NMR Experiment

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Abstract

This document reports on Nuclear Magnetic Resonance (NMR) experiment.

Introduction

Nuclear magnetic resonance (NMR) is a physical phenomenon in which the nuclei of certain atoms absorb and re-emit electromagnetic radiation in the radio frequency range when placed in a magnetic field. This phenomenon is used in a variety of applications, including imaging in medicine, studying chemical structures and properties, and analyzing biological molecules. The basic equation for NMR is:

$$\omega = \gamma B_0$$

where ω is the angular frequency of the absorbed or emitted radiation, γ is the gyromagnetic ratio of the nucleus, and B_0 is the strength of the applied magnetic field. The gyromagnetic ratio γ is a measure of the magnetic moment of a nucleus and is given by:

$$\gamma = \frac{e\hbar}{2m_p}$$

where e is the charge of the electron, $\hbar$ is the reduced Planck constant, and m_p is the mass of the proton. The strength of the applied magnetic field B_0 is typically measured in tesla (T).

NMR spectra are typically plotted with the frequency of the absorbed or emitted radiation on the x-axis and the intensity of the signal on the y-axis. The intensity of the signal is related to the number of nuclei that are absorbing or emitting radiation at a particular frequency. In addition to the basic NMR equation, there are two important relaxation times that are often measured in NMR experiments: T_1 and T_2. T_1 is the spin-lattice relaxation time, which is the time it takes for the nuclear spins to return to their equilibrium positions after being perturbed by an external magnetic field. T_2 is the spin-spin relaxation time, which is the time it takes for the nuclear spins to lose coherence with each other due to interactions with their surroundings.

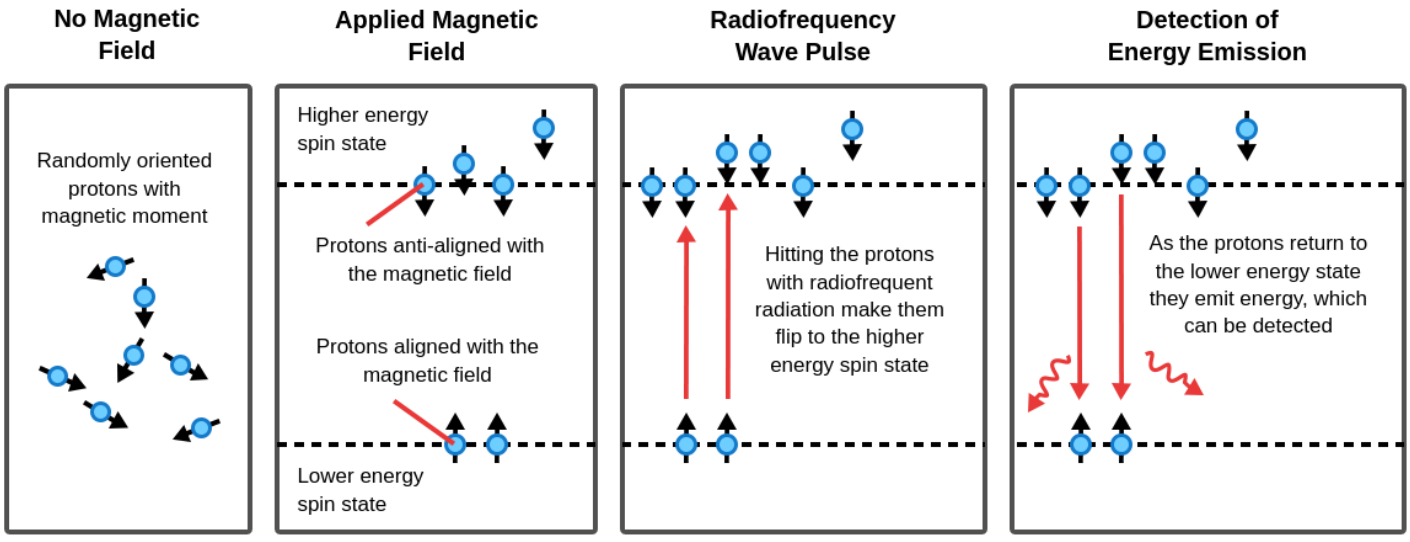


Figure 1: Schematic of the experiment procedure

1 Experimental Setup

- TeachSpin PSA-2 instrument: PS2-A Spectrometer and a PS2 Controller and permanent magnet
- Tektrnoix MD03034 Mixed Domain Oscilloscope
- RF pickup Probe

2 Results & Discussion

To measure T_1 experimentally, a pulse sequence known as inversion recovery can be used. In this sequence, a 180 degree pulse is applied to invert the magnetization of the sample, followed by a series of 90 degree pulses to refocus the magnetization. The time delay between the 180 degree pulse and the 90 degree pulses is varied, and the intensity of the resulting NMR signal is measured as a function of time. The decay of the signal intensity with time is described by an exponential function:

$$M(t) = M_0 e^{-t/T_1} \tag{1}$$

where $M(t)$ is the magnetization at time t, M_0 is the initial magnetization, and T_1 is the spin-lattice relaxation time.

To measure T_2 experimentally, a pulse sequence known as spin-echo can be used. In this sequence, a 90 degree pulse is applied to create a spin echo, followed by a 180 degree pulse to refocus the magnetization. The time delay between the 90 degree pulse and the 180 degree pulse is varied, and the intensity of the resulting NMR signal is measured as a function of time. The decay of the signal intensity with time is described by an exponential function:

$$M(t) = M_0 e^{-t/T_2} \tag{2}$$

where $M(t)$ is the magnetization at time t, M_0 is the initial magnetization, and T_2 is the spin-spin relaxation time.

2.1 Calibration

The first thing to do is to calibrate the device, which we will do using the RF pickup probe. We will vary the frequency until we find the larmor frequency, which will cause a resonance and thus a peak in the oscilloscope. The result is the following picture:

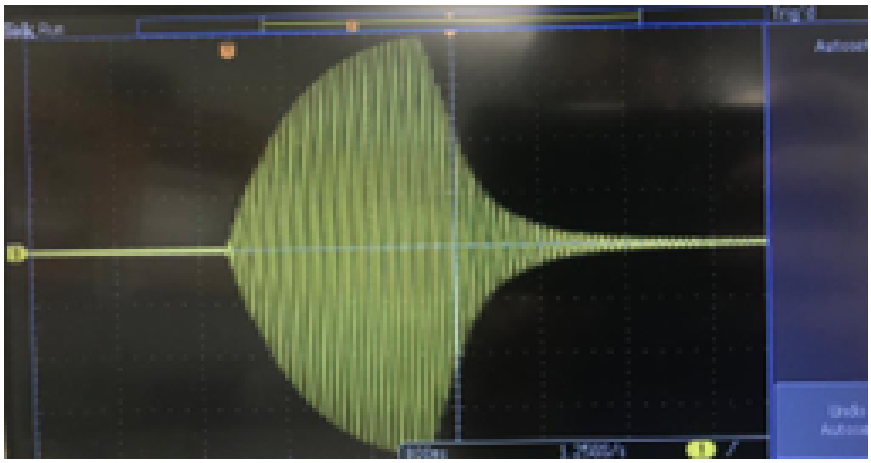


Figure 2: Oscilloscope snapshot

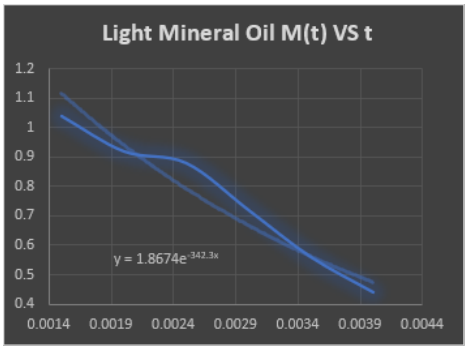
2.2 T1 & T2

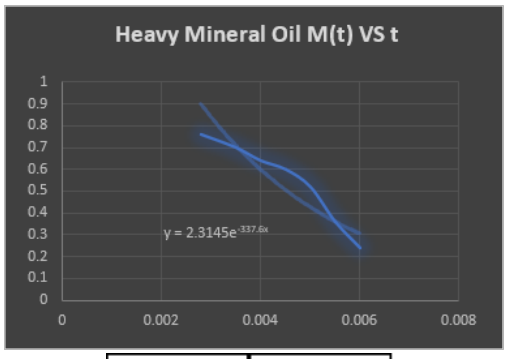
Now we need to find T1 and T2. The typical values are in the following table:

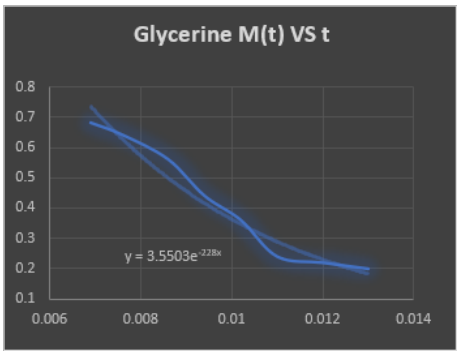
Sample	Tau range for T1	Tau range for T2	Period
Light Mineral Oil	30-200 ms	10-40 ms	200 ms
Heavy Mineral Oil	50-150 ms	6-60 ms	200 ms
Pure Water	1.7-3 s	8-140 ms	5 s
Water w/ FeCl3	240-600 ms	10-100 ms	800 ms

Table 1: Typical values for T1 and T2

After carrying out the experiment, and fitting the results to Equations (1) and (2). We obtain the following:







Type	T3 (ms)
L	8.7
H	5.9
G	5.8

Figure 3: Results for T2

3 Conclusion

In conclusion, NMR is a powerful tool for measuring T1 and T2 relaxation times experimentally. By applying appropriate pulses and analyzing the resulting signals, it is possible to extract detailed information about the relaxation dynamics of various materials. This information can be used to study the structure and properties of a wide range of substances, including biological tissues, polymers, and liquids.