

April 13, 2000

Experiment G7a

Pulsed NMR: Spin Echoes

A horizontal (z axis) magnetic field is used to polarize the proton spins in a liquid sample. These spins are then tipped 90 degrees into the xy plane. This is done with an rf magnetic field which is perpendicular to the dc field. The rf frequency is fixed at the resonance frequency. The resonance is tuned by tweaking the dc field. After the spins are tipped into the plane, they become out of phase with each other due to "relaxation"—random molecular fields due to the other molecules. As a result, the signal, which is due to all the spins acting in concert together, quickly disappears † After they have spread out in the xy plane, they are reversed by tipping them 180 degrees. They will then precess until they are back together. The spin relaxation reduces the magnitude of the "spin echo" observed. Varying the time delay between the 90 degree and 180 tipping pulses allows you to measure the relaxation time T_2 by observing the decay of the echo.

1. Set up the apparatus according to the instructions in the next section. Ask the instructor or Nick if there are any questions about this. You should be able to observe a spin echo in the glycerine sample. Use the Hall probe to measure the magnetic field. Estimate the rf frequency and calculate the proton magnetic moment. Insert (carefully!) a small amount of magnetic material into the magnet, and observe the effect on the signal. Explain. Read the introductory article on NMR by Pake.
2. Measure T_2 and T_2^* for glycerine. This will involve taking a number of data points on the spin echo amplitude vs. delay time between the 90 degree pulse and the echo (2τ).
3. Find a pure water sample. T_1 is very long for pure water— it is hard for the spins to exchange energy with the other degrees of freedom in water. Also measure T_2 and T_2^* . Compare the values you get for T_2^* with the value you get for glycerine. Why are the proton spin relaxation times different for water and glycerine? Could you measure the self-diffusion constant in water? (See Carr and Purcell, page 636ff.)
4. The light blue tubes contain a solution of copper sulphate in water, with the various concentrations, ranging from 10^{17} to 10^{20} ions/cc labelled. Copper is a paramagnetic ion, so the water protons "feel" different fluctuating magnetic fields. Measure T_1 and T_2 for several different concentrations and plot T_2 vs concentration on a log-log plot. What can you conclude from this? (Instead of copper ions you can use iron ions. The yellow colored solutions are ferric nitrate. Try some of these, and see if you agree with the data plotted on page 586 of the 1950 article by Hahn. Also compare with equation (54) on page 705 of the article by Bloembergen, Purcell and Pound. Explain.

† This is called the "free induction decay".