Relaxation Equations for the Extreme Narrowing Limit

Table 3-2 Equations for spin–lattice relaxation rates, T_1^{-1}, of a spin-$\frac{1}{2}$ nucleus, A, for various mechanisms in the extreme narrowing approximation

Mechanism	T_1^{-1}	*Notes*
dd(intra)(homo)	$\left(\frac{\mu_0}{4\pi}\right)^2 \frac{3}{2} \gamma_A^4 \hbar^2 \tau_c / r^6$	for a single pair of spin-$\frac{1}{2}$ nuclei of separation r
dd(intra)(hetero)	$\left(\frac{\mu_0}{4\pi}\right)^2 \gamma_A^2 \gamma_X^2 \hbar^2 \tau_c / r^6$	for a single pair of spin-$\frac{1}{2}$ nuclei AX of separation r
dd(inter)(hetero)	$\left(\frac{\mu_0}{4\pi}\right)^2 \frac{2}{15} N_X \gamma_A^2 \gamma_X^2 \hbar^2 / Da$	for relaxation by a spin-$\frac{1}{2}$ nucleus X
ue(intra)(dipolar)	$\left(\frac{\mu_0}{4\pi}\right)^2 \frac{4}{3} \gamma_A^2 \gamma_e^2 \hbar^2 S(S+1) \tau_c / r^6$	for relaxation by unpaired electrons of total spin S at distance r
ue(scalar)	$\frac{8}{3}\pi^2 a_N^2 S(S+1) \tau_e$	for relaxation by unpaired electrons of total spin S
sr	$2I_r kTC^2 \tau_m / \hbar^2$	for isotropic molecular inertia
sa	$\frac{2}{15} \gamma_A^2 B_0^2 \Delta\sigma^2 \tau_c$	for cylindrical symmetry of shielding
sc	$\frac{8}{3}\pi^2 J_{AX}^2 I_X (I_X+1) \frac{\tau_{sc}}{1+(\omega_X-\omega_A)^2 \tau_{sc}^2}$	relaxation by coupling to spin, X, of quantum number I_X

Meaning of symbols (where not otherwise defined in this Table or Section):

- τ_c Correlation time for molecular tumbling
- τ_e Correlation time related, *inter alia*, to the spin–lattice relaxation time for the unpaired electrons
- τ_{sc} For scalar relaxation of the first kind this is the exchange lifetime; for scalar relaxation of the second kind this is T_{1X}
- N_X Concentration of spins X (per unit volume)
- D Mutual translational self-diffusion coefficient of the molecules containing A and X
- a Distance of closest approach of A and X
- γ_e Magnetogyric ratio for the electron
- a_N Nucleus-electron hyperfine splitting constant (in frequency units)
- C Spin–rotation interaction constant (assumed to be isotropic)
- $\Delta\sigma$ Shielding anisotropy ($\sigma_\parallel - \sigma_\perp$; see Section 6-6)