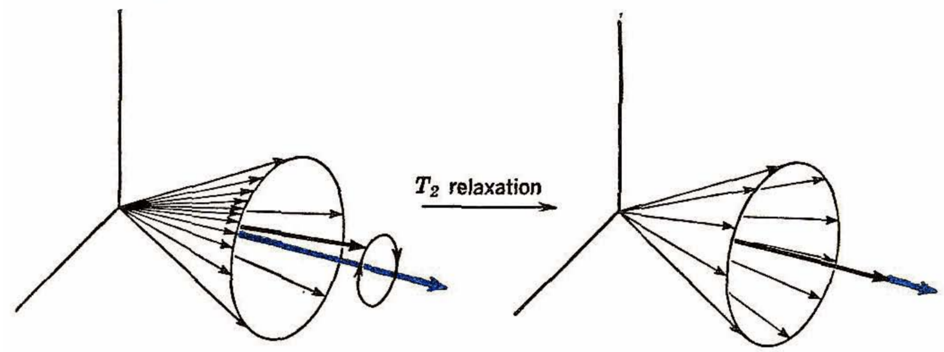
1.8: Transverse Relaxation, T_2

The other variety of relaxation may be illustrated as follows. Consider a group of nuclei which are precessing in phase about the axis of a common magnetic field. If the nuclei were all centered on the same point, their magnetic vectors would be precessing together like a tied-up bundle of sticks. If we take the magnetic field axis to be the Z axis, the nuclei precessing in phase produce a resultant rotating magnetic vector which has a component in the XY plane. If by any process the nuclei tend to lose their phase coherence, their resultant will move toward the Z axis and the macroscopic component of magnetization in the XY plane will go to zero. This type of relaxation is commonly referred to as "transverse" relaxation, and its rate is customarily expressed in terms of the characteristic time T_2. Characteristic time T_2 is the time constant for the kinetically first-order decay of X, Y magnetization.



There are several factors which can contribute to transverse relaxation, and these may be classified as intrinsic in the nature of the sample or arising from the equipment used. The homogeneity of the applied magnetic field will be extremely important as an external factor. If the assemblage of nuclei under consideration is in a nonhomogeneous field, the nuclei will not have identical precession frequencies, and if they start off in phase, they will soon get out of phase because of their different precession rates. In many cases, the inhomogeneity of the applied magnetic field will be the most important factor determining T_2. Nonhomogeneous magnetic fields within the sample will also decrease T_2. Viscosity plays an important part here. In the liquid state, nuclei which might otherwise be expected to have the same precession frequency will not usually have instantaneously identical environments as regards nuclear magnetic dipole-dipole interaction and diamagnetic shielding involving neighboring molecules. Thus, the nucleus of one atom may have one type of molecule as a neighbor while another nucleus may have quite a different molecule as a neighbor. Such nuclei will in general be subjected to different magnetic fields and have different precession frequencies, thus permitting them to lose phase coherence. This effect will be of most importance in viscous media where the molecules move slowly with respect to one another. If the viscosity is low and the molecules tumble rapidly relative to the precession frequencies of their nuclei, the fluctuations in the local magnetic fields are effectively averaged to zero and T_2 is thereby increased.

Another factor which influences T_2 in solids or viscous liquids is the occurrence of what are often called "spin-spin collisions." These "collisions" occur when two identical nuclei exchange spins — one nucleus acting as a rotating field vector for the other. It can be shown by the uncertainty principle that spin-spin collisions limit the time of maintenance of phase coherence for an assemblage of identical nuclei precessing in phase and thus decrease T_2. As will be seen, both T_1 and T_2 are vitally important in determining the character of nuclear resonance signals.