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ELASTIC MAGNETIC FORM FACTORS FOR ^{7}Li

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Abstract

Elastic magnetic electron scattering form factors have been calculated for the ground state J^π $T=3/2^-$ ½ of ^{7}Li in the framework of the many-particle shell model. The calculations are based on the model space wave functions of Cohen-Kurath interaction. The results are compared with the available experimental data. The data are reasonably explained up to q~3.0fm^{-1} when the size parameter of the harmonic oscillator potential is reduced from that used to fit the root mean square charge radius.

الخلاصة

حسبت عوامل التشكل لاستطارة الإلكترون المغناطيسية المرنة للحالة الأرضية ½ J^π $T=3/2^-$ لنواة الليثيوم ^{7}Li ضمن اطار انموذج الأغلفة النووي المتعدد الجسيمات. استندت الحسابات على الدوال الموجية لفضاء الأنموذج لتفاعل كوهين-كوراث. وقد قورنت نتائج الحسابات مع المعطيات العملية الممكنة. فسرت المعطيات العملية بشكل جيد لحد قيمة ~3.0fm^{-1} q عندما يختزل عامل حجم جهد المتذبذب التوافقي عن ذلك المستخدم لتطابق معدل الجذر التربيعي لنصف قطر الشحنة.

Introduction

The scattering of electrons from nuclei gives the most precise information about nuclear size and charge distribution and it has provided important information about the electromagnetic currents inside the nuclei. One of the successes of the shell model picture has been the ability to describe the electromagnetic currents inside the nuclei. The multi-nucleon shell model can reproduce many observed properties of nuclei if the limited model space is used with effective operators rather than the free nucleon operators [1].

The cross section of electron scattering from the ground state of ^{7}Li has been measured by Van Niftrik et al. [2]. The results agree very well with the results of lifetime measurements. The longitudinal and transverse form factors for the ground state doublet ($J^\pi=3/2^-$ g.s. and $J^\pi=1/2^-$, 0.478MeV excitation) were measured up to momentum transfer q ~ 4.2 fm^{-1} by L. Lichtenstad et al. [3, 4]. Also, ^{6}Li and ^{7}Li nuclei have been described successfully in terms of clusters, as α +d in the case of ^{6}Li and α+t in the case of ^{7}Li; K. Langanke [5] performed this description. The simple 0ħω-shell model description of these nuclei automatically contains such clustering. The 1s-shell inert core is the α-particle, while the valence nucleons in the 1p-shell naturally form the other cluster. Higher energy configurations have been studied for some 1p-shell nuclei where (0+2) ħω model space was used [6]. This extension of the model space improves the agreement with transverse form factors in the beginning of the 1p-shell nuclei. Karataglidis et al. [7] have used (0+2+4) ħω wave functions in the analysis of the elastic and inelastic electron scattering form factors in ^{6,7}Li. Their results reproduce the data for q above 1.0 fm^{-1}, and underestimate the data for q <1.0 fm^{-1}. This is associated with the underestimation in the B(C2) value of about a factor of 2. Radhi et al. [8] used the extended model space wave function to calculate the form factors for elastic magnetic electron scattering from ^{19}F. The inclusion of a higher configuration with the model space configuration had produced a second maximum, which was found experimentally.

In the present work, almost same sort of analysis of the previous work [8] is adopted. The twobody interaction of Cohen-Kurath [9] is used to generate the 1p-shell wave functions. The single particle wave functions of the harmonic oscillator (HO) potential are used with the size parameter (b) chosen so that the root mean square (rms) charge radius is reproduced.

To describe the experimental data, the size parameter is reduced from that to fit the measured root mean square charge radius. Also the effective g-factor is considered as a core-polarization effect.

Theory

For many-particle system (N-valence nucleons), the reduced matrix elements between the initial state $|i\rangle$ and the final state $|f\rangle$ for the one-body magnetic operator are expressed as the sum of the product of elements of the one-body density matrix (OBDM) times single-particle matrix elements [1]:-

$$\langle f\|T_J^{mag}(t_z,q)\|i\rangle=\sum_{jj'}OBDM(J,j,j',f,i,t_z)\langle j\|T_J^{mag}(t_z,q)\|j'\rangle \qquad (1)$$

Where t_z =1/2 for proton and -1/2 for neutron, and the sum extends over all pairs of single-particle states in model space ($|1p_{3/2}\rangle$ and $|1p_{1/2}\rangle$). The OBDM are obtained from the work of Cohen-Kurath [9].

The transverse magnetic form factor of the nucleus is defined as [10]:-

$$F_T^{mag}(J,q)=\frac{1}{\sqrt{2J_i+1}}\frac{\sqrt{4\pi}}{Z}\sum_{J,t_z}\langle f\|T_J^{mag}(t_z,q)\|i\rangle f_{f.s}(q)f_{c.m}(q) \qquad (2)$$

Where $f_{c.m}(q)$ is the correction factor of the center of mass motion when shell model wave functions are used, and is given by [11]:-

$$f_{c.m.}(q)=\exp(q^2b^2/4A) \qquad (3)$$

Where b is the harmonic oscillator size parameter, and A is the total number of nucleons in the nucleus. The function $f_{f.s}(q)$ is the finite size form factor correction, which is the same for the proton and the neutron and takes the form [12] :-

$$f_{f.s.}(q)=\exp(-0.43\,q^2/4) \qquad (4)$$

Results and discussion

The calculations have been performed with the Cohen-Kurath interaction for the model space contribution. According to the many-particle shell model, the nucleus ^{7}Li is considered as a core of the ^{4}He plus three nucleons distributed over the $1p_{3/2}$ -$1p_{1/2}$ orbits. The oscillator parameter b is used to be b_{rms}=1.74fm [13]. Free nucleon g-factors are used. The total magnetic (M1+M3) form factor for the state $3/2^-1/2$ with these parameters is shown in Fig.1 by solid curve. This form factor has contributions from M1 and M3 components, which are displayed by the dashed and dotted curves respectively. The M3 component is dominant over the diffraction minimum of M1 component. The data of Niftrik [2] (circles) and Lichtenstad et al. [3] (squares) are well described for momentum transfer values less than 1.5 fm^{-1}. The inclusion of the effective g-factor ($g_{eff.}=0.9g_{free.}$) allows the form factors to be reduced at low q. Reducing the size parameter b from the standard value b_{rms} to be, b=1.65fm allows one to improve significantly the agreement with the experiment at large q as shown in Fig.2 (solid curve). The calculated magnetic moment with g_{free} is found to be $\mu_{the.}$=3.165 n.m which is in excellent agreement with the experimental value ($\mu_{exp.}$=3.256 n.m)[12].

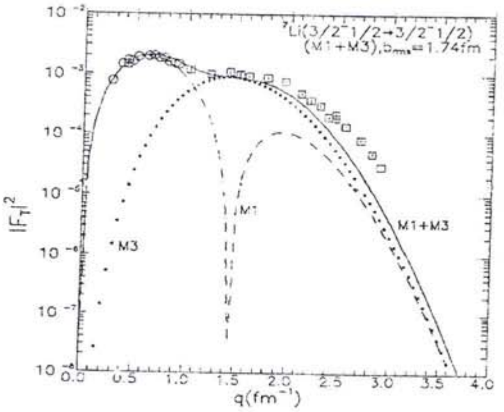

Figure (1): Elastic magnetic form factors calculated with CK interaction, using 1p-shell model space. The data are taken from Ref. 2 (circles) and Ref. 3 (squares).

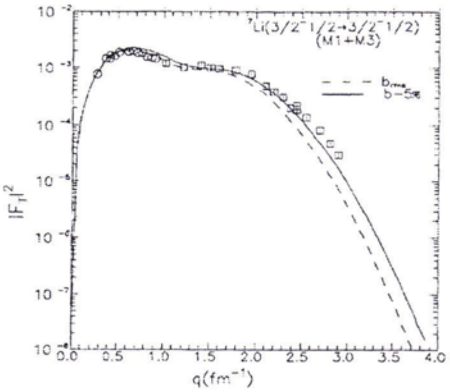

Figure (2): Some as caption to Figure (1), but with b-5%.

Conclusions

The calculations are quite successful and describe the data very well in both the magnetic moment and momentum transfer. We conclude that the calculated (M1+M3) form factors can not explain the experimental data by carrying only the complete multi-nucleon configuration mixing of the ground state of ^{7}Li. The high q-data are sensitive to the size parameter (**b**) of the HO potential and the data are better described when $\mathbf{b}_{\mathbf{rms}}$ is reduced by 5%. The reduction of $\mathbf{b}_{\mathbf{rms}}$ yielded enhancement on the form factor above **q** ~3.5fm^{-1}.

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