
	18614		- 7020		175590		2592
	15604		- 27		174324		
	12418		6967		172875		
	9108		13923		171257		
	5714		20809		169484		
	2273		27601	4.08	167570		
	1187		34279		165526		
	4638		40829	4.24	163365		
	8059		47239		161098		
	11432		53500	4.40	158737		
	14741		59606		156290		
	17972		65552				
	21115		71334	4.56	151182		
.26	24160		76951		145847		
	27098		82399		140346		
.28	29925		87679		134738		
	32634		92788		129070		
.30	35222		97727		123387		

Table 5.10 The wave function for  $\epsilon_{30} = .3800$  rydberg by using the Prokofjew's Na potential



$\rho$	$U$	$\rho$	$U$	$\rho$	$U$	$\rho$	$U$
.0025			- 32643		76965	4.56	152142
The same as those given in table 5.10		.30	- 35231		82415		146902
		.32	- 40031		87697		141501
			- 44317		92308		135997
			- 48084		97750		130439
			- 51336		102521		124869
			- 54080		107121		119326
			- 56330		111552		113841
			- 58104		115814	1.84	108441
			- 59422		119909		103149
			- 60304		123839	1.92	97984
			- 60773		127606		92961
			- 60854		131211	2.00	88093
			- 60570		134657		83389
			- 59944			2.08	78856
			- 59002		141085		74499
			- 57765		146911		70322
			- 56257		152158		66326
			- 54500		156852		62511
			- 52515		161018		58877
			- 50323		164680		55420
		- 47943		167864		52139	
		.72	- 45393		170595		49031
			- 42691		172896		46090
		.76	- 39854		174791		43313
			- 36897		176304	8.56	40695
		.80	- 33835		177456		38232
.11	23875				178269	8.88	35917
	21392				178762		33745
	18612	.84	- 27450		178956	9.20	31712
	15600		- 20798		178870		
	12414		- 13964		178522	9.52	28041
	9103		- 7020		177928		24862
	5709		- 26		177105		22137
	2267		6969		176070		19831
-	1193		13926		174838		17912
-	4645		20813		173424		16354
-	8066		27606		171842		15134
-	11440		34285		170107		14235
-	14749		40836	4.08	168230		13644
-	17981		47247		166226		13355
-	21123		53509	4.24	164105		13369
.26	24168		59616		161880		
	27107		65563	4.40	159561		
.28	29934		71347		157159		

Table 5.11 The wave function for  $\epsilon_{70} = .3815$  rydberg by using the Prokofjew's potential

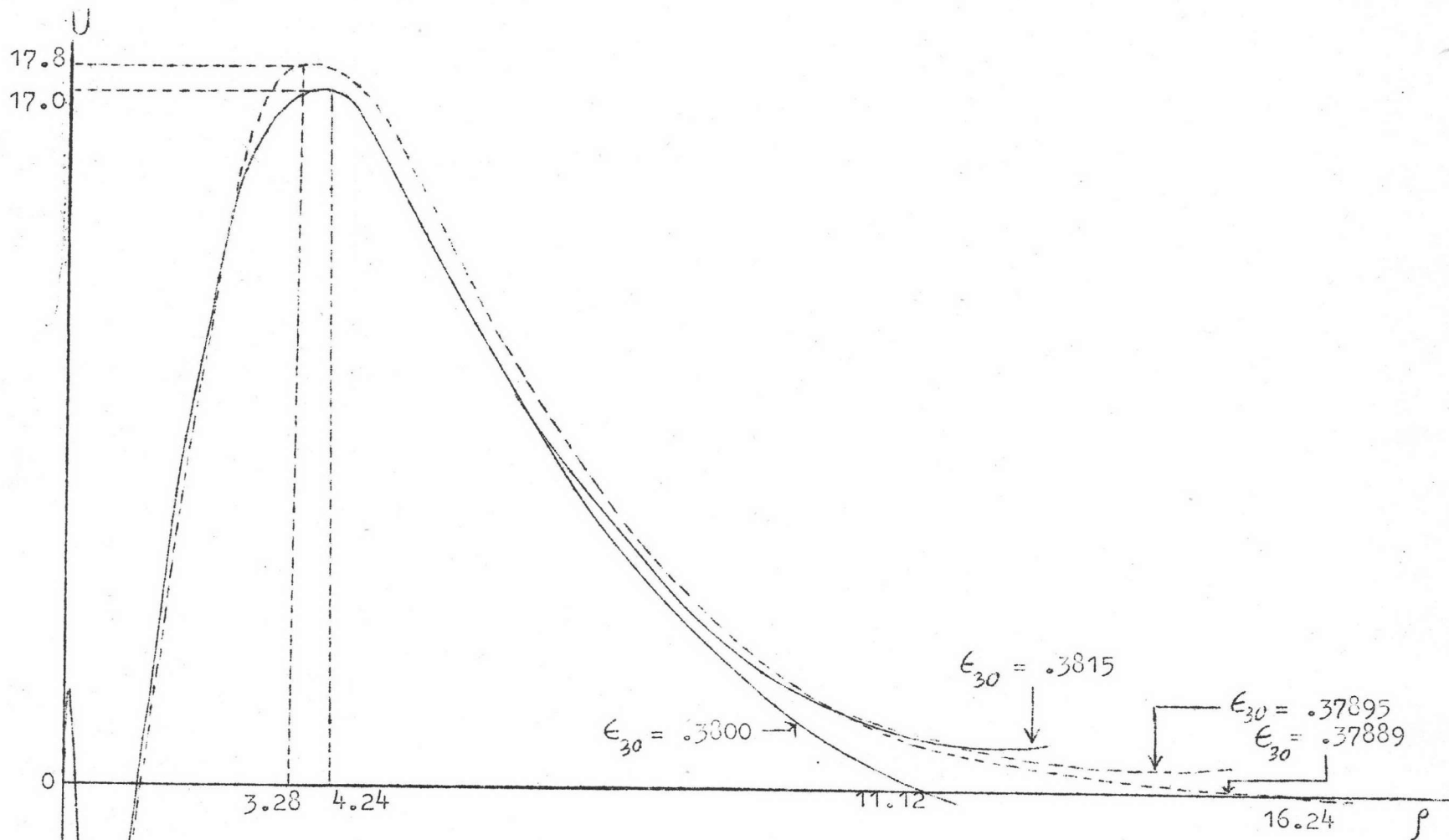


Fig.5.3 The wave functions reproduced from the Prokofjew's Na potential and from the constructed Na potential (dot lines).

$\rho$	U	$\rho$	U	$\rho$	U	$\rho$	U
.0025	.002432	.32	- 40369		98531		126277
.0050	4732		- 44691		104413		120487
.0075	6906		- 48506		108144		114777
.0100	8958		- 51818		112723		109173
	10887		- 54636	1.84	117149		103695
	12696		- 56973		121423		98360
	14389		- 58848	1.92	125544		93182
.020	15970		- 60277		129512		88171
	17442		- 61283	2.00	133328		83335
.025	18809		- 61887				78680
			- 62112	2.08	140507		74209
.030	21242		- 61980		147091		69925
	23296		- 61514		153091		65826
	24999		- 60738		158524		61913
	26375		- 59671		163406		58184
	27449		- 58338		167755		54634
	28243		- 56757		171591		51262
	28778		- 54950		174936		48062
	29075		- 52936		177810		45029
.070	29153		- 50732		180235	8.56	42159
	29029	.72	- 48358		182233		39445
.080	28720		- 45829		183826	8.88	36883
	28243	.76	- 43161		185035		34465
.090	27611		- 40370		185883	9.20	32187
	26839	.80	- 37469		186390		
.100	25940				186578	9.52	28023
		.84	- 31390		186466		24343
.11	28307		- 25019		186074		21102
	21300		- 18438		185421		18254
	18496		- 11719		184526		15758
	15462		- 4919		183406		12574
	12254		1910		182078		11668
	8923		8730		180559		10006
	5509		15509		178863		8557
	2050		22221		177007		7297
-	1425		28847	4.08	175004		6198
-	4891		35372		172868		5241
-	8325		41784	4.24	170611		4405
-	11710		48075		168246		3672
-	15030		54238	4.40	165784		3027
-	18273		60268				2456
-	21427		66162	4.56	160614		1944
.26	- 24484		71916		155181		1481
-	27436		77529		149555		1056
.28	- 30276		82998		143801		657
-	33001		88322		137972	15.92	274
.30	- 35607		93501		132117	16.24	101

Table 5.12 The wave function for  $\epsilon_{30} = .37889$  by using the constructed Na potential

$\rho$	$U$	$\rho$	$U$	$\rho$	$U$
.0025					
<p>The same as those given in table 5.12</p>			98531		138013
			103413		132162
			108144		126326
			112723		120541
		1.84	117150		114835
			121424		109236
		1.92	125545		103763
			129513		98443
		2.00	133329		93261
					88256
		2.08	140508		83426
			147092		78778
			153093		74314
			158525		70036
			163407		65945
			167757		62040
			171593		58319
			174936		54779
			177813		51416
			180238		48226
			182237		45204
			183830	8.56	42345
			185040		39643
			185889	8.88	37094
			186397		34690
			186535	9.20	32427
			186474		
			186083	9.52	28296
	185431		24654		
	184537		21456		
	183418		18659		
	182091		16221		
	180573		14105		
	178879		12277		
	177024		10707		
4.08	175022		9365		
			8228		
	172887		7275		
4.24	170632		6487		
	168268		5850		
4.40	165808		5350		
			4977		
4.56	160641		4725		
	155211		4590		
	149589		4568		
	143838	15.28	4661		

Table 5.13 The wave function for  $\lambda = .37895$   
by using the constructed Na potential