We performed a test measurement of $^{17}$Ne+p for observing proton-rich unbound $^{18}$Na nucleus. Information of $^{18}$Na resonances might be useful for studying direct two proton decay of $^{19}$Mg[1] and also a possible two-proton halo structure of $^{17}$Ne[1][2][3][4][5]. There is few experimental data on $^{18}$Na: an invariant mass spectrum of $^{17}$Ne+p was measured at GANIL using a projectile fragmentation reaction of $^{20}$Mg at 43 MeV/u [6]. Two large peaks were observed in the spectrum at $\Delta = 24.19$ and 25.04 MeV (peak 1 and 2, respectively), where $\Delta$ denotes the $^{18}$Na mass excess. The peak 1 and 2 may be assigned to the ground and the first excited states, respectively. However, $\Delta = 24.19$ MeV for the ground state is significantly lower than theoretical predictions of around 25.3 MeV [6][7]. There is a possibility that the peak 1 is due to the decay $^{18}$Na$_{g.s.}$ $\rightarrow$ $^{17}$Ne$_{g.s.}$+p and the peak 2 is due to the decay $^{18}$Na$_{g.s.}$ $\rightarrow$ $^{17}$Ne$_{g.s.}$+p. It is also pointed out that the experimental resolution is about 250 keV and each of the peaks might contain two levels [7]. To observe the $^{18}$Na resonance levels more directly, we planned measuring $^{17}$Ne+p resonance elastic scattering at the CRIB beam line in the RI Beam Factory. We performed a beam production test and a test measurement of $^{17}$Ne+p scattering as the first step.

The secondary $^{17}$Ne particles were produced using the $^3$He($^{16}$O,$^{17}$Ne)2n reaction at $E_{\text{beam}} = 11.0$ MeV/u and separated by the CRIB separator, which has three focal planes (F1, F2, and F3). The secondary particles were selected at the dispersive focal plane F1 with a momentum width of $\pm 1.6\%$. The Wien filter section between F2 and F3 was used to select particles by velocity. Two parallel plate avalanche counters (PPACs) were mounted in a chamber at F3 to monitor the beam position and direction and time-of-flight (TOF) between the two PPACs. The beam spot size at F3 was approximately 15 mm diameter (FWHM). The $^{17}$Ne purity in the secondary beam was 2 \%, which was not a problem for measuring the $^{17}$Ne+p scattering because we could identify beam particles on an event-by-event basis using the TOF information. Major contaminants in the secondary beam were $^{14}$O and $^{18}$Ne. The $^{17}$Ne beam energy was 4.9 MeV / nucleon after the second PPAC. During the present experiment, we had a primary $^{16}$O (7+) beam intensity of 150 pna, which was half of the maximum record intensity, due to a trouble in the cyclotron RF resonator. The secondary $^{17}$Ne beam intensity was approximately 500 particles/sec with the 150 pna primary beam.

Using the produced $^{17}$Ne+p measurement for 20 hours. Figure 1 shows the experimental setup at F3. A (CH$_2$)$_n$ target of 10 mg/cm$^2$ was mounted at the downstream side of the second PPAC and used as a proton target. We utilized a thick-target method in inverse kinematics (TTIK) [8][9] for deducing the $^{17}$Ne+p excitation function. The beam particles were completely stopped in the target, while recoil protons were detected by a Si detector telescope at $\theta = 0\degree$ (LAB). The Silicon detector telescope consisted of a double-sided strip detector (DSSD) with 16 + 16 strips for $\Delta E$ information and a single pad detector for $E$ information. The $\Delta E$ and $E$ detectors were 70 and 1500 $\mu$m thick, respectively, and had the same sensitive area of 50 $\times$ 50 mm$^2$. The distance of the telescope from the target was 15 cm. Identification of proton was made using the $\Delta E$ and $E$ information. The proton scattering angle was determined using the PPAC and DSSD information. The proton energy was deduced from the sum of $\Delta E$ and $E$. We performed proton energy calibration using secondary proton beams of known energies. In order to deduce the $^{17}$Ne+p excitation function, we reconstructed the center-of-mass energy on an event by event basis from the proton energy and angle by taking into account the elastic scattering kinematics and also energy losses of $^{17}$Ne and proton in the target.

Figure 2 shows a preliminary result of the $^{17}$Ne+p excitation function. We found a narrow peak at $E_{\text{CM}} \sim 2.05$ MeV, which may be attributed to a $^{18}$Na level. The intrinsic peak width was roughly estimated to be $\Gamma \sim 100$ keV from the spectrum by taking into account the energy resolution. Because the peak width is narrow enough, we may neglect interference effects and assume that the peak energy and the width are roughly the same as the level energy and width, respectively. The level energy of $E_{\text{CM}} \sim 2.05$ MeV corresponds to a mass excess of $\Delta \sim 25.80$ MeV, which is a little higher than the prediction of 25.3 MeV for the ground state [6][7]. One possible interpretation is therefore that the
The observed level is one of low-lying excited levels. The narrow width for the \(^{17}\)Ne+p resonance is probably due to the \(l = 2\) orbital angular momentum, which is consistent with the \(d_{5/2}\) or \(d_{3/2}\) orbital predicted for the last proton in the low-lying \(^{18}\)Na levels.

Using \(^{14}\)O contaminant in the secondary beam, we also simultaneously measured an \(^{14}\)O+p spectrum to check the energy calibration. A sharp peak in Fig. 3 at \(E_{CM} \sim 2.7\) MeV is attributed to the first excited \(^{15}\)F level with a resonance energy of \(E_R \sim 2.8\) MeV. Note that the energy at which cross section is maximum is a little lower than \(E_R\) in the present case due to interference effects. The peak position agrees with previous results of \(^{14}\)O+p experiments [10][11] within 50 keV. Since the present test measurement was performed in a limited time, we did not measure a spectrum with a C target for estimating a background contribution from C atoms in the \((\text{CH}_2)_n\) target. The observed peak probably is not due to \(^{17}\)Ne(p,p\(^\prime\)) inelastic scattering because the peak has a relatively large yield in the spectrum. We, however, did not measure angular dependence of the peak energy in a wide angular range, and therefore could not completely exclude the inelastic scattering. The present test experiment confirmed the feasibility of the experimental method for the \(^{17}\)Ne+p resonance scattering.

A future measurement with high statistics, with angular information, and with background subtraction may clarify the ambiguity in \(^{18}\)Na level assignments.

References