Nuclear Magnetic Resonance

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The relaxation times of heavy mineral oil are experimentally determined in this study. The nuclei of heavy mineral oil investigated are very abundant and give particularly strong signals. The spin-lattice relaxation time is (24.5±0.9) ms and the spin-spin relaxation time is (18.2±1.5) ms.

Background and Theory

Nuclear Magnetic Resonance (NMR) spectroscopy was first utilized in 1946. The NMR technique is useful for studying physical phenomena from kinetics to superconductivity, and was recognized with a Nobel Prize in Physics [1]. The major importance of NMR is the ability to characterize materials by probing the nuclei and immediate surroundings. Within a certain solid there are varieties of local magnetic fields, and NMR spectroscopy is able to measure the local field at atomic nuclei. NMR also has implications in the medical field, with Magnetic Resonance Imaging (MRI). The imaging technique allows physicians to produce noninvasive three dimensional images of blood flow patterns in both the brain and heart, and eventually hopes to pinpoint malignant tissue without biopsies [2].

Magnetic Resonance (MR) is observed in constituents that have both a magnetic moment (μ) and angular momentum (J). It's imperative to note that many, but not all, of the stable nuclei exhibit these traits.

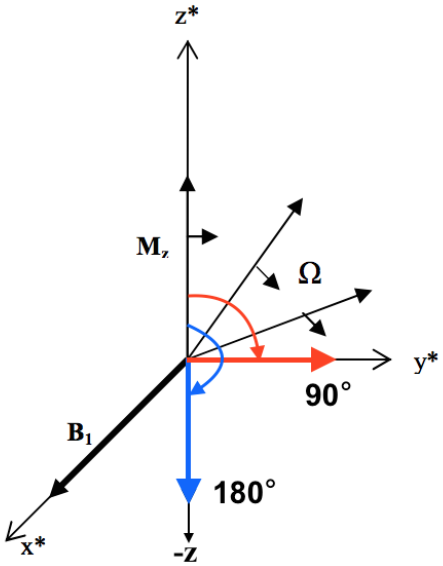

Figure 1. The red arrow illustrates the 90°pulse, and the blue represents the 180°pulse.

The two magnetization states that are concerned in this study include the T_1 and the T_2 states. The initial magnetization is in the positive z-direction.

$$M_0 = M_z \tag{1}$$

T_1 is called the spin-lattice constant relaxation time, which requires a two pulse sequence. An initial 180°pulse flips the magnetization from M_z to -M_z. The 180°pulse is followed by a 90°B pulse, which coverts the -M_z state into the M_{xy} plane-magnetization.

The T_2 state is called the spin-spin relaxation time. As the magnetization reaches the -M_z state, the spin echo is triggered and an exponential decay is seen as time propagates. An initial 90°pulse turns M_z to the M_{xy} plane-magnetization. Following the initiation pulse, a secondary 180°pulse then changes the magnetization plane from M_{xy} to -M_{xy}. Initial magnetization re-phases through the spin echo, and the time decay for this phenomena was measured as exponential decay.

Apparatus

The study used an apparatus, which a schematic is shown in figure 2, consisting mainly of a permanent magnet connected to a mainframe. The mainframe allowed for the manipulation of the A-pulse length (A_len), B-pulse length (B_len), tau (τ), iterations (Num_B), period (P), and start pulse. A PS2 controller was connected to the mainframe to render various gradient configurations of the magnetic field. Voltage amplitudes were generated on the oscilloscope for data of relaxation calculations.

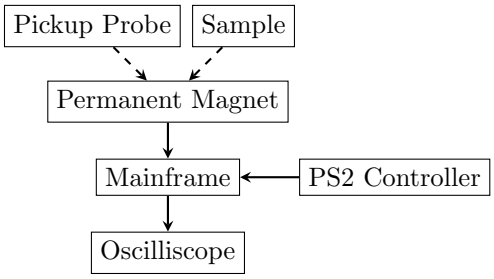

Figure 2. An illustration of the experimental setup. The dashed lines indicate the different samples that are input into the permanent magnet.

Procedure and Relevant Equations

The sample used in this study was Heavy Mineral Oil (HIO). Initially, the NMR needed to be calibrated. Calibration was done using the Radio Frequency (RF) probe, and measuring the voltage outputs. HIO was prepared and placed into the magnetic field of the permanent magnet. A single pulse sequence consists of two bursts of RF magnetic field separated by a variable time, τ. T1 was found by, an initial 180°pulse, followed by a 90°pulse. This two sequence procedure was iterated with varying times, τ, between the A and B pulses. T2 was found by a pulse sequence of 90°to 180° to the echo maximum for a total time, 2τ.

$$M_z = M_0(1 - 2e^{-\frac{t}{T_1}}) \tag{2}$$

The magnetization does not appear instantly, as there is a delay time between 90°and 180°pulses, so the observed quantities will portray an exponential growth, represented in equation 2. The instantaneous value, M, in equation 2 represents the magnetization, while M_0 is the equilibrium value [2].

$$M_{xy} = M_0 e^{\frac{-2t}{T_2}} \tag{3}$$

Secondly, the T_2 state is the second degree magnetization. The exponential decay is represented in equation 3. The coefficient, 2, describes the progression from the 0°to 180° (τ) and from the 180°to spin echo (2τ) state.

Calculation of Results and Errors

Figure 3 was the original data that included the maximum amplitude of the Fee Induction Decay. To achieve the generated fit, the amplitudes before the minimum were flipped to negative amplitudes, resulting in figure 4. The fits in equations 2 and 3 yielded computed results of the relaxation times. T_1 and T_2 were determined to be (24.5±0.9) ms and (18.2±1.5) ms, respectively.

Table I. Resultant decay time for both T1 and T2 relaxation times.

Relaxation Time State	Pulse Sequence (°)	Decay Time (ms)
T1	180→90	24.5±0.9
T2	90→180	18.2±1.5

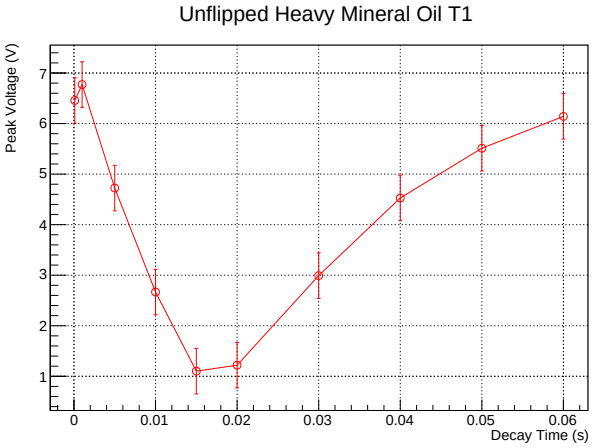

Figure 3. Original T1 mineral oil data before the initial pulses were flipped to negative voltages. Spin-lattice constant relaxation time, T1 fit for heavy mineral oil.

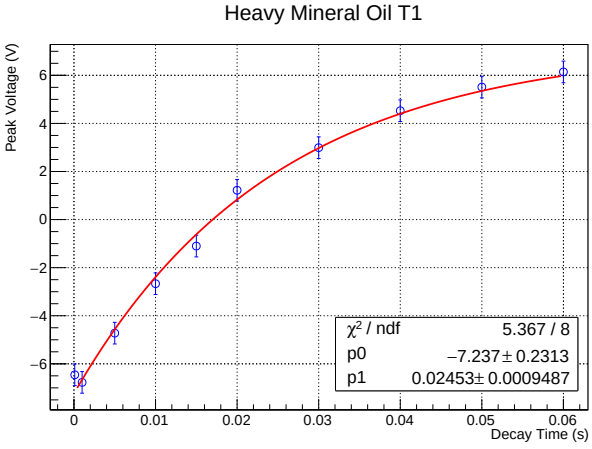

Figure 4. Spin-lattice constant relaxation time, T1 fit for heavy mineral oil.

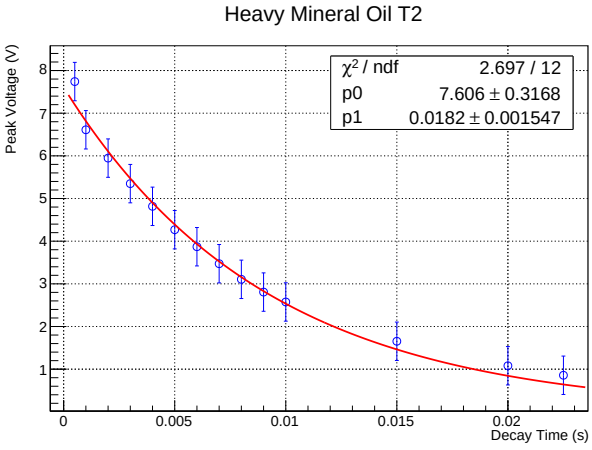

Figure 5. Spin-spin relaxation time, T2 fit for heavy mineral oil.

Discussion and Conclusion

The spin-lattice constant relaxation time was found to be (24.5±0.9) ms. Additionally, the spin-spin relaxation time was determined to be (18.2±1.5) ms. There were no literature values for these decay times, therefore sigma deviations were not reported. Error was mainly resultant from the oscilloscope while reading voltages. The maximum jump observed was 0.45 V, therefore that uncertainty was carried for each value. An analysis was conducted on a fluorine sample, but due to low resolution in data, this sample was nullified.

[1] http://pubs.acs.org/doi/abs/10.1021/ac00054a716?journalCode=ancham
[2] http://www.outreach.phy.cam.ac.uk/camphy/xraydiffraction/xraydiffractionindex.htm