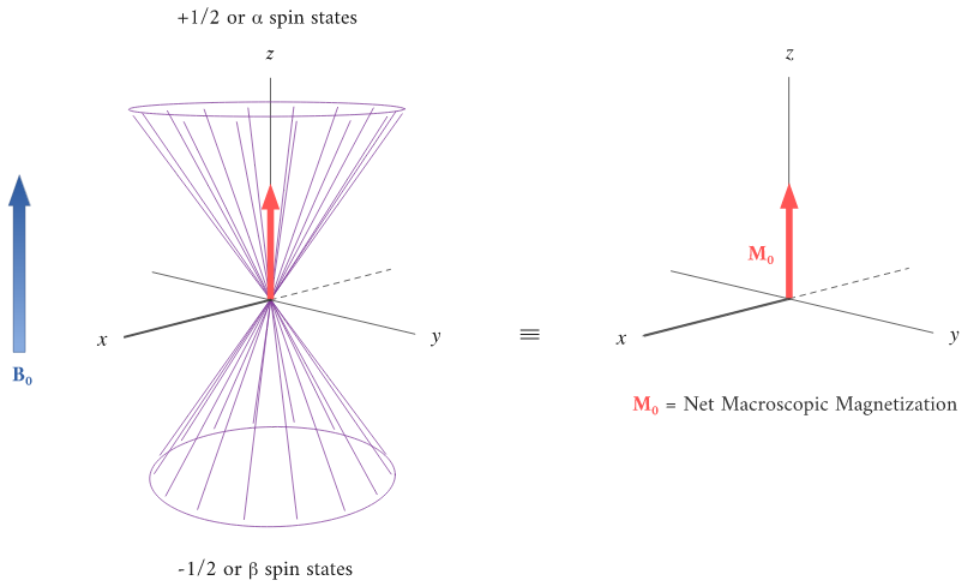
5.8: Precession and Relaxation

What happens when you apply a transverse RF field to the sample with a net magnetization

1. First, the net magnetization shifts away from the z-axis and toward the y-axis. This occurs because some of the +1/2 nuclei are excited to the −1/2 state, and the precession about the z-axis becomes coherent (non-random), generating a significant y component to the net magnetization ($|M|$).
2. After irradiation the nuclear spins return to equilibrium in a process called **relaxation**. As the xy coherence disappears and the population of the +1/2 state increases, energy is released and detected by the receiver. The net magnetization spirals back, and eventually the equilibrium state is reestablished.

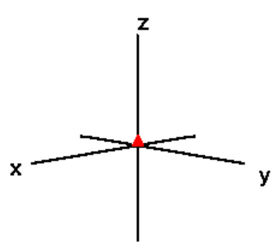
Step 1: Creating a Magnetization with a Magnetic Field

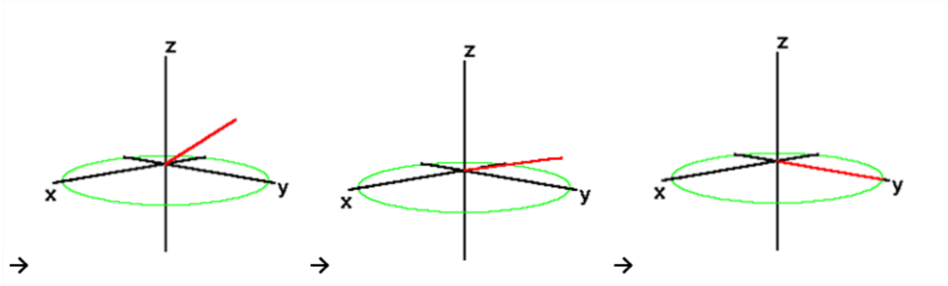
A difference way of looking at the next magnetization:



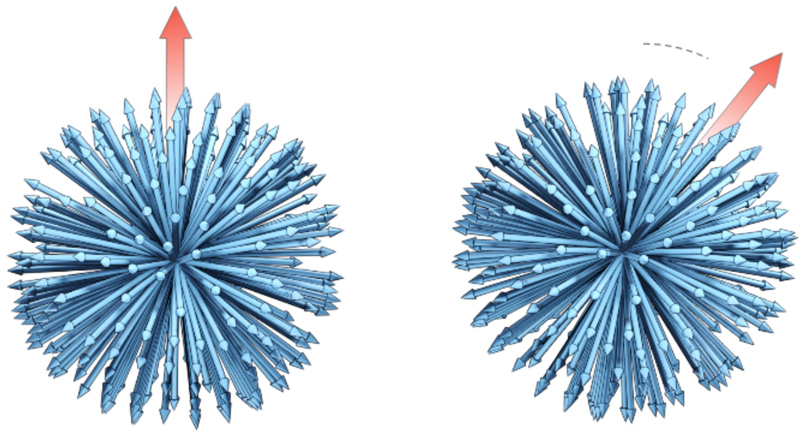
Step 2: Shifting the Magnetization with a Radiofrequency Field

If the net magnetization is placed in the XY plane due to r**esonant radio waves that rotate the equilibrium magnetization in the rotating frame of resonance**, $\vec{M}$ will rotate about the Z axis at a frequency equal to the frequency of the photon which would cause a transition between the two energy levels of the spin at the Larmor frequency.



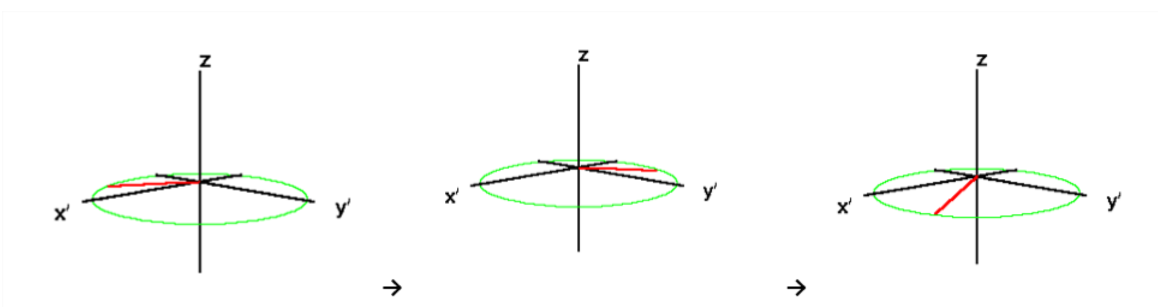


The effect of resonant radio waves is also illustrated in the figure below that shows the rotation of the magnetization distribution resulting from application of a resonant radio frequency pulse



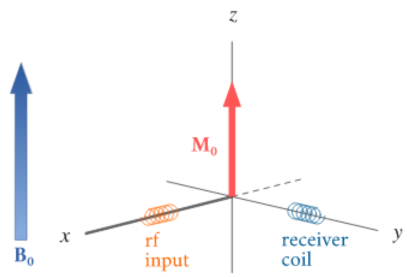
The main magnetic field makes the ensemble of nuclei precess and skews the spin distribution toward the direction of the field as indicated by the higher density of spins along this direction (vertical in the figure). When a resonant radio frequency field is applied, the entire magnetization distribution is rotated around an axis that is rotating perpendicularly to the magnetic field.

Once the magnetication is shifted, it will now rotate (or process)



Lab frame evolution (i.e., not rotating frame)

and so forever (that a magnetic field is applied).



An inherent problem of the NMR experiment must be pointed out here. We have noted that the population difference between the spin states is proportionally very small. A fundamental requirement for absorption spectroscopy is a population imbalance between a lower energy ground state and a higher energy excited state. This can be expressed by the following equation, where A is a proportionality constant. If the mole fractions of the spin states are equal ($\eta_+ = \eta_-$) then the population difference is zero and no absorption will occur. If the rf energy used in an NMR experiment is too high this **saturation** of the higher spin state will result and useful signals will disappear.

$$\text{Probability of Absorption } = A \times \underbrace{\rho\left(v_0\right)}_{\substack{\text{radiation} \\ \text{flux}}} \times \underbrace{\left(\eta_+ - \eta_-\right)}_{\substack{\text{population} \\ \text{imbalance}}}$$

References

- https://www.drcmr.dk/mr