Structure of the A=6 Nuclear System*

by

J. D. Vergados
Department of Physics
University of Pennsylvania
Philadelphia, Pennsylvania, 19174

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ABSTRACT

The energy spectrum, electromagnetic properties, β -decay and π^- absorption rates of the A=6 system are calculated using realistic interactions. The results are in good agreement with experiment and other theories of semileptonic weak processes. Strong π^- absorption rates are predicted for 3^- states around 20 MeV.

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In a recent paper^[1] Donnelly and Walecka (D-W) have obtained nuclear wave functions for the ${}^6\text{He}$ and ${}^6\text{Li}$ ground states (gs) using only electron scattering and other electromagnetic data. No effective interactions were necessary, and no other assumptions were made, except that the nuclear shell model is applicable and that the mesonic degrees of freedom can be neglected. Their method presupposes, of course, the existence of very good experimental data of the above kind, which is no problem for the $A=6$ system (see e.g., the excellent recent review article^[2] by F. Ajzenberg-Selove and T. Lauritsen). The "effective" nuclear wave functions thus obtained were used to make predictions about the β -decay and muon capture rates. The first is in impressive agreement with experiment.

The theory of D-W and, more generally, the elementary particle treatment of nuclei^[3] are, of course, very useful in testing the consistency of the different assumptions about the weak and electromagnetic interactions (soft pion theorems, CVC, PCAC, etc.) in a way which is independent of the nuclear uncertainties. Its use for obtaining nuclear structure information, however, can only be justified if decent nuclear structure calculations are either inaccurate or tedious. It is possible that, if one uses the nuclear form factors to obtain nuclear wave functions, one makes assumptions about the transition operators, which are not

consistent with the model space chosen.

In the present paper we will attempt to study the structure of the A=6 system, motivated partly by the abundance of good experimental data [2,4], in particular the recently obtained π^- capture rates. [4] In addition we will attempt to answer the following questions: How much do the D-W predictions differ from those of a shell model calculation with realistic interactions? When such differences are significant, can one understand them by expanding the model space?

D-W obtained their results assuming that the ground states of ${}^6\text{Li}$ and ${}^6\text{He}$ can be written as follows:

$${}^6\text{Li}(\text{gs}) = A p_{3/2}^2 + B p_{1/2} p_{3/2} + C p_{1/2}^2 \quad (J=1 \ T=0)$$

$${}^6\text{He}(\text{gs}) = D p_{3/2}^2 + E p_{1/2}^2 \quad (J=0 \ T=1)$$

An additional parameter is the harmonic oscillator length parameter, b . The constants A, B, C were obtained as functions of b using the experimentally known values of the g.s. quadrupole and magnetic dipole moments and the normalization condition

$A^2 + B^2 + C^2 = 1$. The quantities D, E and b were obtained by fitting the elastic and inelastic magnetic form factors (assuming isospin conservation). The results obtained are $A = .810$, $B = -.581$, $C = .084$, $D = .80$, $E = .60$, $b = 2.03$ fm.

The use of experimental information as input to nuclear

structure calculations is not unusual. Even the best present day shell model calculations use experimental single particle energies. In earlier calculations^[5], the matrix elements of the 2-body interaction were considered as parameters to be obtained from experiment, if enough experimental information were available. These 2-body interactions were used to obtain the wave-functions and spectra of more complicated nuclei, sometimes with success.^[5] Quadrupole moments and transitions have also been used as input in phenomenological theories of collective motion.

In recent years, however, it has been possible to approach the problem of nuclear structure from a more fundamental view; point thanks to the work of Kuo-Brown^[6] and others^[7]. Admittedly, these theories also use experimental input, the free nucleon-nucleon interaction, but this input is not as directly related to the structure of the nucleus under study. Therefore, when feasible, this is a better approach.

We will investigate the $A=6$ system, making the same assumption with D-W, namely that the mesonic degrees of freedom can be neglected. For the 2-body interaction we will use the recent realistic energy dependent Kuo-Lee^[8] matrix elements. The choice

of the single particle energies is less unambiguous, because the $A=5$ system is not bound. For nuclei with the $1p$ -shell almost full, the single particle energies commonly used^[9] are: -31, 0, 6.24, 17.75, 18.63, 22.03, 36.75, 41.75, 43.75, 44.75 and 47.75 for the $1s_{1/2}$, $1p_{3/2}$, $1p_{1/2}$, $1d_{5/2}$, $2s_{1/2}$, $1d_{3/2}$, $1f_{7/2}$, $2p_{3/2}$, $1f_{5/2}$, $2p_{1/2}$, $1g_{9/2}$ respectively. The calculation using these single particle energies will be referred to as (a). But the energy difference $\Delta\epsilon = 1p_{1/2} - 1p_{3/2} = 6.24$ seems too large. Cohen and Kurath^[5] used a very small value ($\Delta\epsilon = .64$ MeV) but their single particle energies are perhaps inconsistent with our interaction. It is important to obtain an energy difference $\Delta\epsilon$ consistent with our interaction. To achieve this we will use the Kuo-Lee interaction to obtain $\Delta\epsilon = \epsilon(1p_{1/2}) - \epsilon(1p_{3/2})$ to first order in the interaction, i.e. corresponding to the graph:

$$\text{or } \epsilon(j) = \frac{1}{2(2j+1)} \sum_{J,T} (2J+1)(2T+1) \langle (jj')JT | V | (jj')JT \rangle$$

where the index j' runs over the occupied orbitals (here $1s_{1/2}$). This method may not be reliable in general, but it does give the correct spin-orbit splitting in the regions where the latter is known. The result is $\Delta\epsilon = 4.7$ MeV.

Another way of estimating $\Delta\epsilon$ is by noticing that the $2^+_T = 0$

and the 3^+ $T = 0$ states of ${}^6\text{Li}$ within the $1p$ -shell are made of a single configuration, i.e. $1p_{3/2}1p_{1/2}$ and $1p_{3/2}^2$ respectively.

So, setting $\epsilon(1p_{3/2}) = 0$, we get

$$E(3^+) = \langle (1p_{3/2}^2) 30 | V | (1p_{3/2}^2) 30 \rangle = V_1$$

$$E(2^+) = \epsilon(1p_{1/2}) + \langle (1p_{3/2} 1p_{1/2}) 20 | V | (1p_{3/2} 1p_{1/2}) 20 \rangle = \Delta\epsilon + V_2.$$

From the Kuo-Lee matrix elements we get $V_1 = -4.52$ MeV and

$V_2 = -5.77$ MeV, while from the experimental spectrum we get

$$\Delta E = E(2^+) - E(3^+) = 2.12 \text{ MeV. Therefore we obtain } \Delta\epsilon = 3.4 \text{ MeV.}$$

However if more configurations are allowed to mix with the above simple 2^+ and 3^+ states, the correct energy difference ΔE is obtained if $\Delta\epsilon = 4.2$ MeV. So we decided to use $\Delta\epsilon = 4.7$ MeV, i.e. the single particle energies: -28.1, 0., 4.71, 16.22, 17.1, 21.3, 35.22, 40.22, 42.22 and, 43.22 and 46.22 in the above order of the single particle states (this calculation will be referred to as (b)).

The third component of the calculation is the model space. As a first attempt we will consider $0\hbar\omega$ excitations for positive parity states (2 particles in the $1p$ shell) and $1\hbar\omega$ excitations for negative parity states (i.e. one particle in the $1p$ shell and one particle in the $2s$ - $1d$ shell or 3 particles in the $1p$ shell and 1 hole in the $1s$ shell). This will be referred to as calculation I. For positive parity states more elaborate calculations will be performed (see calculations II and III below).

The bare transition operators were used for the electric quadrupole and magnetic dipole operators, i.e., $e_p = 1$, $e_n = 0$ and $(g_s)_p = 5.58$, $(g_s)_n = -3.82$, $(g_l)_p = 1$, $(g_l)_n = 0$ $\frac{eh}{2m_p c}$. The details of calculating the π^- absorption rate will not be given here since they have appeared elsewhere^[4,10] and a more detailed paper is under preparation.^[11] We will give here the main results. The π^- branching ratio is defined by

$$R_\gamma = \omega_s \frac{\Gamma_\gamma(1s)}{\Gamma(1s)} + \omega_p \frac{\Gamma_\gamma(2p)}{\Gamma(2p)}$$

ω_s and ω_p are the absorption probabilities from an s and p pionic orbits and $\Gamma_\gamma(nl)$ and $\Gamma(nl)$ are the radiative and total widths of the nl orbit. $\Gamma_\gamma(nl) = c(nl) \Gamma'_\gamma(nl)$, where $\Gamma'_\gamma(nl)$ is the radiative width calculated assuming hydrogenic wave functions and $c(nl)$ represents the distortion of the pion wave function due to strong interactions calculated from a pion-nucleus optical potential.^[12] For ${}^6\text{Li}$ they are^[4] $c(1s) = .65$, $c(2p) = 1.10$. The values of ω_s , ω_p , $\Gamma(1s)$, $\Gamma(sp)$ are taken from experiment^[4], i.e. $\omega_s = .4$, $\omega_p = .6$, $\Gamma(1s) = 150$ keV, $\Gamma(2p) = .015$ eV. The calculated quantity $\Gamma'_\gamma(nl)$ is obtained as follows:

$$\Gamma_{\gamma}^{\prime}(n\ell) = \hbar \Lambda_{\gamma}^{\prime}(n\ell) ; \quad \Lambda_{\gamma}^{\prime}(n\ell) = \frac{1}{(2J_i+1)(2\ell+1)} S_{if}$$

$$S_{if} = \sum_{m_f s} \int \frac{d\vec{k}}{4\pi} |\langle J_f M_f | H_{eff} | J_i M_i \rangle|^2$$

$$\text{with } H_{eff} = (1 + M_{\pi}/M_N) \frac{1}{\sqrt{k}} \sum_{\lambda, j} e^{-i\vec{k} \cdot \vec{r}_j} H_{\lambda}(j) \varphi_{\ell m}^{n_o}(\vec{r})$$

$\varphi_{\ell m}^{n_o}(\vec{r})$ = the wave function of a bound π^- , M_{π} , M_N are the masses of the pion and nucleon and $H_{\lambda}(j) = 2\pi i t^+(j) [A \vec{\sigma}_j \cdot \hat{\epsilon}_{\lambda} + B (\vec{\sigma}_j \cdot \hat{\epsilon}_{\lambda}) (\vec{q} \cdot \vec{k}) + C (\vec{\sigma}_j \cdot \vec{k}) (\vec{q} \cdot \hat{\epsilon}_{\lambda}) + i D \vec{q} \cdot (\vec{k} \times \hat{\epsilon}_{\lambda})] \delta(\vec{r} - \vec{r}_j)$
 $\vec{\sigma}_j$, $\vec{r}_j$, $t^+(j)$ are the Pauli spin, coordinate and isospin raising operators for the j^{th} nucleon ($t^+|\bar{p}\rangle = |\bar{n}\rangle$), $\hat{\epsilon}_{\lambda}$ and $\vec{k}$ are the photon polarization and momentum and $\vec{q} = -i\vec{v}$ is the pion momentum. The constants A, B, C, D, are^[4,13]: $A = -.032 M_{\pi}^{-2}$, $B = -.0075 M_{\pi}^{-4}$, $C = -.037 M_{\pi}^{-4}$, $D = .014 M_{\pi}^{-4}$.

The resulting wave functions within the 1p-shell expressed in the notation of D-W are: $A = .79955$, $B = -.60004$, $C = -.02580$, $D = .97841$, $E = .20670$ I(a); $A = .73724$, $B = -.67547$, $C = -.01505$, $D = .95895$, $E = .28356$ I(b). The energy spectrum appears in Fig. 1. The Harmonic oscillator parameter used was $b = 1.95$ fm ($\hbar\omega = 11$ MeV) which is almost the same with the value $b = 2.03$ fm obtained by D-W.

We notice that our D and E coefficients for both (a) and (b) are very different from those of D-W. We also notice that, using the Kuo-Lee interaction, the ratio D/E will be larger than that of

D-W even if $\Delta\epsilon$ is taken to be zero, a somewhat unrealistic assumption. Also the sign of the C term obtained in our calculation is different from that of Donnelly and Walecka. However all calculations, with the exception of the ${}^6\text{Li}$ g.s. quadrupole moment and perhaps the β -decay rate, give identical results (see Table 1). The quadrupole moment is a small quantity, the result of large cancellations. The contribution of the small $p_{1/2}^2$ term by itself (linear in C) is equal to the total quadrupole moment. D-W did not predict this quantity, but put it in as input in their calculation. Both calculations I(a) and I(b) give a positive quadrupole moment. However, as we shall see below, we obtained^a/negative quadrupole moment by enlarging the Hilbert space. It is surprising that the complicated operator involved in π capture does not distinguish between our wave functions and those of Donnelly and Walecka, when we look at the branching ratios. Both give a ground state branching ratio larger than experiment (Table 1). However all calculations predict a capture rate to the first excited 2^+ state in ${}^6\text{He}$ ($E_x = 1.80$ MeV) which is in excellent agreement with the Berkeley^[8] results. The Berkeley group managed not only to resolve the two transitions but to assign the branching ratios as well.

Transitions to the states $J^\pi = 0^-, 1^-, 2^-$ $T = 1$, which are

analogs of the G.D.R. (Giant Dipole Resonance) in ${}^6\text{Li}$ were also calculated. Although the branching ratios to the 0^- and 1^- components are negligible (the strength is fragmented) the branching ratio to the 2^- EX = 24 MeV (in ${}^6\text{He}$) was found to be $R_\gamma = .196\%$ (a) and $.224\%$ (b). We also found surprisingly high π^- capture rates to the 3^- T=1 final states at Ex = 20.0 MeV and 36.0 MeV (in ${}^6\text{He}$) with branching ratios $R_\gamma = .204\%$ and $.346\%$ respectively. Although the bound shell model calculation may not be applicable at such high energies, such concentration of strength is suggestive of the presence of collective states in this region. The recent Berkeley experiment^[4] indicates three prominent peaks at 15.6, 23.2 and 29.7 MeV with capture rates $.143 \pm .032$, $.282 \pm .185$ and $.339 \pm .202$ respectively. Unfortunately the experimental transition rates depend strongly on the model used to subtract the quasifree background.

There is experimental evidence^[2] for the existence of a 4^- T=1 resonance at Ex $\sim$ 26 MeV in ${}^6\text{Li}$ (i.e. $\sim$ 22 MeV in ${}^6\text{He}$). However the predicted π^- capture rate to such a state is small ($R_\gamma = .028\%$), which is not unexpected since the leading term in the transition operator is characterized by $\ell = 3$.

The existence of 3^- T=1 collective states with strong π^- capture rates is perhaps related to the fact that the initial nucleus has J=1 T=0 and the transition operator is characterized predominantly

by $J=2$ $L=1$ $S=1$, i.e., it has the same quantum number with the operator responsible for the transition to the $J=2^-$ $T=1$ final dipole states. The total strength for transitions to the 3^- states is related to the 2^- states through the statistical factor $7/5$, but it appears more concentrated. Similar trends have been seen in the π^- capture in ^{14}N (another odd-odd nucleus). Unfortunately these 3^- states cannot be seen as collective ground state $E1$ transition (e.g. in p, γ reactions) but only to excited 2^+ final states, which are not easy to resolve experimentally. There is evidence for such a γ_4 transition in ^6Li [2], but the initial spin and isospin are not known.

The low lying electromagnetic transitions are in good agreement with experiment [2] (see Table 1). Recently special interest has been focused in a 0^+ $T=1$ state at ~ 11.5 MeV in ^6Be (i.e., ~ 15 MeV in ^6Li). Fowler has suggested [14] that if such a state exists, since it falls at the $^3\text{He} + ^3\text{He}$ separation energy, it can explain the low flux of solar neutrinos to which the $^{37}\text{Cl}(\nu, e^-)^{37}\text{Ar}$ experiment is sensitive. The reason is that such a state will favor the reaction $^3\text{He} + ^3\text{He} \rightarrow ^6\text{Be}^* \rightarrow ^4\text{He} + 2p$ at the expense of the reaction $^3\text{He} + ^4\text{He} \rightarrow ^7\text{Be} + \gamma \rightarrow ^7\text{Li} + \gamma + \nu$. This way one can understand the low yields of the above experiment. [15] Recent electron scattering experiments [16] in the region 8.3 to 18.4 MeV set a limit $\Gamma_\gamma \leq 3$ eV for the g.s. $M1$ transition width of such a state. So the experimental evidence is against

any such state.^[2] Our present calculation yields $\Gamma_\gamma = 15.0$ ev (a) and 8.9 ev (b), while D-W predict 49.0 ev (assuming that their 0_2^+ state is $-.60 p_{3/2}^2 + .80 p_{1/2}^2$).

It seems, therefore, that with the exception of ${}^6\text{Li}$ g.s. quadrupole moment and possibly the ${}^6\text{He} \rightarrow {}^6\text{Li}$ β -decay rate, all three calculations give essentially the same results, which are in good agreement with experiment. The best harmonic oscillator parameter is obtained from electron scattering experiments ($b = 1.94$ fm) i.e., close to the one given by Donnelly and Walecka ($b = 2.07$ fm).

In order to examine the sensitivity of the results to the assumption of 1p-shell model space for positive parity states, we expanded the shell model space by including $2h\omega$ excitations i.e., $2p + 3p\text{-}1h$ (II) and $2p + 3p - 1h + 4p - 2h$ (III). The low lying spectrum obtained is presented in Fig. 1. None of the calculations gives a very good agreement with experiment. However previous phenomenological calculations faced similar problems.^[5] Some observable quantities of interest are summarized in Table (2). These results, with the exception of the magnetic and quadrupole moments, were obtained using the results of calculation I for the ${}^6\text{Li}$ g.s. wave function. The results do not change substantially from those of the simple model I (compare Tables 1 and 2). However the ${}^6\text{Li}$ quadrupole

moment and the ${}^6\text{He} \rightarrow {}^6\text{Li}$ ft value are now in better agreement with experiment. The 1p-shell components of the complicated wave functions are:

$$A=.74358, B=-.62988, C=-.02714, D=.96914, E=.20591 \quad \text{II(a)}$$

$$A=.68324, B=-.69176, C=-.01767, D=.95756, E=.24564 \quad \text{II(b)}$$

$$A=.72900, B=-.61992, C=-.02762, D=.94165, E=.21512 \quad \text{III(a)}$$

$$A=.67253, B=-.67443, C=-.02160, D=.92965, E=.25473 \quad \text{III(b)}$$

These results indicate that the more complex wave functions do not lead to renormalized wave functions similar to those obtained by D-W. The coefficient C is still negative and D remains approximately 4 times larger than E. Yet such differences do not seem to affect the experimental quantities of interest. However, the sensitivity of the energy spectrum to such variations and the disagreement between theory and experiment here is a source of worry.

The D-W predictions of the β -decay and μ - absorption were in very good agreement with experiment. When this occurs either the wave functions are very good and they will reproduce well all the experimental results or they were forced to agree on some observables and hence they are bound to disagree on others. Unfortunately, there are not many independent operators left, in addition to β -decay and muon capture, which connect the ${}^6\text{Li}$ and ${}^6\text{He}$ ground states. One such operator is the above

given operator responsible for π^- absorption. This operator via PCAC and soft pion theorems^[3,17] is related to the axial form factor which appears in β -decay ($q^2 = 0$) and muon capture ($q^2 = .54 m_\pi^2$). These relationships however do not hold for 2p absorption which even for a light nucleus like ${}^6\text{Li}$ represents 30% of the total ground state rate. Therefore the total π^- absorption rate provides a more or less independent check. As it can be seen from table 1, the total capture rate predicted by the present calculation is almost the same with that of D-W. Both calculations are 30% higher than the recent Berkeley experiment and 50% lower than the earlier experiment.^[18] Although the transition probabilities from individual orbits have not been isolated experimentally, it is instructive to compare the results of the shell model + impulse approximation to those obtained by treating the nuclei as elementary particles.^[13,17] The transition probabilities Λ_γ from 1s orbits are: $1.64 \times 10^{15} \text{ sec}^{-1}$ (Ia), $1.72 \times 10^{15} \text{ sec}^{-1}$ (Ib), $1.67 \times 10^{15} \text{ sec}^{-1}$ (D-W) $(2.3 \pm .5) \times 10^{15} \text{ sec}^{-1}$ (Delorme¹⁷) and $(1.51 \pm .15) \times 10^{15} \text{ sec}^{-1}$ (Maguire and Wertz¹³). It is not clear whether the disagreement with experiment arises from 2p absorption, since the prediction of the present calculation ($\Lambda_\gamma(2p) = 5.86 \times 10^{10} \text{ sec}^{-1}$) agrees with earlier calculations^[13] ($\Lambda_\gamma(2p) = 5.26 \times 10^{10} \text{ sec}^{-1}$).

In conclusion we can say that the phenomenological approach

of Donnelly and Walecka is very useful when a detailed agreement with experiment is sought. However it does not completely settle the question of the structure of the ground states of the $A=6$ system. First because most of the properties of these states have been fitted to experiment and only a few were left for prediction. Second the most sensitive properties of the system, namely the ${}^6\text{Li}$ ground state quadrupole moment and the energy spectrum, were not predicted. Third, those quantities which D-W have predicted do not discriminate much between the different nuclear models. Finally when it comes to fine refinements, as the present differences between theory and experiment, the effects of the exchange currents and the precise size of the shell model may be important, as e.g. in the ${}^6\text{Li}$ g.s. quadrupole moment. Until these questions are settled, one will not know with certainty whether the $1p$ shell is a good model space.

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Quantity	Units	Present Calculation (I)		Donnelly and Walecka	Experiment
		(a)	(b)		
${}^6\text{Li}$ g.s. Mag. Moment	n.m.	831	852	823*	822 ^[2]
${}^6\text{Li}$ g.s. Quad. Moment	10^{-3}bn	1.17	1.65	-.78*	-.80 ^[2]
$\Gamma_{M1}(0_1^+ T=0 \rightarrow 1^+ T=0)$	ev	8.76	8.70	7.93*	8.44 $\pm$.42 ^[2]
$\Gamma_{M1}(0_2^+ T=1 \rightarrow 1^+ T=0)$	ev	15.0	8.9	49.0**	≤ 3 ^[13]
$\Gamma_{M1}(2^+ T=0 \rightarrow 1^+ T=0)$	10^{-4}ev	.09	1.69	2.96	
$\Gamma_{M1}(2_1^+ T=1 \rightarrow 1^+ T=0)$	ev	1.60	.92		.175 $\pm$.040 ^[2]
$\Gamma_{E2}(3^+ T=0 \rightarrow 1^+ T=0)$	10^{-4}ev	1.03	1.10	1.01	4.15 $\pm$.42 ^[2]
$\Gamma_{E2}(2^+ T=0 \rightarrow 1^+ T=0)$	10^{-3}ev	2.81	2.55	2.28	5.4 $\pm$ 2.8 ^[2]
$\text{ft}({}^6\text{He(g.s.)} \rightarrow {}^6\text{Li(g.s.)})$	sec	773	746	818*	802 $\pm$.002 ^[2]
$R_\gamma(\pi^- + {}^6\text{Li} \rightarrow {}^6\text{He}(0_1^+) + \gamma)$	%	.439	.450	.436	.306 $\pm$.035 ^[4]
$R_\gamma(\pi^- + {}^6\text{Li} \rightarrow {}^6\text{He}(0_2^+) + \gamma)$	%	.032	.036	.015	
$R_\gamma(\pi^- + {}^6\text{Li} \rightarrow {}^6\text{He}(2_1^+) + \gamma)$	%	.147	.128		.148 $\pm$.025 ^[4]
$R_\gamma(\pi^- + {}^6\text{Li} \rightarrow {}^6\text{He}(2_2^+) + \gamma)$	%	.102	.103		
$R_\gamma(\pi^- + {}^6\text{Li} \rightarrow {}^6\text{He}(2^-) + \gamma)$	%	.196	.225		
$R_\gamma(\pi^- + {}^6\text{Li} \rightarrow {}^6\text{He}(4^-) + \gamma)$	%	.027	.028		
$R_\gamma(\mu^- + {}^6\text{Li} \rightarrow {}^6\text{He}(0_1^+) + \nu)$	10^3sec^{-1}	1.46	1.53	1.39 $\pm$.04 ⁺	1.60 $\pm$.33 ^[1] -.13

Table 1: Summary of the results of Calculation I. Experimental energies were used in calculating the widths.
 $\hbar\omega = 11$ MeV was used for the harmonic oscillator wave functions. The notation is explained in the text.

*fitted to experiment

** Assuming $|0_2^+\rangle = +.60 p_{3/2}^2 - .40 p_{1/2}^2$

Calculated Quantity	Units	II		III	
		(a)	(b)	(a)	(b)
${}^6\text{Li}$ g.s. Mag. Moment	n.m.	.812	.815	.784	.786
${}^6\text{Li}$ g.s. Quad. Moment	10^{-3}bn	-2.18	-.29	-1.81	-.02
$\Gamma_{M1}(0_1^+ T=1 \rightarrow 1^+ T=0)$	ev	8.18	8.43	7.82	8.06
$\Gamma_{M1}(0_2^+ T=1 \rightarrow 1^+ T=0)$	ev	25.0	16.8	17.5	11.5
$\Gamma_{M1}(2^+ T=0 \rightarrow 1^+ T=0)$	10^{-4}ev	.009	1.59	.007	1.56
$\Gamma_{M1}(2_1^+ T=1 \rightarrow 1^+ T=0)$	ev	.86	.88	.84	.86
$\Gamma_{E2}(3^+ T=0 \rightarrow 1^+ T=0)$	10^{-4}ev	2.75	1.25	2.61	1.20
$\Gamma_{E2}(2^+ T=0 \rightarrow 1^+ T=0)$	10^{-3}ev	3.30	3.17	3.13	3.02
$\text{ft}({}^6\text{He(g.s.)} \rightarrow {}^6\text{Li(g.s.)})$	sec	827	774	864	808
$R_\gamma(\pi^- + {}^6\text{Li} \rightarrow {}^6\text{He}(0_1^+) + \gamma)$	%	.445	.458	.426	.440
$R_\gamma(\pi^- + {}^6\text{Li} \rightarrow {}^6\text{He}(0_2^+) + \gamma)$	%	.028	.038	.027	.031
$R_\gamma(\pi^- + {}^6\text{Li} \rightarrow {}^6\text{He}(2_1^+) + \gamma)$	%	.153	.132	.144	.123
$R_\gamma(\pi^- + {}^6\text{Li} \rightarrow {}^6\text{He}(2_2^+) + \gamma)$	%	.112	.108	.110	.108

Table 2: Summary of the results of calculations II and III.

See caption of Table 1 for explanations.

ENERGY SPECTRUM FOR ${}^6\text{Li}$