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The Frozen Spin Proton Target at TRIUMF

P.P.J. Delheij, D.C. Healey and G. Wait

TRIUMF, 4004 Wesbrook Mall, Vancouver, B.C. V6T 2A3

At TRIUMF a new polarized proton target of the frozen spin type[1)] has been constructed and operated to study neutron induced reactions at medium energies. A decay time of about 20 days in a magnetic field of .26 T and a polarization of .97 has been obtained for a 55 cm^3 1-butanol sample in the form of beads with a diameter of 1.4 mm and an EHBA doping of 4×10^{19} molec/cm^3 and 6×10^{19} molec/cm^3. Charge-symmetry breaking was investigated in n-p elastic scattering at 480 MeV which will be reported elsewhere during this symposium.

The target is mounted on a vertical dilution refrigerator with a cooling power of 100 mW at 0.5 K. Since a neutron beam cannot be collimated efficiently the target volume (~ 150 cm^3) is split in three equal parts. Vacuum spaces (about 50 cm^3 each) are located above and below the polarized material (Fig. 1). The magnet system consists of a superconducting solenoid and an electromagnet. The solenoid delivers in its center a magnetic field of 2.5 T with a homogeneity of ±50 ppm over the target volume. In this location the polarizing of the sample takes place. When the beam is turned on the target is positioned in the gap between the magnets where the field strength is 0.26 T which is reproducable and stable within 10^{-3} during a target run of three weeks. The opening angles are ±93° horizontally and ±11° vertically. The protons are polarized with microwaves which are produced by a Varian model VRE2101B7 cyclotron with a nominal output power of 600 mW at 70 GHz. Through a K-band transmission line outside the cryostat and a copper plated CuNi-tube in the refrigerator a power of about 350 mW can be delivered to the sample chamber. However, the initial power level during the polarizing process is usually 100 mW which produces a polarization of 50% in about fifteen minutes. Then, the microwave power is gradually reduced to 25 mW. The polarization is measured with a series resonant, constant current NMR system. The phase shift due to the polarization is obtained from the difference signal of the target coil and a reference coil at room temperature. The system is calibrated about once a week during experimental runs with a thermal equilibrium measurement. The signal reproduces over these periods typically within 4%. The digital control system contains in one CAMAC crate two microprocessors and an LSI-11/03. One drives the frequency synthesizer of the NMR system. The other microprocessor receives the digitized signals from the NMR coil, thermometers and pressure gauges. The LSI-11 monitors the target systems, handles the printout of the data and the transmission to the data acquisition computer. For the charge-symmetry experiment the target was operated during about 2000 hours in runs that were up to three weeks long. It was always possible to have the target polarized within 20-24 hours after loading of the butanol was started. Once an unscheduled warming up of the target occurred due to malfunction of a He-4 pump. This caused a loss of two days of beam time.

During the experiment about seventy decay time measurements were obtained in a magnetic field H=0.26 T with EHBA concentrations $n=2.5\text{-}6\times10^{19}\ cm^{-3}$. Some of these data are shown in fig. 2. The temperature is measured with carbon resistors. The error in the calibration against the absolute temperature is estimated to be 5 mK. However, the relative accuracy of the data points is better than 1 mK. The fluctuations in the data must be due to a variation in the temperature difference between the center and the bottom of the target where the NMR coil and resistors are located respectively. The data can be represented (within a factor 2) by the function

$$\tau = 0.7 \times 10^{17}\ \frac{1}{n}\frac{H^4}{T^6}\ \text{(hrs.)} \qquad (1)$$

where T is the absolute temperature (in K). This function can even be used to estimate the order of magnitude of τ when H and T are extrapolated over a wide range.

At H=2.5T T=.51K n=4×10 cm^{-3} a lifetime T=0.53 hrs. was measured while the calculated value would be 3.9 hrs.

The data in ref. 2 indicate for butanol at 55 mK and 0.25 T a decay time of 175 hrs. However, no details about the doping are reported.

References

1) T.O. Niinikoski and F. Udo, Nucl. Instr. Meth., 134 (1976) 219.
2) J. Ball et al., Proc. 4th Int. Workshop Pol. Target Materials and Techniques, ed. W. Meyer, Bad Honnef 1984, p.112.

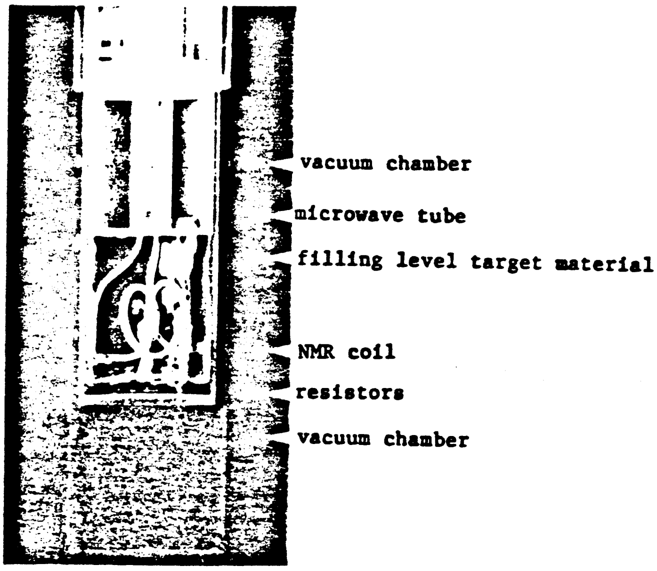

Fig. 1 X-ray of the target chamber.

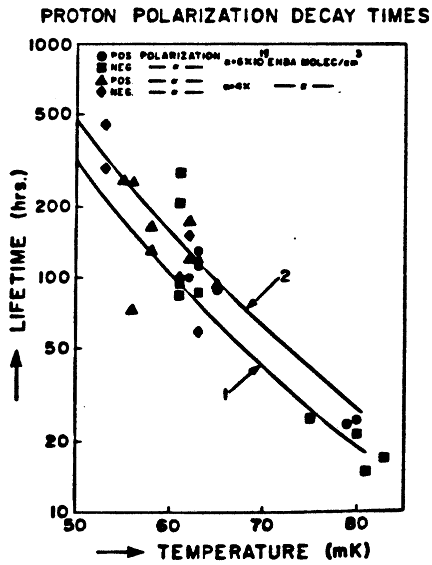

Fig. 2: Temperature dependence of the polarization lifetime. The curves are obtained from equation (1).