Spin-Isospin Properties of Light Nuclei

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(1) Role of \( 3\bar{F}F \) interaction
   - Improved shell model Hamiltonian
   - Effects on spin-dependent modes
     Gamow-Teller transitions
     Magnetic moments
   - Near drip-lines
     \( N=7,8 \)
     Role of LS interaction

(2) Role of tensor interaction
   - Monopole terms of energies
   - Effects on spin-dependent modes
\[ v_M^{T=0} (\text{n-p spin-flip}) \]

\[ M = \text{monopole} \]

Less mixing of \( 0p_{1/2} \) and \( 0p_{3/2} \) orbits

GT, M1 transitions can become more single-particle-like

Weakening of quenching effects in GT and M1 transitions

(Attraction between \( p_{1/2} \) and \( p_{3/2} \) balances this in normal stable nuclei for the energy levels.)
Shell-model interactions

- PSDMK2: p: CK (8-16)2BME , p-sd: MK
  sd, p²-(sd)²: Kuo’s G-matrix
  = 0.3 MeV

- OFU*: Otsuka et al., PRL 87, 082502 (2001)
  = 3.85 MeV
  Vₘ⁰ (p½ , p³ : J= 1, 2 ; T= 0 )
  =-2.0MeV
  For use in the 0-1 configuration space

- SFO:
  = 3.92 MeV
  Vₘ⁰ =-2.14 MeV
  p² - p² renormalized by 0.93
  p² - sd² : renormalized by 0.75
  These renormalizations are
  important to get better agreement of
  spectra in O-isotopes (Sebe).
  For use in the 2-3 configuration space

( present = SFO)
Monopole terms in p-shell

Monopole matrix elements

\[ (\text{MeV}) \]

\[ T=0 \]

\[ \begin{array}{cccc}
\text{C} & \text{T} & \text{Is} & \text{S} \\
(1,1) & & & \\
(2,1) & & & \\
(2,2) & & & \\
\end{array} \]

CK
SFO

C=central  T=tensor  Is=LS  S=Sum

1=0p_{1/2}   2=0p_{3/2}
Energy levels of B and C isotopes
B(GT) values for $^{12}\text{C} \rightarrow ^{12}\text{N}$
B(GT) for $^{11}\text{B} \rightarrow ^{11}\text{Be}$
$^{11}\text{B}(\bar{\nu}_e, e^- \mu^-)^{11}\text{Be}$
Magnetic Moments

s.p. : \[ [ p_{1/2} \quad [ p_{3/2} ] \] \]¹¹¹
\((-g_{p} q + 1/2 g_{q}^s) + 1/2 g_{q}^s = - 0.12 N\)

CK : \( q = 0.778 N \) \( p \) Mixing of \( p_{1/2} \) and \( p_{3/2} \)

![Graph showing M.M. (\( \mu_N \)) for different isotopes and configurations.](image)
Magnetic moments of p-shell nuclei
Magnetic moments with effective $g$ factors
Magnetic moments with effective g factors
Near Drip-Lines

N=7,8

(1) Effective single-particle energies
(2) Structure and magnetic moments of $^{11}\text{Be}$
(3) Levels and transitions in $^{12}\text{Be}$
(4) 2-body LS interaction from M3Y
(5) Energy levels of $^{11}\text{Be}$ and GT transitions in $^{11}\text{Li}$ and $^{12}\text{Be}$
Effective single-particle energies for $N=7$
Effective single-particle energies for N=8
Structure of $^{11}\text{Be}$

- present = SFO
- present' = SFO': $\Box \Box (1s_{1/2}) = -0.5 \text{ MeV}$
- + paring
Levels and E2 transitions in $^{12}$Be

Life time of $0^{2+}$

330ns $\sim 100$ns $\sim 5$ s

exp: Shimoura et al.
Spin-dipole transitions in $^{12}$Be

$^{12}$Be

$0^- + 1^- + 2^-$

SFO, SFO': Splitting of the strength
2-body LS force from M3Y

Monopole matrix elements

(MeV)

LS  T=1  MK  M3Y

j_1  j_2
3  1  0p_1/2
3  2  0p_3/2
4  1  0d_3/2
4  2  0d_5/2
5  1  1s_1/2
5  2  

1=0p_{1/2}  2=0p_{3/2}  3=0d_{3/2}  4=0d_{5/2}  5=1s_{1/2}
LS potential

![Graph showing the LS potential with MeV on the vertical axis and fm on the horizontal axis. The graph includes curves labeled LS odd, M3Y, and MK.]
Levels of $^{11}$Be with 2-body LS from M3Y
GT transitions in $^{11}$Li and $^{12}$Be

<table>
<thead>
<tr>
<th></th>
<th>$^{11}$Li</th>
<th>PSDMK2</th>
<th>SFO</th>
<th>SFO'</th>
<th>SFO-LS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P(p^7)$</td>
<td>88%</td>
<td>60%</td>
<td>39%</td>
<td>28%</td>
<td></td>
</tr>
<tr>
<td>$^{12}$Be</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P(p^8)$</td>
<td>85%</td>
<td>59%</td>
<td>44%</td>
<td>39%</td>
<td></td>
</tr>
</tbody>
</table>

![Graph comparing log ft for $^{11}$Li and $^{12}$Be]
Effects of tensor interaction

Monopole terms from tensor interaction

\[ V_M(j_>, j_<) < 0 \] attractive

\[ V_M(j_>, j_> ) > 0 \] repulsive

\[ V_M(j_<, j_<) > 0 \] repulsive

Monopole matrix elements

![Graph showing monopole matrix elements for different tensor interactions and models. The graph plots (MeV) against various j1 and j2 values, with labels for specific j values (1=0p_1/2, 2=0p_3/2, 3=0d_3/2, 4=0d_5/2) and different models represented by different symbols and styles.](image)
Monopole terms of SFO-T

Monopole matrix elements

tensor \ T=0

- SFO-T
- M3Y
- \pi+\rho
- SFO

\begin{array}{cccccccccc}
  j_1 & 1 & 2 & 2 & 3 & 3 & 4 & 4 & 3 & 4 \\
  j_2 & 1 & 2 & 1 & 2 & 1 & 2 & 3 & 3 & 4 \\
  1=0_{p_{1/2}} & 2=0_{p_{3/2}} & 3=0_{d_{3/2}} & 4=0_{d_{5/2}}
\end{array}
Magnetic moments for SFO and SFO-T
Magnetic moments for SFO and SFO-T
Magnetic moments for SFO-T

\[ |\mu(\text{cal}) - \mu(\text{exp})| \]

\[ \delta g_l, \delta g_s, \delta g_p \]

Tensor \( \pi + \rho \)

\( ^7\text{Li}^8\text{Li}^8\text{B}^9\text{Li}^9\text{Be}^9\text{C}^{10}\text{B}^{11}\text{Li}^{11}\text{Be}^{11}\text{B}^{11}\text{C} \)
Magnetic moments for SFO-T
Magnetic moment of $^9$C

Tensor $\vec{\mu}$

$| \mu p_{3/2} \mu p_{1/2}(J=1), \mu p_{3/2}; 3/2 ->$

J=1          cf. J= 2
$S_z$ 0 0          0 0
$L_z$ 1 -1         1 1
\[ \mu p_{3/2} \mu p_{1/2} \mu \]
$S=1$ 0          0

attractive repulsive

\[ (\mu p_{3/2} \mu p_{1/2}(J)) \]
\[ (J=1) = \frac{5}{6} (\mu p_{3/2}) - \frac{1}{2} (\mu p_{1/2}) \]
\[ = 3.29 \mu_N \]
\[ (^9C) = -1.91 \mu_N^2 + 3.29 \mu_N^2 \]
\[ \mu_N^2 = 0.9, \mu_N^2 = 0.1 \]
\[ \mu exp = -1.39 \mu_N \]

\[ (^9Li) = 3.79 \mu_N^2 - 1.91 \mu_N^2 \]
\[ \mu_N^2 = 0.94, \mu_N^2 = 0.06 \]
\[ \mu exp = 3.439 \mu_N \]
Magnetic moment of $^9\text{C}$ with skin effects

Skin, $<p_2(J, T=1)|V|p_2(J, T=1)>$ (Correspond to isospin and spin mixing)

<table>
<thead>
<tr>
<th></th>
<th>exp.-theory ((\mu_N))</th>
</tr>
</thead>
<tbody>
<tr>
<td>a: SFO</td>
<td>0.3</td>
</tr>
<tr>
<td>b: SFO-T</td>
<td>0.2</td>
</tr>
<tr>
<td>c: SFO-Skin</td>
<td>0.1</td>
</tr>
<tr>
<td>d: SFO-T-Skin</td>
<td>0.0</td>
</tr>
</tbody>
</table>

$^9\text{C}$: \(\delta g_l\), \(\delta g_s\), \(\delta g_p\)
Summary

1. Enhanced spin-flip n-p interaction and tensor component of monopole terms is enhanced with right signs (attractive for \( j_{<j>} \) and repulsive for \( j_{>j>} \) and \( j_{<j<} \)).

   • Weakening of quenching effects in GT transitions

   • Improvements of agreement of calculated magnetic moments with experiments in most of p-shell nuclei

2. Near drip-lines
   Effects are more apparent.
   2-body LS term is found to be important

3. Effects of enhanced tensor interaction are investigated.