Larmor Precession

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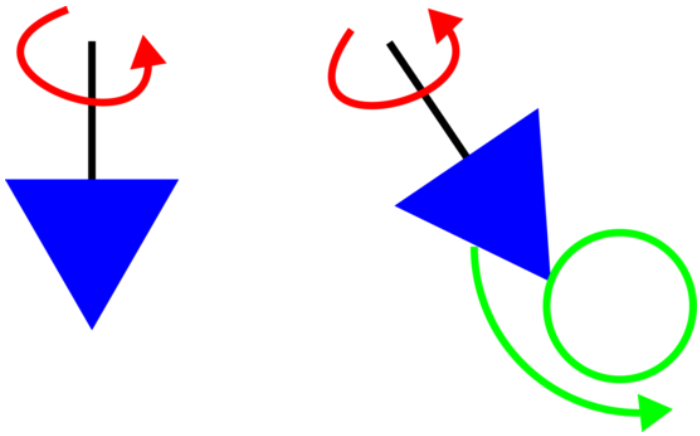
Introduction

When placed in a magnetic field, charged particles will precess about the magnetic field. In NMR, the charged nucleus, will then exhibit precessional motion at a characterisitc frequency known as the Larmor Frequency. The Larmor fequency is specific to each nucleus. The Larmor fequency is measured during the NMR experiment, as it is dependent on the magnetic field that the nucleus experineces.

Spinning Top Analogy

Often it is difficult in NMR to understand the microscopic processes that are occuring. However, precession is easily observed on the macroscopic scale, as toy tops. When a top is spun, it rotates about a central axis. The angular momentum of the top is aligned along this central axis. If the top is set at an angle, the central axis will move in a circle. The top now spinning along its own central axis precesses around in a circle around earths gravitational field.



Atomic Nuclei as Spinning Tops

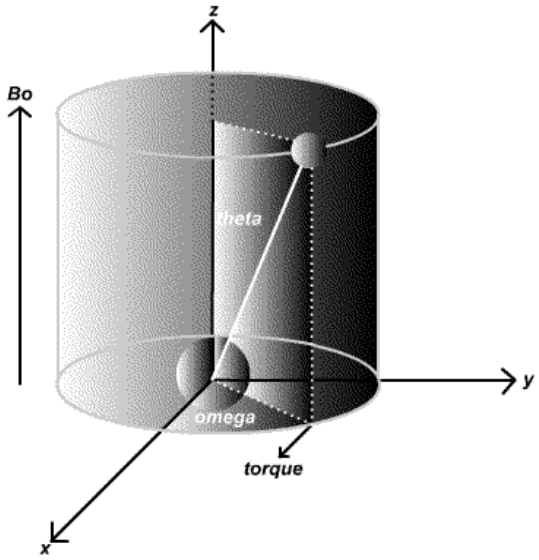
Atomic nuclei contain intrinsic spin. The nucleus, like a top, will spin along an axis, which is the direction of the angular momentum for the nucleus. The spin of the nucleus can be related to the magnetic moment of the nucleus through the relation

$$\mu=\gamma I$$

where μ is the magnetic moment and γ is a proportionality constant known as the gyromagnetic moment. This constant may be positive of negative, dependin on if the nucelus precesses clockwise or counterclockwise, respectively. The nuclear magnetic moment will couple to the external magnetic field. This coupling produces a torque on the nucleus and causes precession around the magnetic field. This is analgous to the macroscopic tops in that the gravitational force couples with the mass of the top. In the absence of friction, the top would precess forever! The frequency of precession is known as the Larmor frequency, ν_0 where

$$\nu_0=\gamma B_0$$

The effect is illustrated below:



Mathematical Treatment

The net magnetization for a sample is the sum of the individual magnetic moments in the sample

$$M=\sum i\mu i$$

we have already defined the magnetic moment for a nucleus with spin I. The magnetization can then be written as

$$M=\gamma J$$

where J is the net spin angular momentum.

The torque, T, of the sample will then be

$$T=dJdt$$

Subsituting M for J we obtain

$$T=MxB$$

and finally

$$dMdt=\gamma MxB$$

then

$$dMdt=\gamma MBsin\theta$$

since M and B are parallel the sin term drops out. We want to know the rate at whcih the magnetization is changing with respect to time so we take the second derivative and the result is the Larmor frequency

$$\omega_0=\gamma B$$

since M and B are both vector quantities, the cross product with B in only the Z direction i.e. (B=(0, 0, B_o)) then we obtain the Larmor frequency

$$\omega_0=\gamma B_0$$

References

1. Duer, M.J., *Solid State NMR Spectroscopy: Principles and Applications*. Blackwell Science Ltd. USA. 2002
2. Fukushima, E., Roeder, S.B.W., *Experimental Pulse NMR A Nuts and Bolts Approach*. Perseus Books Publishing, USA. 1981

Outside Links

- https://en.wikipedia.org/wiki/Larmor_precession

Contributors

- Derrick Kaseman (UC Davis)

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