HIGH RESOLUTION STUDY OF THE RELATIVE DIPOLE STRENGTH DISTRIBUTION IN Sc ISOTOPES*

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Experimental data from the Ca(^{3}He,t)Sc charge exchange reaction on the targets ^{40,42,44,48}Ca at 420 MeV beam energy are presented. The achieved energy resolution of 20 keV, and the measured angular distributions allowed the extraction of the dipole strength for excitation energies lower than 15 MeV in the Sc isotopes for the first time. The possible existence of a new type soft dipole vibration mode is dicussed.

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1. Introduction

During the last few years much interest has been devoted to the experimental investigation of electric dipole strength distribution, in connection with the neutron-skin thickness [1] and with the so-called Pygmy Dipole

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Resonance (PDR) in even–even nuclei. In a macroscopic picture this resonance is described as an out-of-phase oscillation of a neutron skin against an inert core. Therefore, properties such as integrated strength and mean excitation energy of the PDR should strongly depend on the N/Z ratio. The microscopic nature of the pygmy dipole resonance in the stable Ca isotopes has been investigated by Hartmann *et al.*, [2] in high resolution photon scattering experiments for the first time. So far, no high resolution studies have been performed, however, for the dipole strengths distribution excited in charge exchange reactions.

The aim of the present work was to study the fragmentation of the dipole strengths into low-lying excited states in $^{40-48}$Sc. The (^{3}He,t) charge-exchange reaction was used to access the dipole strengths distribution assuming a simple proportionality between the cross-sections and the dipole strength values.

2. Experimental methods and data analysis

The experiment was performed at the Research Center for Nuclear Physics, Osaka University. The ^{3}He beam of 420 MeV incident energy was transported to the self-supporting metallic ^{40}Ca,^{42}Ca,^{44}Ca,^{48}Ca targets with thicknesses of 1.63–1.87 mg/cm^2. The typical beam current was 25 nA.

The energy of tritons was measured with the magnetic spectrometer Grand Raiden, using complete dispersion-matching techniques [3]. The energy resolution was about 20 keV. The spectrometer was set at 0° and 2.5° with an opening angle of ±20 mrad horizontally and ±40 mrad vertically defined by a slit at the entrance of the spectrometer.

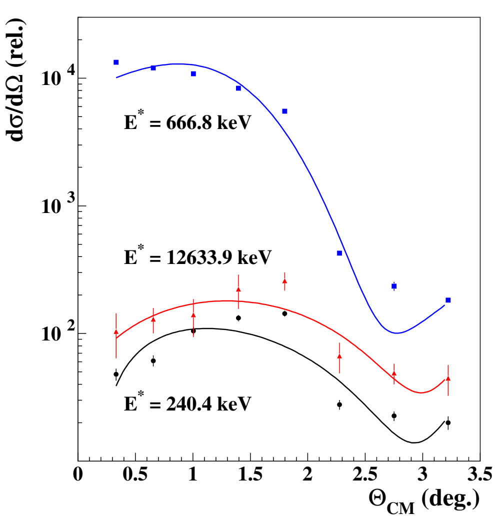

Fig. 1. Angular distribution of a well-known 1^+ level in ^{44}Sc — upper line (blue) and two $\Delta L = 1$ levels shown in lower line (black) and middle line (red).

We analyzed the spectra using the program package: Gaspan. We could fit for the given energy range many peaks at the same time. The peaks were fitted with Gaussians with exponential tails and second order polynomials was used for describing the background. The excitation energies of the IAS's and a few well known excited states were used for determining the energy calibration. The level energies and intensities were determined for each isotope. The spectra were studied in eight distinct angular regions for all Sc isotopes. The angular distributions were determined for each of the known levels, and also for new peaks. They were normalized to the corresponding opening angles.

Fig. 1 shows a few typical angular distributions for 1^+ and $\Delta L = 1$ levels. The angular distributions of the newly identified levels are very similar to those of levels of the same multiploraty known from the literature.

3. Results and conclusions

We have found 609 new excited levels out of the 754 ones observed in the present experiment in the Sc isotopes. Their angular momenta were also determined. We reproduced in 130 cases the values of the well-known excited levels. Table I shows the number of the new $\Delta L = 1$ excited states.

TABLE I

Number of $\Delta L = 1$ states and newly identified levels

	$\Delta L = 1$	New levels	Studied energy region
^{40}Sc	92	105	0.4–16.0 MeV
^{42}Sc	81	150	0.0–15.1 MeV
^{44}Sc	59	189	0.0–14.2 MeV
^{48}Sc	45	165	0.0–14.5 MeV

In the following step we collected the levels with $\Delta L = 1$ (0^-, 1^-, 2^-) corresponding to dipole (spin–dipole) transition. Figure 2 shows the obtained dipole strengths distributions for ^{40}Sc,^{42}Sc, ^{44}Sc and ^{48}Sc.

The dipole strength distribution in ^{40}Sc shows some interesting periodic feature, which is clearly seen in Fig. 2 (e). It resembles to a soft, fragmented vibrational band with $\hbar\omega = 1.8$ MeV. Pygmy dipole resonances might play a more enhanced effect in the heavier isotopes. The strong peaks observed in the strength between 8 and 11 MeV for the different isotopes might be identified as pygmy resonances. This is indicated also by Hartmann *et al.* [2]. However, in heavier isotopes the pygmy resonances dominate the distribution so we have not observed such an enhanced periodic feature. In a simple macroscopic liquid-drop model description of the vibration, the restoring force should be much softer compared to the one of the giant dipole

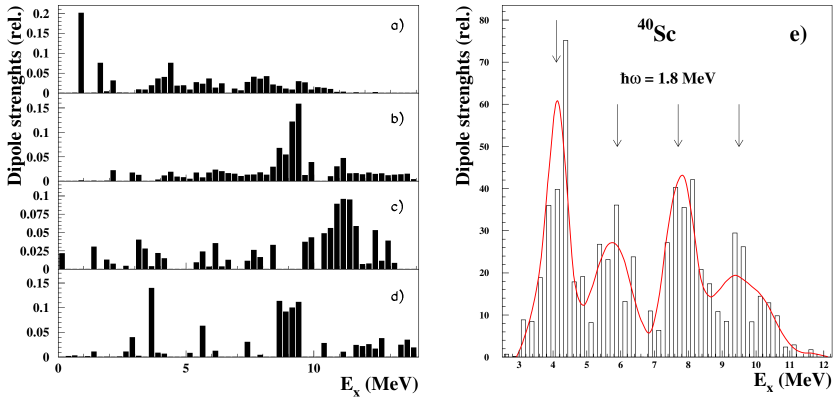

Fig. 2. Relative dipole strengths distributions for ^{40}Sc (a), ^{42}Sc (b), ^{44}Sc (c) and ^{48}Sc (d) as a function of the excitation energy. The distribution for ^{40}Sc is also shown separately (e) with a smoothed (red) curve produced by spline, and with arrows placed with equidistant energy gaps suggesting the presence of a dipole vibrational band.

resonance, which is located at around 22 MeV in ^{40}Ca. In a paper published recently [4] the unique nature of the $N = Z$ nuclei is expressed, in which enhanced correlations arise between neutrons and protons. Since the (^{3}He,t) reaction preferentially excites spin–isospin flip modes, such correlations might play an enhanced role in ^{40}Sc. That might give rise to a new type of nuclear superfluidity; isoscalar neutron–proton pairing in addition to the normal isovector modes, which might explain the considerable softening of the restoring force of the vibrations. Two-particle two-hole correlations in the ground state of ^{40}Ca might also play a role in enhancing the low-energy dipole strengths in ^{40}Sc, which would complicate the above description.

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