Measurement of the g Factor of the 1+ 583-keV State in Na^{22} Using the $F^{19}(Po^{210}\alpha, n)Na^{22*}$ Reaction*

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The $F^{19}(\alpha,n)Na^{22*}$ reaction which takes place in a source of Po^{210} dissolved in HF was used to prepare Na^{22*} in the 0.66-MeV 0+ excited state. The subsequent $0+\rightarrow 1+\rightarrow 3+$ γ-γ angular correlation was magnetically perturbed in order to measure the g factor of the 0.58-MeV first excited state. A value $g=+0.535\pm0.010$ was obtained. The energy and half-life of the 1+ state were remeasured as 583.0 ± 0.5 keV and $(243\pm2)\times10^{-9}$ sec, respectively.

THE observation of gamma rays and particle groups in various reactions has helped establish[1] excited states in Na^{22} at about 0.59 MeV ($J,\pi=1+$) and 0.66 MeV ($J,\pi=0+$). The Na^{22} ground-state spin and parity is known to be 3+. The half-life of the 0.59 MeV $1+\rightarrow 3+$, $E2$ transition has been measured[2] as 266 ± 10 nsec. The half-life of the similar $3+\rightarrow 1+$ 0.937-MeV $E2$ transition in F^{18} is 4.7×10^{-11} sec.[3] The strengths of these $E2$ transitions are about 0.008 and 5.8 Weisskopf units, respectively. When account is taken of the final-state spin, the $E2$ strengths differ by a factor of about 1700. This marked difference in the radiation rates makes it of considerable interest to gain additional experimental information which could help clarify the configurational character of the Na^{22} 1+ state. We have measured the g factor of this state by magnetically perturbing the 73 keV $-$583 keV $0+\rightarrow 1+\rightarrow 3+$ γ-γ directional correlation. The method of observing the Larmor-spin precession of the intermediate state as a modulation of the time spectrum of delayed γ-γ coincidences due to a magnetic field applied perpendicular to the γ-ray detection plane was used.[4]

The F^{19}(5.3 MeV α,n) Na^{22*} reaction was used to continuously prepare Na^{22} in the 0+ excited state. α particles from about 300 mCi of Po^{210} dissolved in about 0.2 cc of 30 normal HF were used to produce the reaction. The Po^{210} source strength was chosen after a determination of the 73-keV and $\approx$590-keV γ-ray yield from a thick CaF_2 target bombarded with 5.1 MeV doubly ionized He^4 ions from the Brookhaven electrostatic accelerator. Since an aqueous solution environment for the Na^{22} was desired in order to minimize possible quadrupole perturbations of the angular correlation, the use of Po^{210} as an α-particle source was chosen for convenience in this respect. A large expansion volume was provided in the Teflon source holder in order to contain the gas generated by decomposition of the solvent by the α particles. Periodic checks were made to ensure that sufficient solvent remained.

As a preliminary to the g-factor measurements, the angular correlation of the cascade

$$0+\xrightarrow{73\text{ keV}}1+\xrightarrow{590\text{ keV}}3+$$

was measured with the Po^{210} dissolved in HF. The γ-rays were detected in 3-in.$\times$3-in. NaI(Tl) scintillation counters with energy selection windows on the photopeaks in the usual way. The geometry-corrected angular-correlation coefficient $A_2=-0.069\pm0.010$ derived from this measurement is consistent with expectations for an unperturbed

$$0+\xrightarrow{L=1}1+\xrightarrow{L=2}3+$$

cascade ($A_2=-0.071$).

The half-life and energy of the $\simeq$0.59-MeV transition were also remeasured. A half-life of $(243\pm2)\times10^{-9}$ sec was measured with a time-to-amplitude converter of the overlap type. This value is slightly lower than the previous[2] measurement. The γ-ray energy of (583.0 ± 0.5) keV was measured with a 3.5-cc Li-Ge γ-ray detector calibrated with the Bi^{207} (569.62 ± 0.06) keV γ-ray line[5] as an energy standard.

The Larmor precessional frequency was measured in a magnetic field of 6111 ± 30 G. The γ-ray detectors were two 3-in.$\times$3-in. NaI(Tl) scintillation counters positioned about 8 cm from the source. The angle between the counters was 135°. Signals from single-channel analyzers which were set to accept the 73-keV and 583-keV photopeaks served as "start" and "stop" inputs to the time to amplitude converter. The 73-keV line was masked by the intense Pb K x rays produced by the K_1-shell ionization of the daughter Pb nucleus[6] by the outgoing Po^{210} α particles. The time distributions of delayed coincidences were recorded for about equal times at opposite directions of the applied magnetic field. These runs were corrected for random coinci-

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[4] A review of this technique is given, for example, in *Perturbed Angular Correlations*, edited by E. Karlsson, E. Matthias, and K. Siegbahn (North-Holland Publishing Company, Amsterdam, 1964).
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dences and normalized. The quantity

$$R(t)=2\frac{N_1(t)-N_2(t)}{N_1(t)+N_2(t)},$$

where $N_1(t)$ and $N_2(t)$ are the normalized coincidence counts at time delay t is shown in Fig. 1. The resolution time of the coincidence system in these measurements was about 30 nsec. The total measuring time corresponding to the data shown in Fig. 1 was about 2 weeks. The solid line in Fig. 1 is a computed fit giving the most probable Larmor frequency $\omega_L=(1.565\pm0.025)\times10^7$ rad/sec as derived from these data. The assumption has been made that the correlation is not attenuated as a function of time. For an attenuation of the form $e^{-\lambda_c t}$, there is about a 90% confidence level in the statement that $\lambda_c\leq8.2\times10^5$/sec. For the extreme case of $\lambda_c=8.2\times10^5$/sec the most probable value for ω_L is reduced by 0.3%, a result which is not significantly different from that derived on the basis of no attenuation. The sense of the observed rotation for a given field direction determines the sign of g as positive. The value $\omega_L=(1.565\pm0.025)\times10^7$ rad/sec leads to $g=+0.535\pm0.010$ for the 583 keV 1+ state of Na^{22}. The 3+ ground state of Na^{22} has a measured[7] $g=+0.582\pm0.001$. This g factor is in good agreement with both the shell-model expectation and with a rotational-model description[8] for a 3+, $K=3$, $T=0$ Na^{22} ground state. Similarly, the measured[9] g factor of the 1+ 583-keV excited state of Na^{22} is consistent with both the $K=0$, $T=0$ rotational-model expectation ($g_R\cong Z/A=0.5$) and

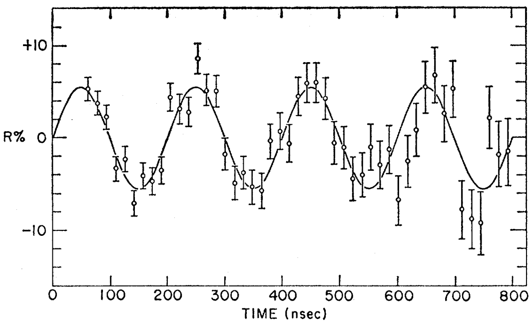

FIG. 1. $R(t)\equiv2[N_1(t)-N_2(t)]/[N_1(t)+N_2(t)]$, where $N_1(t)$ and $N_2(t)$ are the normalized coincidence counting rates for opposite directions of the 6111±30-G magnetic field, is shown plotted as a function of delay time t.

with the expectation that in a shell-model description, the configurations of the 1+ and 3+ states are similar. An experimental determination of the quadrupole moments of the Na^{22} ground and first excited states could provide a basis for differentiating between the deformed or shell-model descriptions. The shell-model quadrupole moment for a half-filled shell of $d_{5/2}$ protons and neutrons is zero. A deformation of about the value calculated by Rakavy[8] would imply a quadrupole moment whose magnitude was a few times a typical single-particle moment. The strong inhibition of the 583-keV $1+\rightarrow3+$ $E2$ transition is consistent with the shell model expectation for half-filled $d_{5/2}$ proton and neutron shells in Na^{22}. Alternatively,[2] in the rotational description, the inhibition is due to K forbiddenness.

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[8] G. Rakavy, Nucl. Phys. **4**, 375 (1957).

[9] *Footnote added in proof.* H. Schmidt, J. Morgenstern, J. Braunsfurth, H. J. Körner, and S. J. Skorka [Physik. Verhandl. **17**, 28 (1966)] have measured the g factor by the spin-rotation method using a pulsed-beam technique. The value $g=0.555\pm0.017$ has just been communicated to us by Dr. H. Schmidt.