^{3}He relaxation in uncoated glass cells – orientation, magnetic field and pressure dependence

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Introduction and Method

The aim of these experiments was to investigate the spin relaxation of ^{3}He in glass cells in order to develop a good recipe for producing and storing the HP ^{3}He used in lung MRI. A significant dependence of ^{3}He relaxation times in glass spin-exchange optical pumping cells due to the physical orientation of the cell relative to the applied magnetic field has already been noticed [1][2]. We measured the NMR lineshape and T_1 with different field directions. The orientations were the following: **+** with Earth's field, **-** opposing Earth's field.

The system consists of two uncoated glass cells: Storage cell - 1720 Corning; 62% SiO_2, 17% Al_2O_3, 5% B_2O_3, 1% Na_2O, 7% MgO, 8% CaO and Optical Pumping Cell – 7740 Corning Pyrex;80.6% SiO_2, 4% Na_2O, 13% B_2O_3, 2.3% Al_2O_3, 0.1% K_2O

For measuring the T_1 in the storage cell, the gas was transferred from the optical pumping cell into the storage cell with a low pressure of up to 20 mBar. A NMR tipping pulse was applied every 40 minutes and a FFT was taken. We then plotted the FFT peak heights and fitted with an exponential decay.

Results and Discussion

1. Field orientation dependence

The T_1 relaxation times are shown in Table 1, for the OPC, and Table 3, for the Storage Cell. The evolution of the applied magnetic field orientation during the experiments is shown in Figure 1.

+ orientation During period *a* T_1 was longest. In period *b* T_1 was reduced following 2 days at B=0. Starting during period *c* the T_1 with + orientation started to recover.

– orientation T_1 values in this orientation were always lower than with + orientation. T_1 increased during all four *a-d,* and were not affected by time spent at B=0.

Looking at Figure 1 we conclude that the longest T_1 was obtained with + orientation immediately after changing the orientation from – to +. After magnetizing the storage cell the T_1 was dramatically shorter but demagnetizing and heating the cell improved T_1.

A magnetic field orientation dependence was also observed by RAL group (Table 2).

2. Field strength dependence

The field strength is given by the current through the Helmholtz coils (0.07mT·A^{-1}). The T_1 was measured at 0.5 A, 1.5 A, 3.37 A or 3.48A and 4.81 A. The measuring field was 3.37 A for + orientation, 3.48 A for – orientation corresponding to 0.02 mT . Table 3 displays the T_1 measured with different field strengths and orientations. The T_1 varies weakly with field strength and the longest T_1 was obtained at the measuring field. Similar results were obtained with – orientation.

3. Pressure dependence

Usually the gas was stored and measured at 20 mBar. We noticed that with + orientation (Figure 2) the FFT shape is much more asymmetric than with – orientation (Figure 3). Also, with both orientations, below 10 mBar the FFT shows distinct features. The FFT shape becomes wider with increasing pressure. For pressures exceeding 160 mBar the peak of the FFT shape is much more rounded. Motional narrowing occurs at low pressures.

4. Temperature and magnetization dependence

Heating the storage cell did not affect the NMFR lineshape as shown in Figure 4 but we did notice that the T_1 is improved after heating the cell. The FFT shape is not affected by the cell magnetization either (Figure 5). It is only the T_1 that is very short after this event. The T_1 returns to its previous values or even longer after degaussing the storage cell.

Conclusions

The cell appears to contain magnetic materials in the wall which can be magnetized and demagnetized to some extent. It is not known whether this is due to Co in the glass or contamination with iron during fabrication.

The glass magnetization at room temperature is time and history dependent

The lineshape confirms the magnetization of the glass cell and shows unexpected structure. Classic motional narrowing is observed when the pressure is reduced and diffusion increases such that gas samples an average B over the cell.

There seems to be an optimal B ~ 20 gauss for long T_1 in this cell.

T_1 is longest when the gas is stored with B parallel to Earth's field immediately after changing the orientation from opposing the Earth's field and after degaussing and/or heating the cell.

References

1. R.E. Jacob et al., Phys. Rev. A 69, 021401 (2004)
2. R.E. Jacob et al., J. Appl. Phys. 92, 1588 (2002)

Table 1. T1 relaxation time in Optical Pumping Cell

Orientation	T1 (min)
+	224[a]
-	213[a]

Table 2. T1 relaxation time obtained by RAL group

Cell Name	T_1 Norm	T_1 Rev
Sammy	96	58
Cyrill	6	13
Bob(Kate)	20	100
Bertha	12	40

Table 3. T1 relaxation time in Storage Cell

Orientation	T1(min) @ 0.5 A	T1(min) @1.5 A	T1(min) @3.37 A	T1(min) @4.81 A
+	82[c]	432[a]	430[a]	165[b]
		142[b]	202[b]	165[c]
		153[c]	297[c]	
			315[d]	
Orientation	**T1(min) @ 0.5 A**	**T1(min) @1.5 A**	**T1(min) @3.48 A**	**T1(min) @4.81 A**
-	45[b]	189[a]	139[a]	138[a]
		153[c]	148[b]	121[a]
			161[c]	156[b]
			188[d]	108[c]

a – before B=0 for 60 hours
b – after B=0 for 60 hours
c – starting a week after B=0
d – after heating and degaussing the storage cell

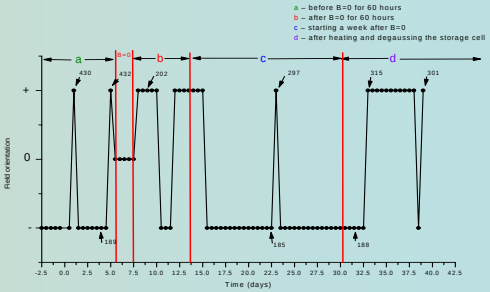

Figure 1. The evolution of the field orientation during the experiments

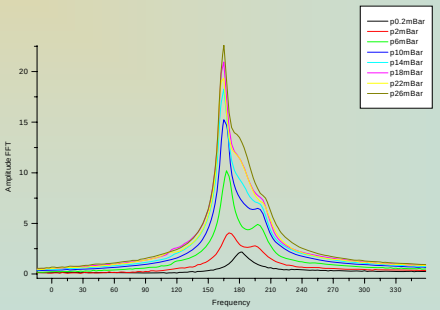

Figure 2. The FFT shapes with + orientation

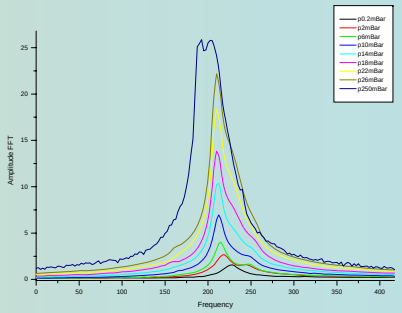

Figure 3. The FFT shapes with - orientation

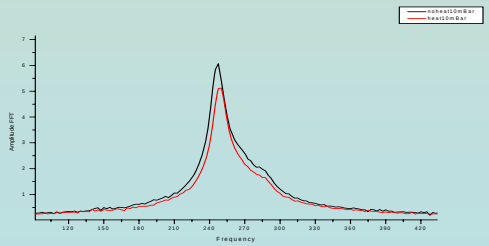

Figure 4. The FFT shapes before and after heating the storage cell

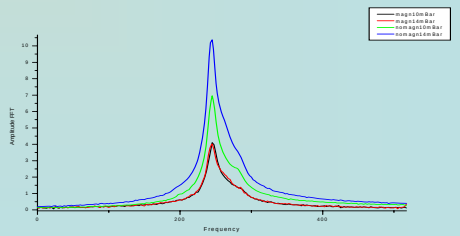

Figure 5. The FFT shapes before and after magnetizing the storage cell