1.10: How do T_1 and T_2 relaxation affect NMR spectra?

The decay of the FID corresponds to the loss of intensity of the macroscopic magnetization vector in the xy plane (called the transverse plane) by a process called spin-spin relaxation (or transverse or T_2) relaxation. T_2 relaxation occurs when a nucleus in a –½ spin state transfers its spin to a nearby nucleus in a + ½ spin state, and vice versa. Since T_2 relaxation occurs through mutual spin flips, the energy of the system is unaffected, it is an entropic process. In terms of our vector model, T_2 relaxation corresponds to a loss of coherence or dephasing of the magnetization vector. The recovery of magnetization along the z (longitudinal) axis (aligned with B_o) to its equilibrium position occurs by a process called spin lattice (or longitudinal or T_1 relaxation). T_1 relaxation occurs through interactions of the nuclei with the lattice (or the nuclei that surround our sample). Lattice motions at the same frequency as the Larmor frequency stimulate the magnetization in the higher energy – ½ spin states to lose this excess energy by transferring it to the lattice via a process called radiationless decay. Since T_1 relaxation involves a loss of energy by the system as the spins return to their equilibrium populations, it is an enthalpic process. These relaxation processes are first order processes characterized by the relaxation time constants T_1 and T_2. The width at half-height of a resonance is inversely related to the T_2 relaxation time of the nucleus, $w_{1/2} = (\pi T_2)^{-1}$. Because the magnets we use are not perfectly homogeneous, there is a secondary contribution to the line width that comes from magnetic field inhomogeneity. Therefore, the apparent spin-spin relaxation time constant or T_2* observed in the FID includes both the natural T_2 relaxation time of the nucleus as well as the effect of magnetic field inhomogeneity, $w_{1/2} = (\pi T_2^*)^{-1}$. If you want to know the real T_2 value for a nucleus, a special experiment, called the spin echo can be used.

? Exercise 1.10.5

What are the resonance line widths of nuclei that have apparent T_2 relaxation times (i.e.T_2* values) of 1 and 2 sec.

The effects of T_1 relaxation are more difficult to observe directly, because it corresponds to the return to equilibrium populations following the pulse. However, if several FIDs are coadded, as is usually the case in NMR, and if the time between successive pulse and acquire steps is insufficient for complete T_1 relaxation, the resonances in the resulting NMR spectrum will be less intense than they would otherwise appear. Because quantitative NMR measurements rely on resonance intensity, understanding the effects of T_1 relaxation is very important for obtaining accurate qNMR results. Therefore this subject is treated in greater depth in the Practical Aspects section of this module.