Study of resonance states in ^{26}Si by elastic scattering of ^{22}Mg+α

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The data of ^{26}Si are important not only in the astrophysics but also in the nuclear structure. The resonance states of ^{26}Si are valuable for investigating the reaction rate of $^{22}Mg(\alpha,p)^{25}Al$ and $^{25}Al(p,\gamma)^{26}Si$ reactions in the Supernovae II and X-ray bursts, which are important in understanding the astrophysical nomalies. In addition, the alpha-cluster structure, above the alpha decay threshold (E_{thr} = 9.164 MeV), is expected to be obtained in the ^{26}Si nucleus because of the alpha-cluster threshold rule. Futhermore, although the energy levels of the mirror nucleus, ^{26}Mg, are well-known, there are many unknown spin-parities. These quantum parameters can be assigned using the ^{26}Si data. There were some experimental efforts for the levels near and above the alpha decay threshold, but the data is still limited. Several resonance states in the energy region considered were obtained by the works in ref.[1, 2], but such states had a large uncertainty because of unknown spin-parities. Therefore, we performed the elastic scattering of the $^{22}Mg(\alpha,\alpha)^{22}Mg$ reaction using a radioactive ion (RI) beam of ^{22}Mg to obtain the experimental data corresponding to the mentioned aims for ^{26}Si at the CRIB facility of RIKEN in October 2011. We performed the experiment of $^{22}Mg+\alpha$ by applying the thick-target method using the active-target detector GEM-MSTPC in inverse kinematics.[3] The RI beam of ^{22}Mg, which was produced via the $^{3}He(^{20}Ne,^{22}Mg)n$ reaction, with the intensity of 1200 particles/s satisfied the energy condition of E_{cm} = 0.5 – 3.0 MeV in the center-of-mass of the elastic scattering $^{22}Mg(\alpha,\alpha)^{22}Mg$.[4] Therefore, the energy corresponded to the region of E_x = 9.5 – 12.5 MeV in ^{26}Si. The RI beam was incident on the gas target, which was a gas mixture of ^{4}He+CO_2 (10%) at 140 Torr at room temperature. The gas was filled in a chamber in which the electrode structures of GEM-MSTPC and arrays of silicon detector telescopes were installed. The trajectory and timing information of the incoming ^{22}Mg were obtained using the beam monitors PPACs for particle identification. The ejectiles coming from the elastic scattering $^{22}Mg(\alpha,\alpha)^{22}Mg$ were distinguished from those due to the $^{22}Mg(\alpha,p)^{25}Al$ reaction based on the ΔE-E method by using the information from the silicon telescopes. The events due to the elastic scattering and the production of the beam contaminants were identified based on the Bragg curves of the outgoing ^{22}Mg and the contaminants determined by GEM-MSTPC.

The data were analyzed event by event. The calculation of the kinematics was carried out by considering the energy loss of the projectile measured by the active-target detector. The energy of alphas was measured by the active-target detector and the silicon telescopes. The excitation function of the cross section of the elastic scattering $^{22}Mg(\alpha,\alpha)^{22}Mg$ could be determined in the forward angles, which related to 0-5 degrees and 5-10 degrees in the laboratory frame. The resonances in the excitation function were applied to the R-matrix analysis performed by the AZURE code[5] to deduce the quantum quantities of the resonance states of ^{26}Si above the alpha threshold. We could obtain six states, in which three new states (11.245, 11.493, and 11.807 MeV) and three lower states matched well with the results obtained by previous works.[1, 2] In addition, the spin-parity assignment for the first and sixth states is satisfied with two values, as shown in Table 1.

Table 1. The resonance states above the alpha threshold of ^{26}Si obtained by the elastic scattering of ^{22}Mg(α,α)^{22}Mg.

Levels	E_r (MeV)	Γ(MeV)	J^{π}
1	10.325 ± 0.071	0.218 ± 0.011	$(2^+, 1^-)$
2	10.678 ± 0.016	0.194 ± 0.006	0^+
3	10.831 ± 0.113	0.186 ± 0.013	1^-
4	11.245 ± 0.028	0.208± 0.027	4^+
5	11.493 ± 0.216	0.292 ± 0.010	3^-
6	11.807 ± 0.117	0.156 ± 0.032	$(0^+, 2^+)$

According to the study in ref.[6], the first, third, and sixth level in the ^{26}Si nucleus are very close to the three resonances located at 10.300 MeV (0^+), 10.844 MeV (1^-), and 11.828 MeV (2^-), respectively, in ^{12}C. In addition, such states of ^{12}C might have a structure of 3α.[7] Therefore, the ^{26}Si may exist under alpha cluster as a structure of (p+3α+3α+p).

The direct measurement of alpha elastic scattering was performed for the first time. The data of ^{26}Si is very limited so far. The cluster structure of the isotopes with a number of nucleon nearby the value of 4N (N = 2, 3, 4…) is very uncertain. Hence, we need such type of data significantly more to investigate the structure of ^{26}Si in future.

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