8. Relaxation

There is no perpetual motion. The system tends to go back the thermodynamic equilibrium

Two phenomenon coexist:

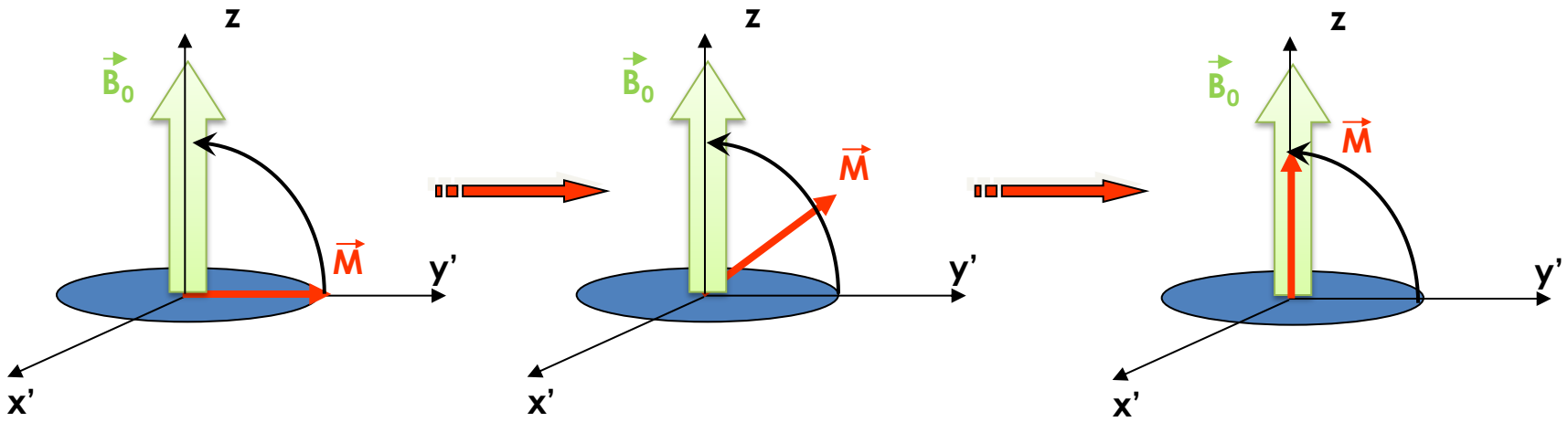
- The longitudinal relaxation time (or spin-lattice relaxation) characterized by T_1 parameter.

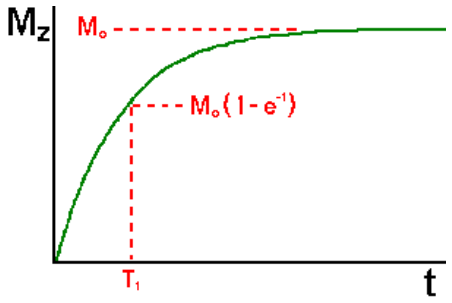
- The transverse relaxation time (or spin-spin relaxation) characterized by T_2 parameter

8. Relaxation

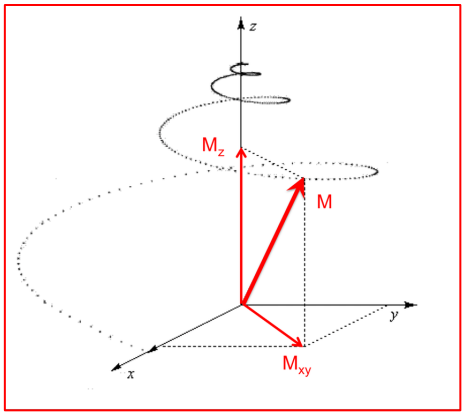
T_1 relaxation: return of M along the z axis (longitudinal or spin-lattice relaxation)

Evolution of the magnetization under T_1





The signal is maximum for $t > 5T_1$

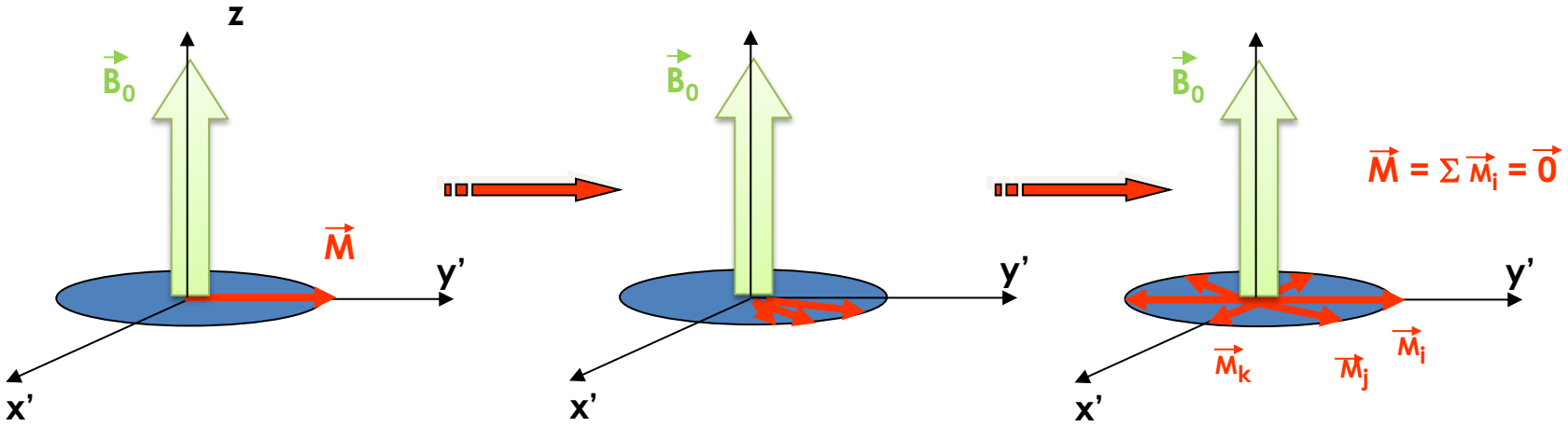


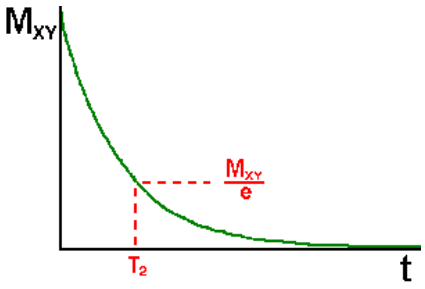
Movement of M with combining precession and T_1 relaxation

8. Relaxation

T_2 relaxation: loss of the magnetization in the (xy) plane (transverse or spin-spin relaxation).

Evolution of the magnetization under T_2

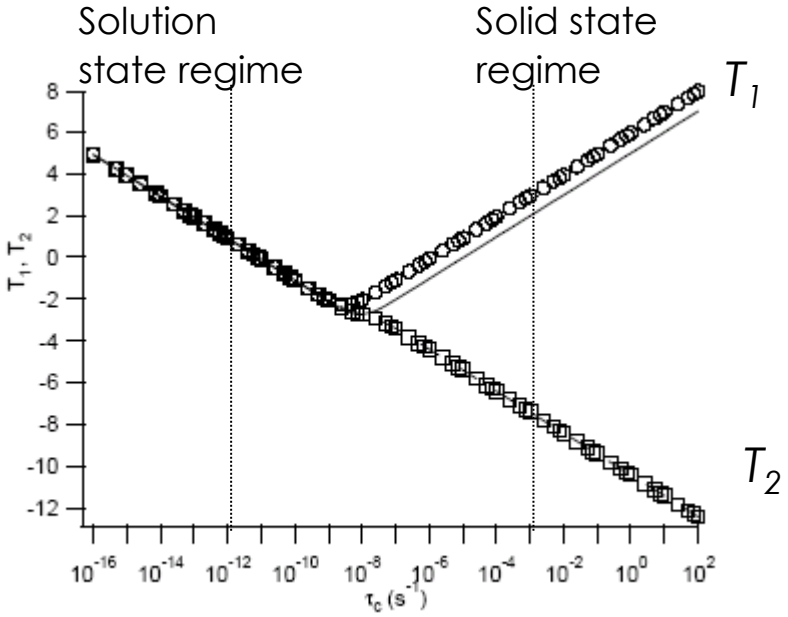




In a real sample, the magnetization is composed of numerous individual M_i corresponding to all the spins I involved in the experiment. **The magnetization tends to 0**

Because all the spins do not precess at the same frequency !

8. Relaxation



τ_C : Correlation time.

For a spherical molecule, average time to do a rotation of 1 rad.

Solution state : $T_2 \approx T_1$ *few seconds*

Solid state : $T_2 \leq T_1$

T_1 *can be very long.* ^{1}H *: up to 60s*

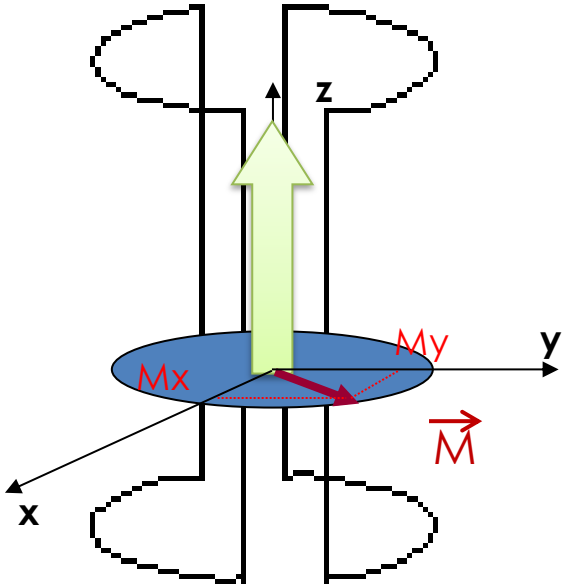
^{29}Si *: up to 1h for quartz !*

T_2 *very small : 10 – 100 µs*

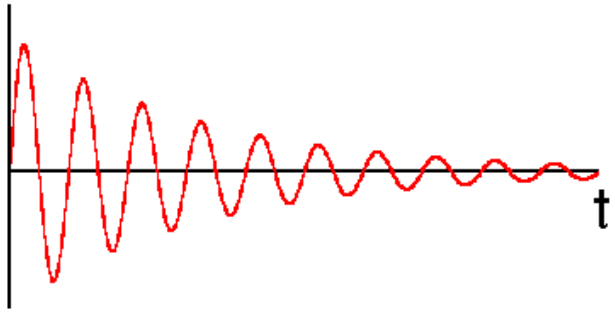
8. Relaxation

The movement equations are becoming :

$\pi/2$ without relaxation		$\pi/2$ with relaxation	
$Mx(t) = M_0 \sin(2\pi\nu_0 t)$	$\Leftrightarrow$	$M_x = M_0 \exp(-t/T_2)\sin(2\pi\nu_0 t)$	Decreases as a function of time
$My(t) = M_0 \cos(2\pi\nu_0 t)$		$M_y = M_0 \exp(-t/T_2)\cos(2\pi\nu_0 t)$	Decreases as a function of time
$Mz(t) = 0$		$M_z = M_0 [1 - \exp(-t/T_1)]$	Increases as a function of time

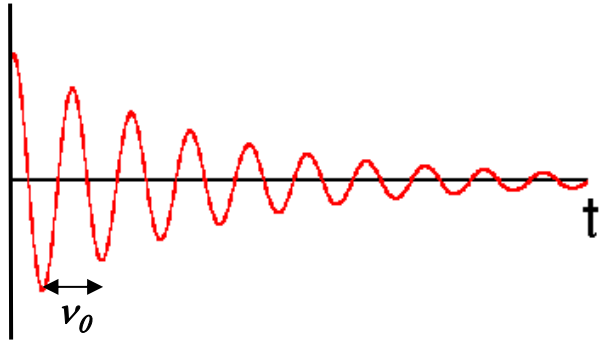


Measurement along x:



Damped sinosoïd

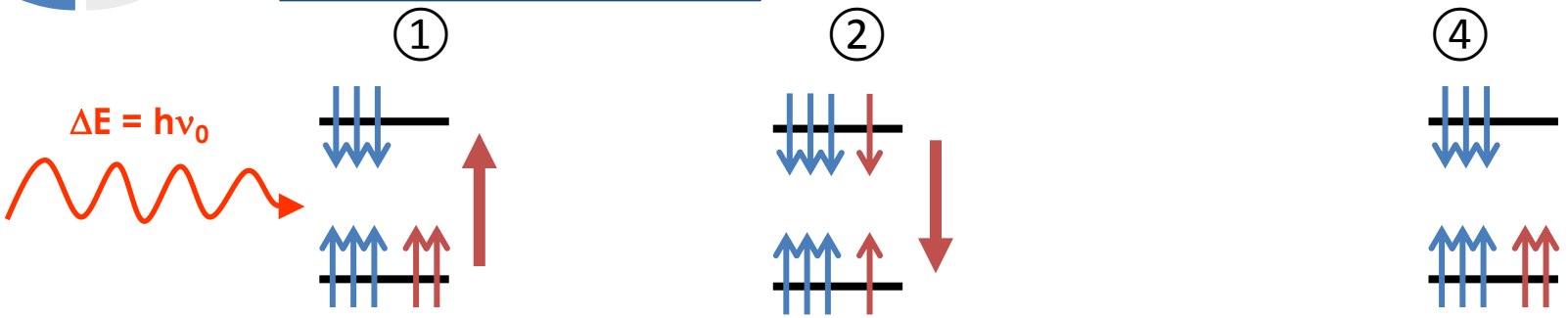
Measurement along y:



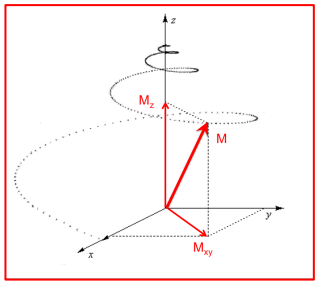
Damped cosinosoïd

9. Summary of the NMR experiment

Energy level model



③ Precession/Relaxation

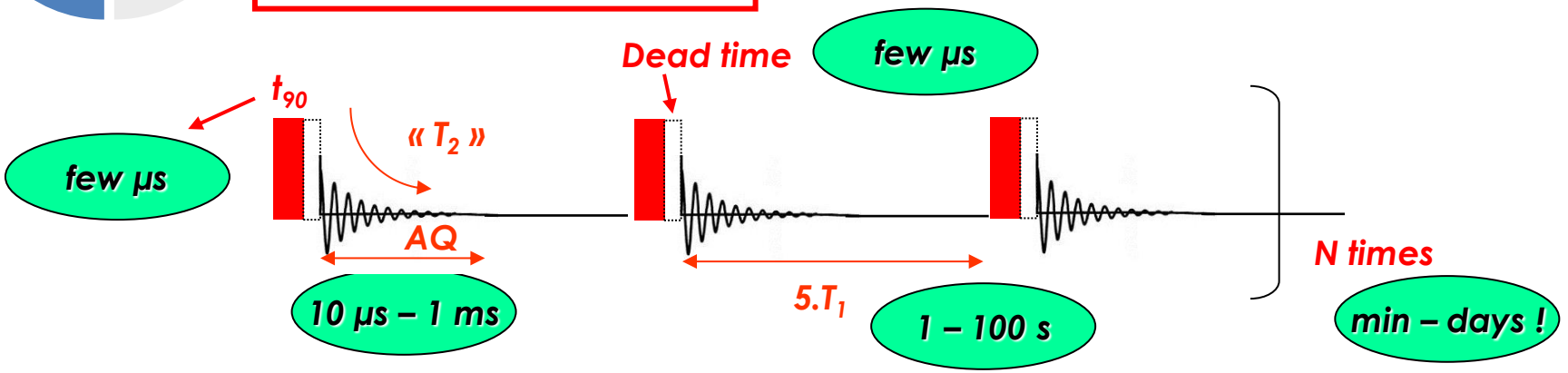


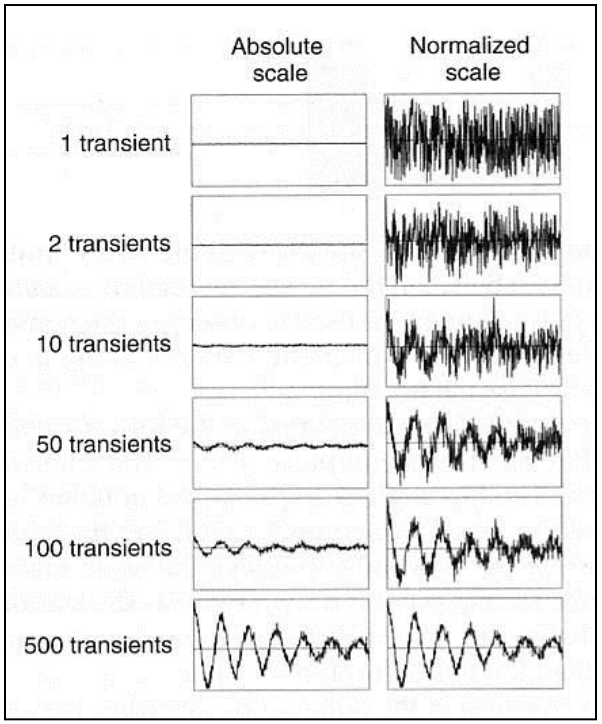
$\nu_0 = \gamma B_0 / 2\pi$

Vectorial model

10. Signal acquisition

FID (Free Induction Decay)





Final signal = addition of N FIDs

Signal : coherent addition

Bruit : incoherent addition

Signal/Noise ratio ~ $\sqrt{N}$

Levitt, Spin dynamics, 2002.