Lab writeups individual. (Due last day of class.)

Professional lab report, 10-20 pages, procedure and example data.

To do: Bloch equations

Total NMR Hamiltonian?
And/or spin operators

Recall

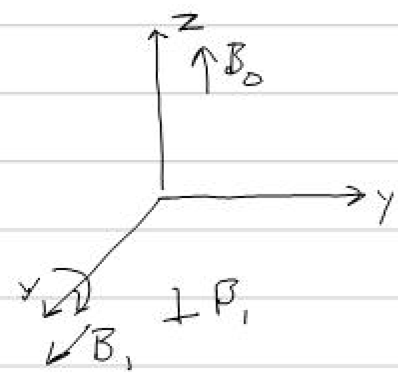
$$\frac{dM_x}{dt} = \omega_0 M_y - \overset{\substack{\text{Relaxation} \\ \downarrow}}{\frac{M_x}{T_2}}$$

$$\frac{dM_y}{dt} = -\omega_0 M_x - \frac{M_y}{T_2}$$

$$\frac{dM_z}{dt} = 0 - \frac{M_z - M_0}{T_1}$$ ← equilibrium magnetization

Add a $\perp$ B_1 field.

Had components like $\gamma(\vec{M} \times \vec{B})$



$$\omega_0 = \gamma B$$

$$\omega = \gamma B_1.$$

$B_{1x} = B_1 \cos(\omega t)$

$\cancel{B_{2y}} =$ $B_{1y} = B_1 \sin(\omega t)$

Complete Bloch Equation

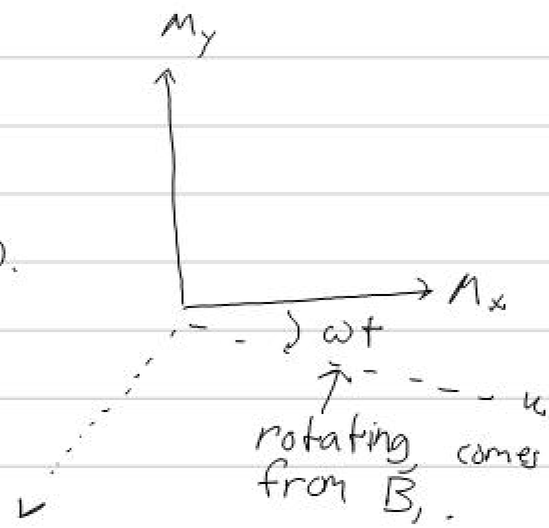
$$\frac{dM_x}{dt} = \gamma(-M_y B_0 + M_z B_1 \sin(\omega t)) - \frac{M_x}{T_2}$$

$$\frac{dM_y}{dt} = \gamma(M_z B_1 \cos(\omega t) - M_x B_0) - \frac{M_y}{T_2}$$

$$\frac{dM_z}{dt} = \gamma(-M_x B_1 \sin(\omega t) - M_y B_1 \cos(\omega t)) - \frac{M_z - M_0}{T_1}$$

From some algebra

Like a frequency offset $\omega_0 - \omega$.



1) Slow passage case – old time CW NMR

- B_1 is negligible
  → sweep spectrum, record absorptive & dispersive signals:
- First case of nuclear induction: rotating magnetic fields led to signal in a coil

$$u = M_0 \left(\frac{\gamma B_1 T_2^2 (\omega_0 - \omega)}{1 + T_2^2(\omega_0 - \omega)^2 + \gamma^2 B_1^2 T_1 T_2} \right)$$

$$v = M_0 \left[\frac{1 + T_2^2(\omega_0 - \omega)^2}{1 + T_2^2(\omega_0 - \omega)^2 + \gamma^2 B_1^2 T_1 T_2} \right]$$

u predicts a dispersive signal, v an absorptive one

2. Short pulse experiment, B_1 important

· use a rotating frame of reference

Rotating frame: in a magnetic field, even at equilibrium the spins at precessing at ω_0.

If your frame at reference also moves around z at ω_0, "B_0 field disappears."

→ Drop B_0 dependent terms

· rf pulse must be short compared to T_1, T_2, γB_0

· apply along x-axis, so neglect T_1, T_2, γB_0 or B_y terms

$$\frac{dM_z}{dt} = -M_y \gamma B_1$$

$$\frac{dM_x}{dt} = 0$$

$$\frac{dM_y}{dt} = M_z \gamma B_1$$

$$M_z = M_0 \cos(\omega_{1x} t)$$

$$M_x = 0$$

$$M_y = M_0 \sin(\omega_{1x} t)$$

Let $\alpha = \omega_{1x} t$, pulse angle

If $\alpha = 0$, $M_z = M_0$, $M_y = 0$.

→ all magnetization along z

$\alpha = 90°$, $M_z(t) = 0$, $M_y(t) = M_0$.

At the end of the pulse you go to free precession

$$M_z(t) = M_0(1 - e^{-t/T_1})$$

Free precession

$$M_x(t) = M_0 \cos[(\omega_0 - \omega)t]\, e^{-t/T_2}$$

$$M_y(t) = M_0 \sin[(\omega_0 - \omega)t]\, e^{-t/T_2}$$