temperatures lower than 10°C. The observed $T_{1\rho}$ of methine groups diverges from the values calculated from τ_{c1} at temperatures above 35°C, indicating that the motion of methine groups has greater activation energy at temperature above 35°C. The temperature at which a break is observed in the temperature dependence is coincident with T_{mc}, described in the section of proton T_2.

Molecular Mobility as Determined by High-Resolution NMR

Laboratory and Rotating Frame Spin-Lattice Relaxation Times of Carbon

Figure 7 shows the typical spectra of freeze-dried γ-globulin formulation containing dextran, freeze-dried γ-globulin, and freeze-dried dextran, measured by high-resolution ^{13}C solid-state NMR (31). Peaks at 70 and 180 ppm are assigned to the dextran methine carbon and γ-globulin carbonyl carbon, respectively. The T_1 of each carbon, calculated from the signal decay, decreases with increasing temperature, indicating that relaxation occurs in the slow motional regime. The τ_c of dextran methine carbon then can be calculated from the observed T_1 according to equation (7), if the dipole-dipole interaction between carbon and proton is predominant in the relaxation process, and if the relaxation time can be expressed by a single τ_c.

$$\frac{1}{T_1} = \frac{1}{10}\gamma_C^2\gamma_H{}^2\left(\frac{h}{2\pi}\right)^2 r_{C-H}{}^{-6} \times \left[\frac{\tau_c}{1+(\omega_c-\omega_H)^2\tau_c{}^2} + \frac{3\tau_c}{1+\omega_c^2\tau_c{}^2} + \frac{6\tau_c}{1+(\omega_C+\omega_H)^2\tau_c{}^2}\right] \quad (7)$$

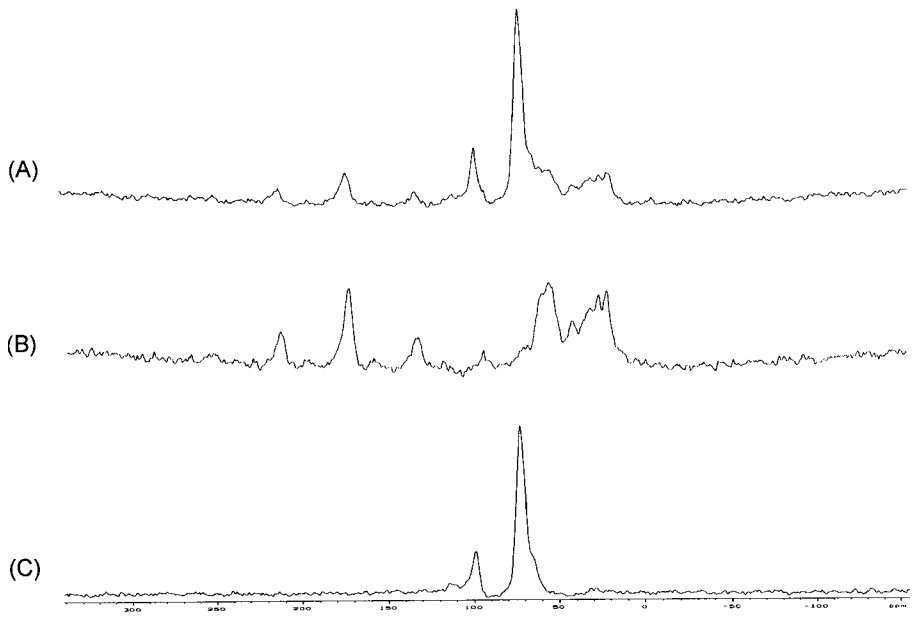

FIGURE 7 ^{13}C-NMR spectra of freeze-dried γ-globulin formulations containing dextran **(A)**, freeze-dried γ-globulin **(B)**, and freeze-dried dextran **(C)**.