Highly excited high spin states in $^{22}$Ne


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The main aim of this work is to study the high spin states of some highly excited levels in $^{22}$Ne and to investigate their nature. The data on the presence of highly excited high-spin states in $^{22}$Ne which decay by $\alpha$-particles were obtained previously using the $^{18}$O+$^{12}$C reaction (see [1] and references therein). However, in spite of a number of theoretical predictions for the properties of the $^{22}$Ne quasimolecular bands [2], mainly experimental data are available only for the low lying levels which decay by $\gamma$-rays [3,4]. The scarce information on high-spin states in $^{22}$Ne is in strong contrast with the data on $^{20}$Ne, where many high-spin states were interpreted as members of ten rotational bands [5].

We used the $^{14}$C($^{12}$C, $\alpha_1$)$^{22}$Ne$^*$$\rightarrow$$\alpha_2$+$^{18}$O reaction to populate high spin states in $^{22}$Ne. If $\alpha_1$ detected at zero degrees, then the $\alpha_1$- $\alpha_2$ angular correlations provide for a reliable way to make spin-parity assignment. The angular correlation function, $W(\theta)$, will be

$$W(\theta) \sim (2J + 1) / 4\pi [P_J(cos\theta)]^2$$

where $\theta$ is the angle of the second $\alpha$-particle, $J$ is the spin of the level in neon and $P_J$ is the ordinary Legendre polynomials.

Experiment

The experiment was carried out using the K-130 Cyclotron of the University of Jyvaskyla, Finland and a 44 MeV $^{12}$C beam. The target was a self-supporting carbon foil with a thickness of 280 $\mu$g/cm$^2$ (80% of $^{14}$C). A schematic of the experimental arrangement is shown in fig. 1. The primary $\alpha$-particle was detected using two 10 mm$^2$ silicon detectors of $380 \mu$m thickness placed at $\pm 3^0$ (below and above the horizontal plane) behind a $15 \mu$m platinum foil used to absorb the elastically scattered $^{12}$C ions. The $\alpha$-particles were separated from other light products by pulse-shape discrimination techniques [6]. The $\alpha$-particles from the decay of states in $^{22}$Ne were detected in $dE - E$ detector telescopes. Each telescope consisted of a position-sensitive gas proportional counter used as the $dE$ detector combined with 10 silicon PIN diodes as $E$ detectors. The total active area of the $dE - E$ detectors is $18 \text{ cm}^2$. The thickness of the fully depleted PIN diodes was $380 \mu$m. The $dE$ gas proportional counter has a single resistive wire and measures the energy loss of the particles and the $X$-coordinate of the points of
penetration. The counter was filled with Ar+10% CH4 gas mixture (pressure 250 Torr). A continuous renewing of the gas in the counter volume was provided. The length of the detectors (100 mm) spanned 40° in the laboratory system. The angles at the center of each diode were measured with the precision of better than ±0.5°. The (α-α) double coincidence events were analyzed to generate the α2 angular distributions for the decays to the ground state of 18O. The decay channel was selected using a two-dimensional plot E\(\alpha_2\) versus E\(\alpha_1\) at each α2 angle as given by the position sensitivity of the α2 detector.

Results

The measured angular correlation functions together with a fit by squared Legendre polynomials are shown in Fig. 1. Results of the analysis are summarized in Table I.
Table I. \(^{22}\text{Ne}\) levels. Energy, spin and parity information from this and other work.

<table>
<thead>
<tr>
<th>Present work</th>
<th>Adopted levels</th>
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<tbody>
<tr>
<td>17.0 MeV (unres. group)</td>
<td>17.05 MeV 7(^-) [23]</td>
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<tr>
<td>18.45 MeV (\Gamma \sim 330) keV</td>
<td>18.42 MeV 7(^-) [22]</td>
</tr>
<tr>
<td>19.13 MeV (unres. group)</td>
<td>19.28 MeV 7(^-) [9]</td>
</tr>
<tr>
<td>20.0 MeV 9(^-) (\Gamma \sim 270) keV</td>
<td>19.89 (10(^+)) [12]</td>
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<tr>
<td>20.7 MeV 11(^-) (\Gamma \sim 340) keV</td>
<td>20.85 MeV 9(^-) [9]</td>
</tr>
<tr>
<td>21.6 MeV 9(^-) (\Gamma \sim 350) keV</td>
<td>21.84 9(^-) [9]</td>
</tr>
<tr>
<td>22.2 MeV 12(^+) (\Gamma \sim 250) keV</td>
<td>(22.2) MeV [22]</td>
</tr>
<tr>
<td>22.9 MeV (\Gamma \sim 290) keV</td>
<td>24.14 MeV [24]</td>
</tr>
<tr>
<td>24.0 MeV (unres. group)</td>
<td>24.14 MeV [24]</td>
</tr>
<tr>
<td>25.0 MeV 9(^-) (\Gamma \sim 350) keV</td>
<td>25.0 MeV [24]</td>
</tr>
<tr>
<td>25.9 MeV (unres. group)</td>
<td>26.89 MeV [24]</td>
</tr>
</tbody>
</table>

A very characteristic back bending observed for the high spin states with the positive parity in \(^{22}\text{Ne}\) and the comparison with \(^{20}\text{Ne}\) (Fig.2) evidences that new 12\(^+\) level is the yrast level in \(^{22}\text{Ne}\).

**FIG. 2.** Effective moment of inertia versus of the square of the rotational frequency for the \(^{20}\text{Ne}\) and \(^{22}\text{Ne}\) yrast lines. The inset compares the yrast-spin trajectories for these nuclei as was obtained in [10].
Summary

The spins of five highly excited states in $^{22}\text{Ne}$ were determined by measuring double $\alpha$-$\alpha$ angular correlations $^{14}\text{C}(^{12}\text{C},\alpha_{1})^{22}\text{Ne}^{*} \rightarrow \alpha_{2}+^{18}\text{O}$ reaction. The 22.2 MeV (12$^{+}$) state is assigned to the yrast line of $^{22}\text{Ne}$ in good agreement with theoretical prediction based on the Nilsson-Strutinsky formalism. The states at 20.7 MeV (11$^{-}$) and 21.6 MeV (9$^{-}$) were considered as members of the $\alpha$-cluster rotational bands supporting the cluster model predictions.