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1.25 Mixing of Breathing Oscillation into β-vibrational States

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^{12}C and ^{24}Mg nuclei have been thought to be deformed with oblate and prolate shape, respectively[1,2]. From the level structures, 0_2^+ levels at 7.66 MeV in ^{12}C and 6.43 MeV in ^{24}Mg are thought to be head states of the β-vibrational band of the deformed nuclei. We intended to show a mixing of radial compressional mode of oscillation into the 0_2^+ states using the data of cross section and analyzing power of (p,p') scattering on the 0_2^+ states.

Inelastic scattering of protons on these levels are analyzed by coupled channels (CC) calculation. The CC analyses of (p,p') scattering from light s-d shell nuclei have been shown to be successful in providing the deformation parameters for the ground band states[2,3]. The analyses were also shown to be successful in simultaneous explanation of the cross section and analyzing power data for the β-vibrational states[3]. The CC calculations were done by using the code JUPITOR[4,5] in a modified form in which an L-S potential was included with the full Thomas form. The optical parameters are listed in Table I.

Table I. Optical parameters for 65 MeV protons.

	V MeV	r_R fm	a_R fm	W_V MeV	r_V fm	a_V fm	W_S MeV	r_S fm	a_S fm	V_{SO} MeV	r_{SO} fm	a_{SO} fm
^{12}C	32.3	1.16	0.682	11.20	0.669	0.375	5.10	1.33	0.462	6.56	0.953	0.529
^{24}Mg	37.8	1.14	0.722	8.04	1.39	0.542	1.65	1.39	0.542	5.52	1.00	0.621

r_C=1.25 fm.

The radius parameter $R(\theta')$ is angle dependent according to

$$R(\theta')=R_0 \left| 1+\beta_2 Y_{20}(\theta')+ \alpha_{20}Y_{20}(\theta') \right|.$$

We defined coupling parameter η_β between the ground and 0_2^+ state as

$$\eta_\beta=\langle \text{ ground state } | \alpha_{20} | 0_2^+ \text{ state } \rangle.$$

The breathing oscillation was taken into account assuming a simple radial scaling of the nuclear density distribution with $r'=r(1-\alpha)$[5]. Upon quantization, the deformation parameter α was thought to be an operator. The central part of the optical potential was deformed in the same way as the density. The breathing mode yielded additional terms in the optical potential. The additional term to the central optical potential $V_{central}$ was

$$-\frac{\alpha}{r^2}\frac{d}{dr}(r^3 V_{central}).$$

The extra term arose in the spin orbit potential was

$$-\alpha V_{LS}\left(\frac{\hbar}{m_\pi c}\right)^2\left(\frac{4}{r}\frac{df}{dr}+\frac{d^2f}{dr^2}\right)L\cdot S$$

where f means the usual Woods-Saxon function. We took the same geometrical parameters for the additional L-S term as the original L-S term. The value of the matrix element

$$\eta=\sqrt{4\pi}\ \langle \text{ ground state } | \alpha | 0_2^+ \text{ state } \rangle$$

should be determined to give the best agreement between experimental and theoretical

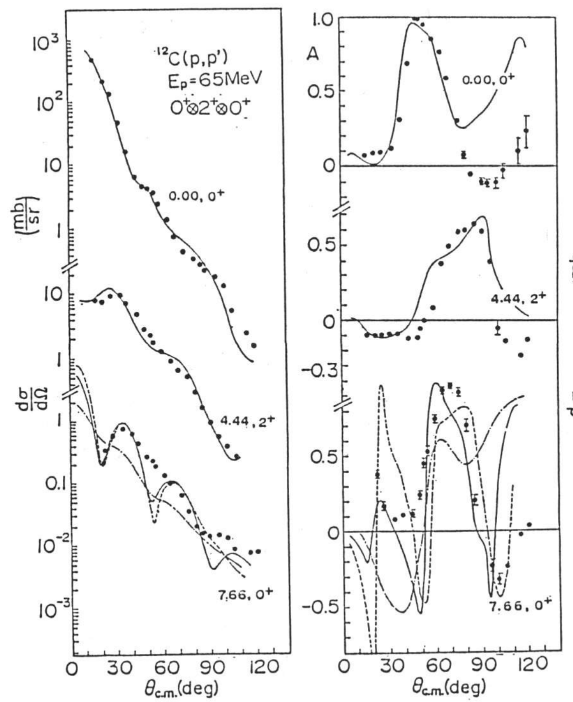

Fig. 1. Data of the cross sections and analyzing powers and CC calculations for (p,p') scattering on ^{12}C exciting 0^+,0.00; 2^+,4.44 and 0^+,7.66 MeV levels. For three kinds of CC curves, see the text.

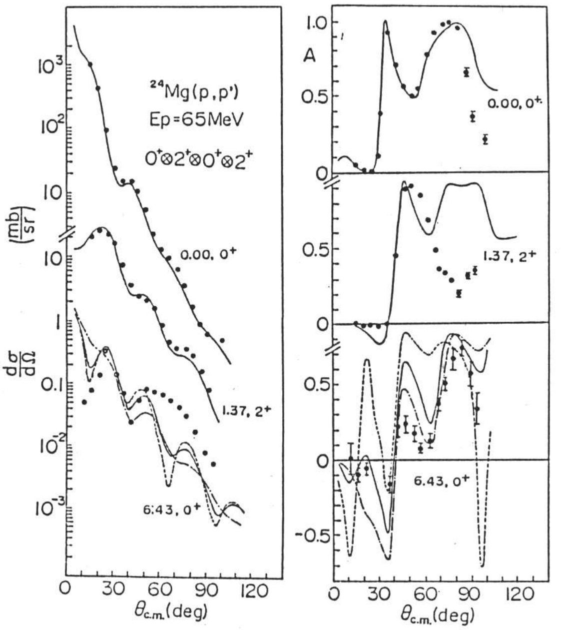

Fig. 2. Data of the cross sections and analyzing powers and CC calculations for (p,p') scattering on ^{24}Mg exciting 0^+,0.0; 2^+,1.37 and 0^+,6.43 MeV levels. For three kinds of CC curves, see the text.

results.

The ^{12}C(p,p') and ^{24}Mg(p,p') data were taken by using the cyclotron at Research Center for Nuclear Physics, Osaka University. The experimental details and the results were already published elsewhere[3]. Comparisons between the data and the CC calculations are shown in Figs. 1 and 2.

In the figures, dashed curves are the results which include the β-vibration alone, dot-dashed curves are those for the breathing oscillation alone and solid curves are those which include both β-vibration and breathing oscillation. In Fig. 1, the deformation length of the ground band $\beta_2 R$ was fixed to be -1.86 fm to fit the CC curve to the cross section data of 4.44 MeV level. The η_β parameter was determined by the data of the 7.66 MeV state and was dependent on η parameter. The η parameter was determined in a way to remove the unphysical dip at 20° of analyzing power CC curve though there are no experimental data around the dip.

In Fig. 2, same curves for ^{24}Mg(p,p') scattering are shown. The unusal dip at θ= 10° in CC curve of analyzing power for 0_2^+ level (dashed curve) was raised toward data by the mixing of the breathing oscillation.

A good fit between the data and CC calculation for 0_2^+ states could only be obtained by including a breathing oscillation in addition to the β-vibration in this level.

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