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LEVELS OF ^{20}Ne FROM RADIATIVE ALPHA-CAPTURE IN ^{16}O

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Radiative alpha-capture in ^{16}O is considered to be the principal process in the stellar production of ^{20}Ne. The rate of this process depends critically on the properties of the 4.97, 5.62 and 5.79 MeV levels of ^{20}Ne [1]. The $J^{\pi} = 2^-$ assignment to the 4.97 MeV level excludes this level from contributing to the synthesis of ^{20}Ne [2]. The investigation of the $^{16}O(\alpha,\gamma)^{20}Ne$ reaction, reported here, was undertaken to determine the resonance strengths and partial widths of the "astrophysical levels of ^{20}Ne" [3] at 5.62 and 5.79 MeV, with $J^{\pi} = 3^-$ and 1^- respectively [4], and also those of the next level at 6.72 MeV, with $J^{\pi} = 0^+$ [5].

From the viewpoint of nuclear structure studies, these measurements are also of interest, since they extend the recent determinations of the radiative widths of the low-lying ^{20}Ne levels [6] to the next higher excited states.

In the ranges of interest $^{16}O(\alpha,\gamma)^{20}Ne$ yield curves were measured with natural SiO_2 and CaO targets. One of these is given in fig. 1. The two lowest resonances stand out clearly, but the third one is partially obscured by the $^{18}O(\alpha,n)^{21}Ne$ resonance at 2.47 MeV [7], which produces neutron-capture gamma rays. Measurements of the gamma-ray spectra at the three resonances confirm the assignment to the reaction under investigation. So far, a search for the doubtful level at 6.17 MeV [8] has been inconclusive.

A survey of the resonance data is given in table 1. The $^{28}Si(\alpha,\gamma)^{32}S$ resonance at 2618 ± 4 keV [9], measured with the same target, was used for the energy calibration. The ^{20}Ne excitation energies are calculated with the reaction Q value, $Q = 4729.7 \pm 0.5$ keV [10]. The resonance strengths, determined from the yield of a thick SiO_2 target, indicate that the contribution

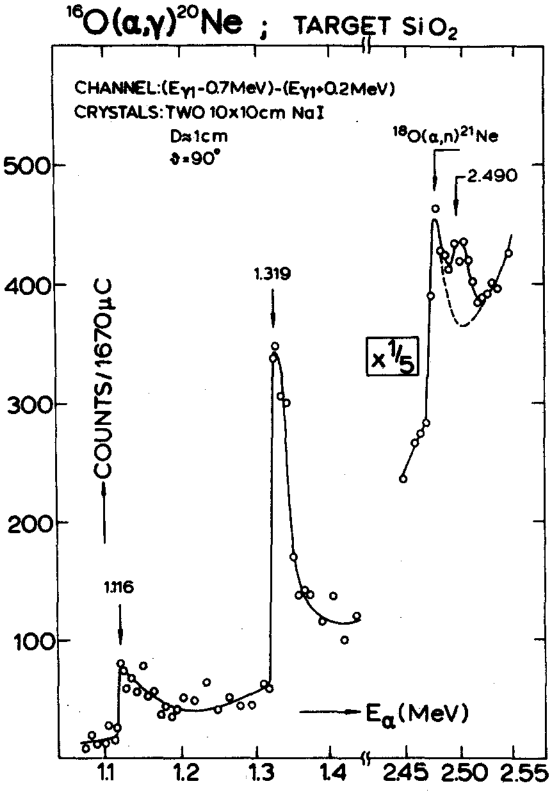

Fig. 1. Yield curve of the $^{16}O(\alpha,\gamma)^{20}Ne$ reaction measured with a SiO_2 target. The points represent the sum of the number of pulses detected in two 10 × 10 cm^2 NaI crystals, positioned as close to the target as possible (D = 1 cm) at 90° with respect to the proton beam. The gamma-ray channel, 0.9 MeV wide, was gradually adjusted to include primarily the transition to ^{20}Ne(1.63). Room-background has been subtracted. The dotted line gives the shape of the (α, n) resonance as measured with a higher setting of the gamma-ray channel.

Table 1
Resonances in the reaction $^{16}O(\alpha,\gamma)^{20}Ne$.

E_α (keV)	$^{20}Ne^*$ (keV)	main decay (in perc.) γ_0	γ_1	$(2J+1)\Gamma_\gamma\Gamma_\alpha/\Gamma$ (meV)	J^π a)	Γ_γ b) (meV)	Γ_α c) (meV)	θ_α^2 d)
1116 ± 4	5623 ± 4	< 15	100	1.4 ± 0.4	3^-	0.20	2.6	0.006
1319 ± 3	5785 ± 3	18 ± 5	82 ± 5	12 ± 3	1^-	4.0	$> 13 \times 10^3$	> 0.9
2490 ± 8	6722 ± 8	< 10	100	33 ±15	0^+	33	19×10^6	0.7

a) Literature values [4, 5]. The spin and parity of the 1319 keV resonance were confirmed in an angular distribution measurement of the ground-state transition.
b) $\Gamma_\alpha \gg \Gamma_\gamma$ [12], therefore $\Gamma_\gamma\Gamma_\alpha/\Gamma = \Gamma_\gamma$.
c) The widths of the first two resonances are calculated from Γ_γ, using the relation $\Gamma_\gamma/\Gamma = 0.077$ and $< 3 \times 10^{-4}$, respectively [12]; for the 2490 keV resonance Γ_α is given in ref. 7; this value is in agreement with our rough estimate of 15 ± 7 keV.
d) Calculated with $r_0 = 1.2$ fm.

Table 2
Transition strengths in ^{20}Ne.

E_α(keV)	E_γ(MeV)	Transition	$J_i \rightarrow J_f$	Type	Γ_γ (meV)	$\lvert M\rvert^2 = \Gamma_\gamma/\Gamma_{\gamma w}$
1116	(5.62)	5.62 → 0	$3^- \rightarrow 0^+$	E3	0.017 a)	10
	3.98 ± 0.03	5.62 → 1.63	$3^- \rightarrow 2^+$	E1	0.20 b)	6.3×10^{-6}
1319	5.81 ± 0.05	5.79 → 0	$1^- \rightarrow 0^+$	E1	0.7	7.2×10^{-6}
	4.17 ± 0.03	5.79 → 1.63	$1^- \rightarrow 2^+$	E1	3.3	9.2×10^{-5}
				M2	⩽ 0.016	⩽ 0.12
2490	5.13 ± 0.04	6.72 → 1.63	$0^+ \rightarrow 2^+$	E2	34	3.8

a) Calculated with the branching ratio given in ref. 13.
b) Within the experimental errors, this value is in agreement with recent lifetime measurements [6, 13].

of the 5.79 MeV level to the synthesis of ^{20}Ne might be an order of magnitude higher than that of the 5.62 MeV level. The last columns of table 1 give the partial widths deduced from the resonance strengths. The large θ_α^2 of the 5.79 MeV level is consistent with the large values found for other levels in the same rotational band.

The gamma-ray energies measured at the three resonances are listed in table 2. Since J^π is known for all levels involved in the decay, the type of radiation is unambiguous for all transitions to or from a $J^\pi = 0^+$ level. The amplitude mixing ratio of the 4.17 gamma ray, $x = -0.03 \pm 0.04$, was determined from the analysis of double and triple angular correlation measurements at the 1319 keV resonance. The 3.98 MeV transition is known to have nearly pure E1 character [13].

The $\lvert M\rvert^2$-values of the E1 transitions fall on the low side of the $\lvert M\rvert^2$-distribution for T-forbidden E1 transitions in $A = 20-40$ nuclei [11]. This might reflect on the T-spin purity of these relatively low-lying ^{20}Ne levels. The strength of the 3.98 MeV E1 transition is insufficiently low for the interference of any $\Delta K = 2$ inhibition. The strength of the 5.13 MeV interband E2 transition, which falls within the normal range of E2 strengths in A = 20-40 nuclei, is about a factor of four lower than those of other recently measured intra-band E2 transitions in ^{20}Ne [6].

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