21.3.1 Spin-Lattice Relaxation

Spin-lattice relaxation occurs when the applied dc magnetic field **H** is much stronger than the local magnetic field $\mathbf{H}_{loc}$. Therefore, a small increase in **H** will change the magnitude of the total magnetic field $\mathbf{H} + \mathbf{H}_{loc}$, but will not change its direction by very much. In this case the spin interacts with the lattice and exchanges energy with it. The lattice interaction may cause some of the magnetic dipoles to slip from the antiparallel direction to the parallel one, thereby producing a finite magnetization **M** defined as

$$\mathbf{M} = \hat{\mathbf{i}}_1 \mathrm{M}_1 + \hat{\mathbf{i}}_2 \mathrm{M}_2 + \hat{\mathbf{i}}_3 \mathrm{M}_3 \qquad (21.20)$$

The time taken by the material to reach the equilibrium value M_0 is called the *spin-lattice relaxation time* t_{sl} and the phenomenon is called the spin-lattice relaxation. The time t_{sl} is also sometimes called the longitudinal relaxation time. When the magnetic field is switched off the material returns to its initial unmagnetized state.

Let the magnetic field **H** be applied in the z-direction, that is, $\mathbf{H} = \hat{\mathbf{i}}_3 \mathrm{H}$ with M_0 as the equilibrium magnetization. Further, let $M_z(t)$ be

Scanned with CamScanner

equilibrium magnetization. Further, let $M_z(t)$ be the magnetization at any time t in the z-direction, which is different from M_0. If the rate of change of $M_z(t)$ is assumed to be proportional to its deviation from M_0, then one can write

$$\frac{dM_z}{dt} = \frac{M_0 - M_z}{t_{sl}} \quad (21.21)$$

where $1/t_{sl}$ is the constant of proportionality. The above equation can be written as

$$\int_0^{M_z} \frac{dM_z}{M_0 - M_z} = \frac{1}{t_{sl}} \int_0^t dt \quad (21.22)$$

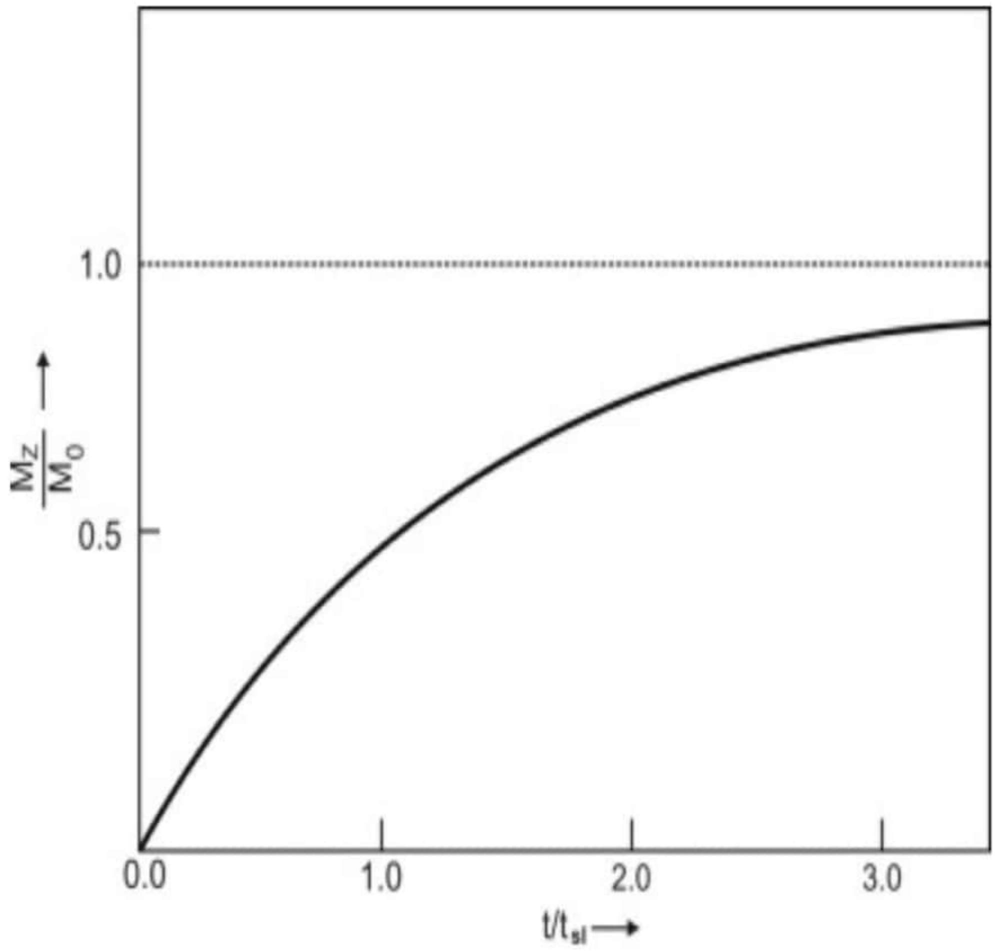
Integrating the above equation, one gets

$$M_z(t) = M_0 \left[1 - e^{-t/t_{sl}}\right] \quad (21.23)$$

Fig. 21.3 shows how a precessing magnetization **M** (about the z-direction) acquires the equilibrium value of magnetization $\mathbf{M_0}$ in the spin-lattice relaxation phenomenon. The variation of $M_z(t)$ with time is shown in Fig. 21.4. The spin-lattice relaxation is measured in strong fields but at low frequencies. It is important to point out that t_{sl} is strongly temperature dependent and decreases with increasing temperature. This variation is due to

Scanned with CamScanner

increasing temperature. This variation is due to an increase in the mobility of the magnetic dipoles with an increase in temperature. The time t_{sl}, due to the nuclear moments in solids, may have a value from a few seconds to hours. In solids in which the paramagnetism is due to the electrons, t_{sl} varies between 10^{-11} and 10^{-6} s at room temperature.



Sign in to download full-size image

Fig. 21.4. The variation of the z-component of magnetization $\mathbf{M}_z(t)$ with time t in the spin-lattice relaxation phenomenon.

Scanned with CamScanner