crystal occurs. Figure 3(b) can of course also describe two successive spontaneous scatterings; the observed intensity at $\omega_{LO} \pm \omega_{SF}$ is about 10^3 too large for such an explanation.

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Comparison of the $^{16}N^m(0^-)$ β-Decay Rate with the Inverse Muon-Capture Rate: The Induced Pseudoscalar Form Factor in Nuclei*

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We report on the observation of the $^{16}N^m(0^-) \to {}^{16}O(g.s.)$ β decay. The comparison of the measured decay rate, 0.43 ± 0.10 sec^{-1}, with the rate of the inverse muon-capture reaction in ^{16}O yields for the induced-pseudoscalar form factor: $13 \leq g_P(q^2 \simeq m_\mu^2) \leq 20$. Subject to the approximations of the analysis and neglecting possible second-class currents, this result indicates an upward renormalization of this form factor in nuclei.

It has been recognized by many authors[1,2] that the rate of the partial muon-capture reactions with spin sequence $0^\pm \to 0^\mp$ is particularly sensitive to the magnitude of the induced-pseudoscalar form factor g_P. For this reason, the rate of the partial $0^+ \to 0^-$ capture reaction

$$\mu^- + {}^{16}O(0^+, \text{g.s.}) \to {}^{16}N^m(0^-, 120 \text{ keV}) + \nu_\mu \quad (1)$$

has been measured in several laboratories.[3-6] The comparison of the induced-pseudoscalar form factor in this reaction with the one obtained in the $\mu^- + p \to n + \nu_\mu$ process should throw light on possible renormalization of g_P in nuclear matter.[7,8] However, as the rate λ_μ of Reaction (1) depends also on nuclear-structure parameters, the value of g_P cannot be deduced from λ_μ in a model-independent way.[2,9]

In analogy to a procedure successfully applied to other partial muon-capture reactions,[10] the nuclear-structure effects in Reaction (1) can be circumvented by a measurement of the rate λ_β

of the inverse weak process:

$$^{16}N^{m}(0^-,\ 120\ \mathrm{keV}) \to {}^{16}O(0^+,\ \mathrm{g.s.}) + \beta^- + \bar{\nu}. \qquad (2)$$

Indeed, the ratio $\lambda_\mu/\lambda_\beta$ turns out to be nearly independent of the details of the wave function of $^{16}N^{m}(0^-)$ and rather sensitive to the value of g_P.[11] In the present paper, we describe an experiment performed to measure λ_β and we discuss, in the framework of Ref. 11, the conclusion which can be drawn from its result on the induced-pseudoscalar form factor in Reaction (1).

Figure 1 shows the relevant properties of the states involved. Because of the competition of the strong electromagnetic $E2$ transition of 120 keV $^{16}N^{m}(0^-) \to {}^{16}N(2^-)$, the β-γ branching ratio R of $^{16}N^{m}(0^-)$ is expected to be rather small,[11] $R \cong 10^{-6}$, implying a strong background from the β decay of the $^{16}N(2^-)$ ground state. Considering however, the large difference in the lifetimes of the $^{16}N^{m}(0^-)$ and $^{16}N(2^-)$ states [$T_{1/2}(0^-) = 5.26 \pm 0.06$ μsec[12] and $T_{1/2}(2^-) = 7.13 \pm 0.02$ sec[13]], the intensities of the two β groups are comparable if they are detected during a short observation interval after a short and single-production period. The identification of the $^{16}N^{m}(0^-)$ β rays is then carried out by a lifetime measurement.

The ^{16}N activity is produced by the reaction $^{15}N(d,p)^{16}N$ using an electrostatically pulsed 4-MeV deuteron beam from the Van de Graaff accelerator of the University of Louvain. The target material, NH_4NO_3 powder[14] enriched up to 97% in ^{15}N, is melted into a circular groove, 1 mm deep and 3 mm wide, machined on the periphery of an aluminium wheel, 4 mm thick and 70 cm diam. The wheel rotates in front of the pulsed beam with an angular velocity of 25 turns/sec at a distance of 1 mm from the exit window of the beam (4 mg/cm^2 Havar). After a "beam-on" period of 10 μsec, the induced β acitivity is measured as a function of time during 15 μsec by a telescope consisting of three plastic scintillators. The 5.26-μsec β activity is normalized to the 120-keV γ rays detected during the same time interval with a Ge(Li) detector. The irradiation is repeated every 150 μsec; in this way, a new irradiation takes place only when the part of the target irradiated by the preceding one is already out of sight of the telescope. The irradiations are repeated during a complete revolution of the wheel (40 msec) and are then stopped for 14 sec in order to eliminate the induced $^{16}N(2^-)$ β activity. The $^{16}N(2^-)$ β background is further reduced by absorbing the 68% internal β branch with aluminum absorbers inserted between the first and second detectors of the telescope. The characteristic decay time of the beam is measured to be 1.5 μsec, and is continuously controlled during the experiment by observing the time dependence of the nuclear reaction γ rays produced during the irradiation.

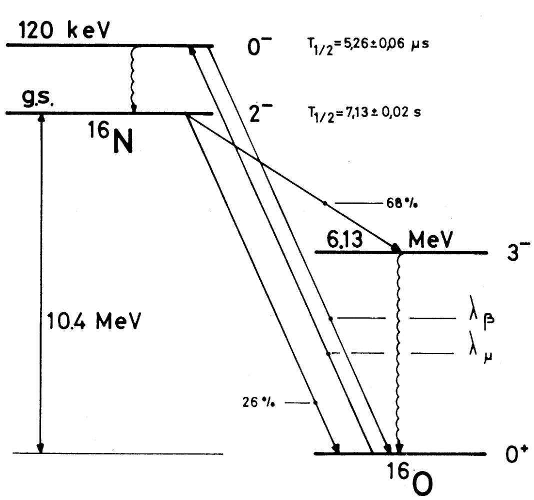

FIG. 1. Levels and transitions in $A = 16$ relevant to this work.

The three components of the experimental time spectrum, i.e., (i) the β rays originating from $^{16}N^{m}(0^-)$, (ii) those from $^{16}N(2^-)$, and (iii) the background, are found to be about equal at the beginning of the observation interval. The $^{16}N(2^-)$ β background is determined from measurements during the 14-sec "beam-off" periods; the remaining background is determined by a least-squares adjustment of a function $Ae^{-\lambda t} + B$ to the data. The time independence of this background, shown in Fig. 2, was verified by inserting aluminum absorbers in the telescope. Figure 2 also displays the $^{16}N^{m}(0^-)$ β activity after subtraction of backgrounds (ii) and (iii).

The absolute efficiency of the Ge(Li) detector at $E_\gamma = 120$ keV is determined with a calibrated ^{57}Co source. The absolute efficiency of the β telescope is measured in the stopped-target position by observing both the β rays of $^{16}N(2^-)$ with the β telescope and the 6.13-MeV γ rays of ^{16}O with the Ge(Li) detector. The absolute double-escape-peak efficiency of the Ge(Li) detector at 6.13 MeV is obtained, with an accuracy of 15%, using radioactive sources and the γ rays from the proton-capture reaction $^{27}Al(p,\gamma)^{28}Si$ at $E_p = 992$ keV.[15] The corrections of the efficiency of the telescope due to the displacement of the target during the 15-μsec observation period and

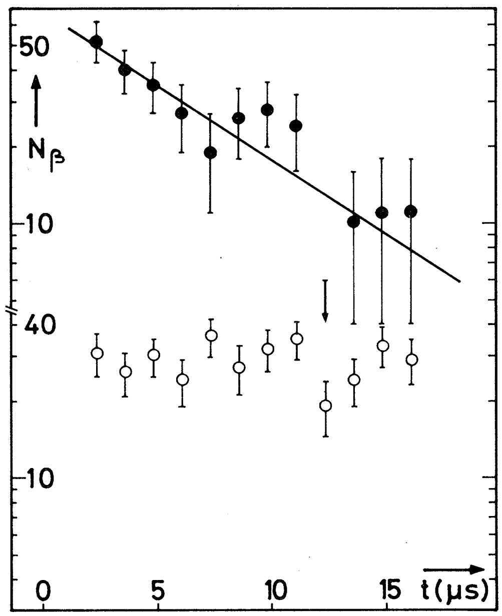

FIG. 2. Time distribution of β rays from $^{16}N^{m}(0^-)$ (full circles). The represented points are the weighted average of the data from two runs. The straight line corresponds to the mean life of $^{16}N^{m}(0^-)$. The background observed in the control measurement (inserting Al absorbers in the telescope) is shown by open circles.

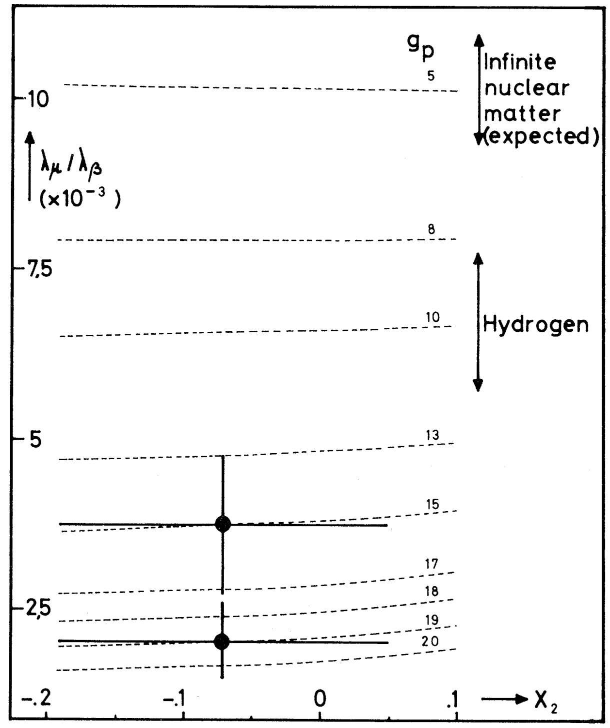

FIG. 3. The ratio $\lambda_\mu/\lambda_\beta$ as a function of the configuration mixing parameter in x_2 of the $^{16}N^{m}(0^-)$ state and the induced-pseudoscalar form factor g_P (in units of g_A). The points are deduced from this experiment using $\lambda_\mu = 1600 \pm 200\ \mathrm{sec}^{-1}$ (Ref. 4), $\lambda_\mu = 850^{+140}_{-60}\ \mathrm{sec}^{-1}$ (Ref. 5). Indicated also are the ratios $\lambda_\mu/\lambda_\beta$ expected for $g_P = 10.0 \pm 1.6$ (hydrogen) and $g_P \simeq 5$ (infinite nuclear matter).

to the different shapes of the $0^- \to 0^+$ and $2^- \to 0^+$ β spectra are calculated to be negligibly small. The sensitivity of the β telescope to γ rays of 120 keV is measured to be less than 10^{-8}.

The results for the β-γ branching ratio of $^{16}N^{m}(0^-)$ from two independent runs are $R_1 = (3.2 \pm 0.8)\times 10^{-6}$ and $R_2 = (3.5 \pm 1.3)\times 10^{-6}$, respectively. The final result is the weighted average of these two numbers, i.e.,

$$R = (3.3 \pm 0.7)\times 10^{-6}.$$

From this value of R and from the mean life of the $^{16}N^{m}(0^-)$ level,[12] one deduces the β decay rate of $^{16}N^{m}(0^-) \to {}^{16}O$(g.s.).

$$\lambda_\beta = 0.43 \pm 0.10\ \mathrm{sec}^{-1}.$$

In the framework of Ref. 11, the $^{16}N^{m}(0^-)$ level is described as a (p-hole, sd-particle) state:

$$|^{16}N^{m}(0^-)\rangle = x_1 |p_{1/2}^{-1}, s_{1/2}\rangle + x_2 |p_{3/2}^{-1}, d_{3/2}\rangle,$$

where x_1 and x_2 satisfy the normalization condition $x_1^2 + x_2^2 = 1$. A first conclusion from our result, $x_2 = -0.07 \pm 0.12$, agrees with the computations of Elliott and Flowers.[16] A second conclusion can be deduced from the ratio $\lambda_\mu/\lambda_\beta$. The dependence of this ratio on x_2 and on the induced-pseudoscalar form factor g_P (in units of the axial form factor g_A) is shown in Fig. 3. Because of the discrepancies between the presently published values of λ_μ ($1100 \pm 200\ \mathrm{sec}^{-1}$, $1600 \pm 200\ \mathrm{sec}^{-1}$, $850^{+140}_{-60}\ \mathrm{sec}^{-1}$, and $1560 \pm 170\ \mathrm{sec}^{-1}$; Refs. 3, 4, 5, and 6, respectively), we indicate, in Fig. 3, the $\lambda_\mu/\lambda_\beta$ values deduced from the two extreme results only. They yield $g_P = 15 \pm 2$ (from $\lambda_\mu = 1600 \pm 200\ \mathrm{sec}^{-1}$) and $g_P = 19.0 \pm 1.5$ (from $\lambda_\mu = 850^{+140}_{-60}\ \mathrm{sec}^{-1}$), respectively. For illustration, we also show the ratio $\lambda_\mu/\lambda_\beta$ for the value of g_P obtained in hydrogen[17] ($g_P = 10.0 \pm 1.6$) and for the one expected in infinite nuclear matter[18,19] ($g_P \cong 5$).

The dispersion in the muon-capture results does not allow, for the present time, a more precise determination of g_P in the $A = 16$ system. Even at this stage, however, our result indicates an upward renormalization of g_P instead of the downward one expected on the basis of Refs. 18 and 19. A solution of this interesting issue requires (1) a clarification of the conflicting λ_μ results, and (2) an investigation of the implications of the restricting $x_1^2+x_2^2=1$ hypothesis.[20]

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Correlations in Compound-Nucleus Decay Amplitudes in the Vicinity of Isobaric Analog States

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Polarization and $(p,p'\gamma)$ angular-correlation studies near isobaric analog resonances in proton scattering from ^{92}Mo and ^{106}Cd indicate strong correlations between compound-nuclear decay channels. A modified Hauser-Feshbach formula which includes correlations among those channels which belong to the analog resonance can explain the data.

One of the basic assumptions of the statistical model of nuclear reactions is that decay amplitudes to different channels are uncorrelated. Whether this assumption remains valid in the presence of direct reactions has been the subject of considerable study.[1-4] Since a direct transition amplitude is often found in conjunction with a compound-nuclear amplitude, for example in heavy-ion reactions, this question of channel-channel correlations (CCC) is an important one. In this Letter, we present convincing experimental evidence for CCC in compound-nuclear scattering from a study of the inelastic scattering of protons at isobaric analog resonances (IAR).

Significant correlations between the magnitudes of partial neutron and γ-ray widths have been previously observed for a number of well-resolved neutron resonances.[5] Here the direct-reaction background is unknown and no phase information is obtained. The study of CCC in energy-averaged quantities (cross-section, polarization, and angular-correlation coefficients) in the vicinity of an IAR offers several advantages: The "direct" background is the well-known IAR itself; its effect on CCC can be studied by small variations in the incident proton energy. Statistical validity is assured by averaging experimentally over many compound-nuclear levels. Finally, correlations in phases as well as magnitudes can be studied. Conditions suitable for such a