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11 262 keV 1^+ state in ^{20}Ne

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The excitation energy of the lowest 1^+, $T=1$ state in ^{20}Ne, which is important for parity nonconservation studies, has been determined in a photon scattering experiment to be $11\,262.3 \pm 1.9$ keV. Values for the γ-ray branching of this level to the ground state and to the first 2^+ level in ^{20}Ne are $84 \pm 5\%$ and $16 \pm 5\%$, respectively.

[NUCLEAR REACTIONS ^{20}Ne(γ,γ), $E_\gamma < 18$ MeV, bremsstrahlung; measured E_γ, γ branching. Ne natural targets.]

Striking concentration of magnetic dipole strength in ^{20}Ne into one level at 11.22 ± 0.05 MeV has been observed in an inelastic electron scattering experiment by Bendel *et al.*[1,2] The exact excitation energy of this 1^+, $T=1$ level is of special importance for parity nonconservation studies.[3–5] Energetically very close to the 1^+ level are two $J^\pi = 1^-$ states. The energy of the broad ($\Gamma = 170$ keV) $T=0$, 1^- state is reported to be 11.261 ± 0.005 MeV (Ref. 6) and the values for the excitation energy of the narrow ($\Gamma < 0.3$ keV) $T=1$, 1^- state scatter between $11\,268 \pm 4$ keV (Ref. 6) and $11\,273 \pm 4$ keV.[7]

As pointed out by Davidson and Lowry[3] the observable quantities for a parity nonconserving nucleon-nucleon interaction [the circular polarization P_γ of ^{16}O(α,γ) capture γ rays from the $T=1$, 1^- state to the ground state in ^{20}Ne or the parity nonconserving α decay width $\Gamma_\alpha^{\rm PNC}$ for the 1^+ state[5]] are very sensitive to the energy differences ΔE between the 1^- states and the 1^+ level.

The energies, however, reported for the 1^+ state range from 11.22 to 11.27 MeV.[1,8–12] The adopted value for the excitation energy of the 1^+ state in the most recent compilation of Ajzenberg-Selove is $E_x = 11.23 \pm 0.01$ MeV.[6]

We have performed nuclear resonance fluorescence experiments to determine the exact excitation energy of the 1^+ state in ^{20}Ne, and to find out, with the good energy resolution of Ge(Li) detectors (full width at half maximum of the peaks ≤ 10 keV at about 10 MeV γ-ray energy), if possibly more than one level contributes to the strong $M1$ excitation seen in ^{20}Ne(e,e').

The ^{20}Ne(γ,γ') experiments were performed at the bremsstrahlung beam of the University of Giessen 65 MeV electron linear accelerator. Two well shielded 100 cm^3 Ge(Li) detectors recorded scattered γ rays at 90°, 125°, or 127.6° with respect to

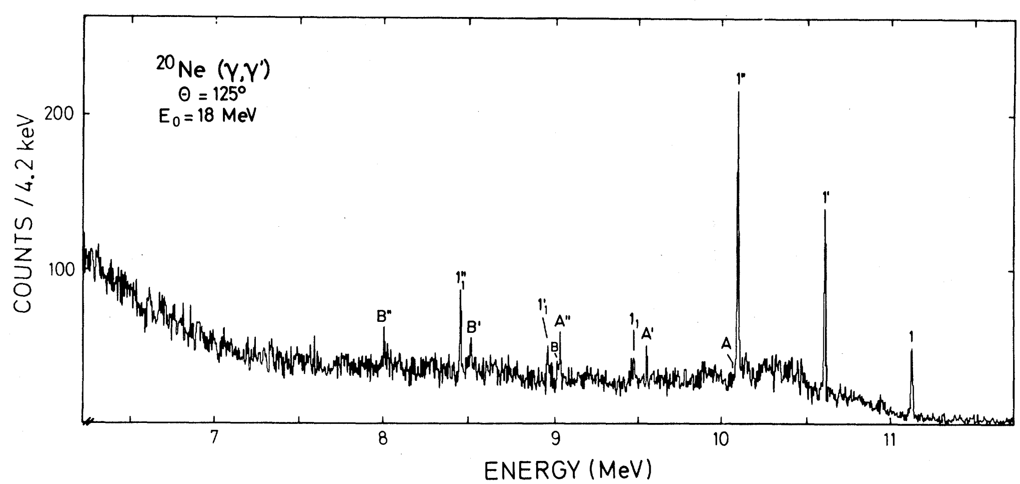

FIG. 1. Spectrum obtained at 125° with help of a Ge(Li) detector from photon scattering of 18 MeV bremsstrahlung on natural neon gas. Single- and double-escape peaks due to a transition are labeled with one and two primes, respectively. The measured excitation energies and branching ratios are given in Table I.

TABLE I. Transitions observed in the nuclear resonance fluorescence experiment on neon. Peak labeling corresponds to Fig. 1.

Nucleus	Peak No.	Transition Energy (keV)	Final state	Branching (%)
^{20}Ne	1	11 262.3 ±1.9	g.s.	84 ±5
	1_1	9628.6 ±1.9	1633.7	16 ±5
^{22}Ne	*A*	10 212.3 ±2.9	g.s.	
	B	9177.5 ±2.4	g.s.	

the incident beam. The target chamber of 12 cm length and 7 cm diameter contained natural Ne gas under a pressure of 3.3 bars. A detailed description of the experimental setup can be found in Refs. 13 and 14.

Part of a ^{20}Ne(γ,γ') spectrum measured at $\theta=125°$ with 18 MeV bremsstrahlung is depicted in Fig. 1. As in the ^{20}Ne(e,e') experiment[1] at $\theta=180°$ one strong transition dominates the ^{20}Ne(γ,γ') spectrum. A γ ray (labeled 1_1) from the decay of this level to the first excited state at 1633.7 keV in ^{20}Ne is also observed. Weaker peaks, which are tagged by capital letters in Fig. 1, stem from the 9.2% content of ^{22}Ne in natural neon gas. Energies and γ-ray branching of the transitions observed are given in Table I.

A ^{28}Si target was placed inside the ^{20}Ne gas for the energy calibration experiments. The nucleus ^{28}Si exhibits a strong $M1$ transition with a very well known excitation energy [11 446.2 ±0.5 keV (Ref. 15)]. This experimental arrangement allowed a simultaneous measurement of the ^{20}Ne and ^{28}Si transitions and, thereby, an exact determination of the excitation energy of the transition in ^{20}Ne. For this purpose the observed γ-ray energies of the scattered photons were corrected for recoil from the absorbed and emitted photon.

The excitation energy of the 1^+, $T=1$ state in ^{20}Ne obtained from this experiment is $E_x=11\,262.3\pm1.9$ keV. The error contains a 1.4 keV experimental standard deviation $s=\{[1/(N-1)]\sum(\Delta E_x)^2\}^{1/2}$ representing the observed scattering of the transition energies ΔE_x from the mean value $\bar{E}$. This $\bar{E}$ was calculated from the fitted peak positions of full energy, single and double escape peaks in spectra being recorded in different runs. The 0.5 keV calibration error from the aforementioned 11 446.2 keV level in ^{28}Si was added linearly.

Kuhlmann *et al.*[10] report observation of a 1^+ level at $E_x=11\,252\pm2$ keV from an ^{19}F($d,n\gamma$) experiment. On the other hand, Davidson and Sargood[16] remeasured the excitation energy of this state with the same reaction and found $E_x=11\,263.9\pm1.0$ keV. The results from ^{19}F(d,n) studies, where the energy of the outcoming neutrons was measured, are $E_x=11.259\pm0.010$ (Ref. 8) and 11.26 ±0.04 MeV.[9]

The measured γ-ray branching of the 1^+ state to the ground state from this ^{20}Ne(γ,γ') experiment is 84 ±5%, and 16 ±5% to the first excited state.

Excitation energy and γ-ray branching are in very good agreement with a branching of 83% and 17% to the ground and first excited state, respectively, reported by Ingalls[12] for a 1^+ state at 11 261 ±5 keV in ^{20}Ne populated in the β^+ decay of ^{20}Na, and shown by him to be very probably the level seen in (e,e').

There are obviously no other strong transitions in the neighborhood of the 11 262.3 keV transition as can be seen from Fig. 1. If we adopt the ground state decay width of $\Gamma_{\gamma0}=11\pm2$ eV for the 1^+ state from the ^{20}Ne(e,e') experiment,[1] we calculate a lower detection limit $\Gamma_{\gamma0}^2/\Gamma$ between 0.5 and 1.0 eV in the energy range from 7 to 12.8 MeV. The photon scattering experiments were performed with 18 MeV bremsstrahlung but the particle threshold for proton decay at 12.8 MeV limits this experiment to excitations below that threshold.

In summary we find that the $M1$ transition seen previously in ^{20}Ne(e,e') (Ref. 1) is due to only one state at 11 262.3 ±1.9 keV. As a result of the good agreement between the excitation energies and γ-ray branching we conclude that this is the same state, which is populated in β^+ decay of ^{20}Na, in ^{19}F($d,n\gamma$),[10,19] and in ^{19}F(d,n) experiments.[8,9] Finally, with this photon scattering experiment, one of the dominant uncertainties stated in Ref. 3, namely, the exact excitation energy of the lowest 1^+, $T=1$ state, for a proposed parity nonconservation experiment on ^{20}Ne, has been reduced considerably.

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