Experimental Report

15/01/2015

Proposal: **5-32-801** **Council:** 4/2014

Title: Nanocluster molecular magnetic gels in superfluid helium: cold neutron scattering

This proposal is a new proposal

Research Area: Other...

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Samples: oxygen gel sample; heavy water gel sample in superfluid helium

Instrument	Req. Days	All. Days	From	To
D33	6	4	03/11/2014	07/11/2014

Abstract:

An oxygen gel sample could be prepared by condensation of the helium gas with small impurity of molecular O2 on the surface of superfluid He-II. Based on results of SANS studies of the oxygen gel sample at D22 diffractometer and subsequent theoretical estimations, we conclude that if the cell with an oxygen sample at the temperature below 1.8 K were placed in an external magnetic field H>200 Gs than the magnetic structure of the nanocluster backbone should be close to ferromagnetic, substantially different from that in the bulk impurity substance. In order to check this conclusion, we propose to perform a set of SANS measurements with oxygen (and heavy water for comparison) gel samples at D33 instrument. Magnetic field would be provided using external electromagnetic coils. Cold neutrons should be spin-polarized. In addition to studying nanostructured gel samples we would like also to measurefine-grained icy structures formed after decaying the gel on heating in the magnetic field of up to 800 Gs. Samples would be grown in-situ in our specialized cryostat. This study could open new options for expanding our knowledge on properties of molecular cluster magnets.

Nanocluster molecular magnetic gels in superfluid helium: cold neutron scattering.

Preliminary report.

The impurity-helium oxygen gel samples were prepared by codensation of the gas mixture ^{4}He with an impurity vapors at the surface of superfluid He-II in the quartz glass experimental cell placed in the middle part of our crystat. Unfortunately the construction features of the installation D33 had not permitted us to install an aditional electromagnetic coil necessary for the preliminary magnetization of the free impurity clusters created near the vapor-superfluid He-II interface before their aggregation at the surface and in the bulk of superfluid He-II as it was planned in our proposal. All the samples under study were prepared in zero magnetic field, and the backbone of the gel sample in He-II was consisted of the aggregates formed by the occasionally oriented oxygen nanoclusters.

At the beginning we had measured the angular dependence of intensity I(q) of the beam of spin-polarized neutrons scattered at our sample in the range q = 0.003 – 0.5 Å $^{-1}$ for neutrons polarized along (+) or in opposite (-) direction of the outer magnetic field in different magnetic fields H from 0 to ~ 3kGs at fixed temperature T=1.6 K. The field dependence of the total intensity $N^+/s = \int I(q)^+ dq$ and $N^-/s = \int I(q)^- dq$ of the neutrons scattered at the sample №1 is shown in Fig. 1. For comparison we presented here results of the measurements of the beam propagation through the bottom (lower) and the top part of the same freshly prepared sample №1. The field was increasing by steps from ~0.02 up to ~2 kGs, initially (the current through the electromagnet coil was raised up to 9.4 A), and then the field was decreasing, as shown by the arrow in the dashed curve (the time direction) in fig.1. The total time duration of the study was about 4 hours (20 min. for a point with the same polarity). The observed increasing in the beam intensity N/s with a time might be attributed: a) - to a slow growth of the local density of the both parts of the sample №1 (the nuclear scattering), and/or b) - to any changes in the magnetic structure of the gel backbone (the magnetic scattering). To try to clear the situation and to reveal the role of relatively weak magnetic scattering against the background of the strong nuclear scattering we'll need further careful analysis of results of all the measurements carried out at 3 different samples.

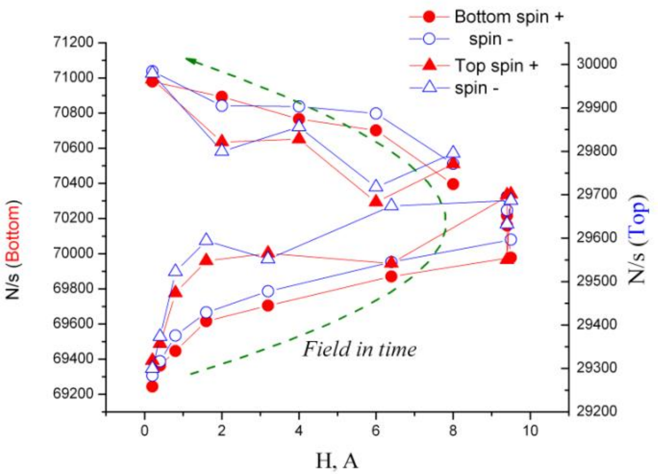

Fig. 1. Oxygen gel sample number 1. The total intensity N/s of the beam scattered at small angles in the range q = 0.003 – 0.5 Å^{-1}. The measurements were made at T=1.6 K with increasing of the current through the electromagnet coil up to 9.4 A (to H~ 2kGs; shown by points at the lower side at the frame) and next with decreasing the current (points at the upper side of the frame). The dashed curve illustrates the changes of the current with time. Left scale – the neutron propagation through the bottom of the sample, and the right scale – propagation through the top (really it was the middle part of the long sample №1).

In Fig. 2 we presented some results of estimations of the difference in intensity { I(q)$^+$ - I(q)$^-$ } for the spin polarized neutron directed towards (+) or against (-) the external magnetic field H, as it was observed in the “top part” of the sample. It is seen that after the field was switched off the difference { $I(q)^+$ - $I(q)^-$ } had decreased. But the total time spared for this measurement had reached a few hours, and this might be explained that at the last series of the measurements the velocity of any changes in the density of the sample could be diminished. It ought to be noted once again that to divide between the relatively weak magnetic and the strong nuclear scattering we’ll need a time for further careful treatment of the data obtained.

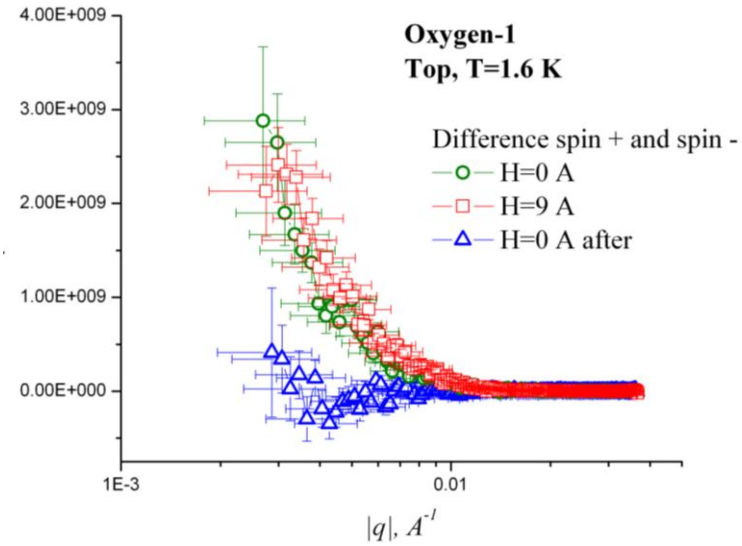

Fig. 2. Difference in intensity of the spin polarized neutron scattering { $I(q)^+$ - $I(q)^-$ }. The measurements of I(q) were made in zero magnetic field (H<20 Gs, green dots), in the strong magnetic field ((I= 9A, H~ 2 kGs, red squares), and the next - after switching off the outer field (blue triangles).

From results of the measurements of the direct beam propagation N/s through the sample with increasing the temperature of liquid helium in the bath from 1.6 to 4.2 K (Fig 3, a) and of the temperature of He vapors in the cryostat at T above 4.2K at constant pressure P=1 atm (Fig 3, b) one could judge on any changes in the sample structure.

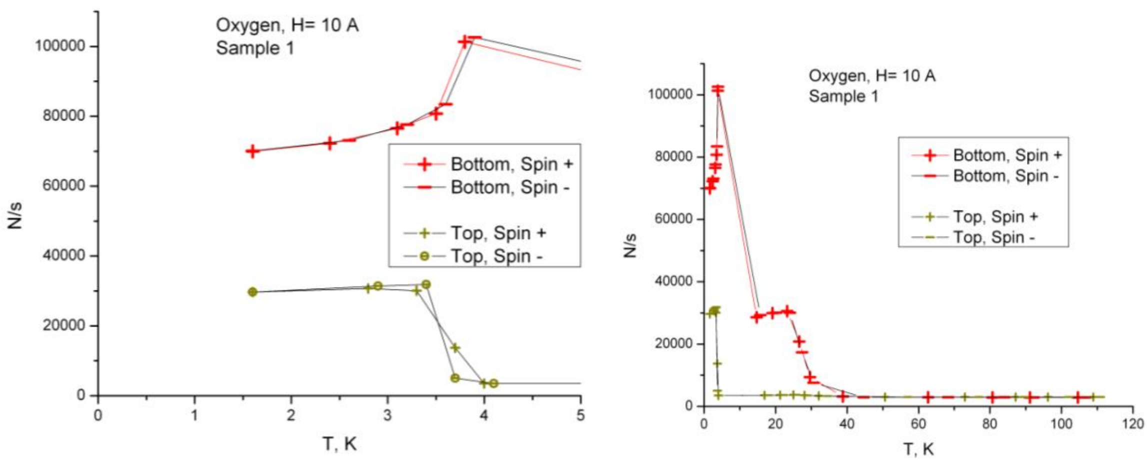

Fig. 3. A) The direct beam propagation N/s through the sample №1 in liquid helium in the temperature range T= 1.6 - 4.2 K. B). Propagation through the sample in He gas atmposhere.

It is seen that in liquid helium (3,a) the intensity of the beam propagating through the “bottom part” of the sample is increasing with temperature, and the same time it is decreasing for the “Top” part of the sample. In He gas atmosphere (3,b) the intensity of the beam propagation through the bottom part is increasing up to ~10 K (due to increasing in density of the lower part of the sample) and then it starts to decrease, due to decay of the gel, apparently. As for the “Top” part of the sample the total intensity N/s starts to decrease on heating above 5 K due to decay of the upper part of the sample. It could be of a great interest to compare the results observed on 3 different samples. Most of the results of the study are planned to be presented in the full report and published elsewhere.

At the last night when finishing with the allocated for our SANS study time interval we were able to measure the scattering of cold neutrons on the gel sample prepared from the deuteromethane CD_4 . The structure of methane gel sample in He-II was studied for the first time. Any results of this preliminary study are planned to be presented in the full report and published elsewhere.