объединенный
институт
ядерных
исследований
дубна

E3-94-291

E.B.Dokukin, S.V.Kozhevnikov,
Yu.V.Nikitenko, A.V.Petrenko

INVESTIGATION OF Fe_3O_4 COLLOID BEHAVIOUR IN A MAGNETIC FIELD BY POLARIZED NEUTRON TRANSMISSION

Submitted to «ICM'94», Warsaw, Poland, August, 1994

1994

Magnetic colloids exhibit various static magnetic properties [1,2]. They can be explained if the magnetic field induction microdistribution is known. Neutrons are an irreplaceable instrument here, but up to now their utilization has been restricted mostly to small-angle scattering [3-5] techniques. Transmission of polarized neutrons through a sample makes it possible to study magnetic colloids by measuring the beam depolarization from magnetic clusters or by observing the coherent motion of the polarization vector in a magnetic field, which varies over the distance of the sample dimension scale. In this case, the normalized polarization $P_s(\lambda) = P(\lambda)/P_0(\lambda)$ of a beam that was transmitted through the sample is determined by the spin-flip cross-section [6].

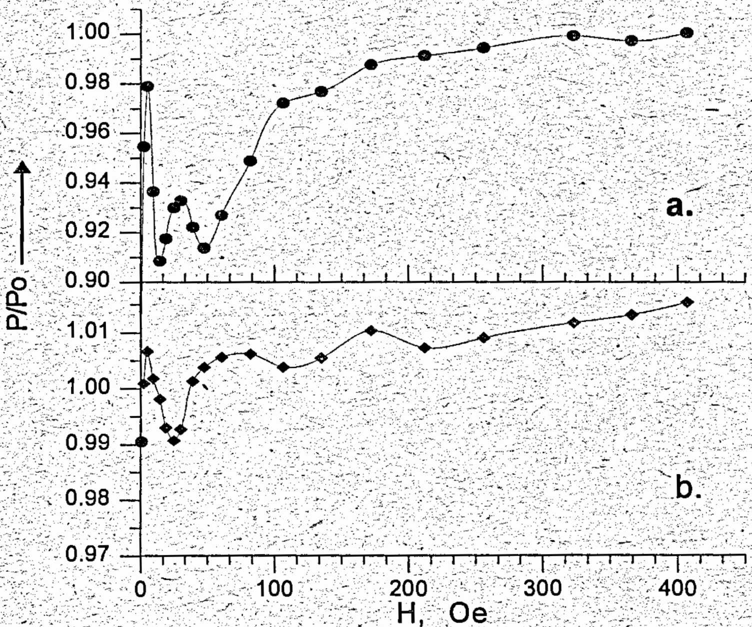

Fig.1. Integral over neutron wavelength interval 1÷12Å polarization P_s via magnetic field : a)-colloid concentration $c = 20\%$; b)-colloid concentration $c = 10\%$

Figure 1a shows $P_s(H)$ for a colloid with a solid phase concentration of $c = 20\%$. $P_s(H)$ has minima at H=15, 45, 130, and 370 Oe. Figures (2a-2c) show the $P_s(\lambda)$ dependencies for the same concentration at H=15, 45, and 130 Oe. Within the interval of 1÷4Å this dependence has a sine character. The sinusoidal period decreases as the magnetic field strength increases. The data presented in Figs. 1, 2 show that a coherent change in neutron polarization takes place.

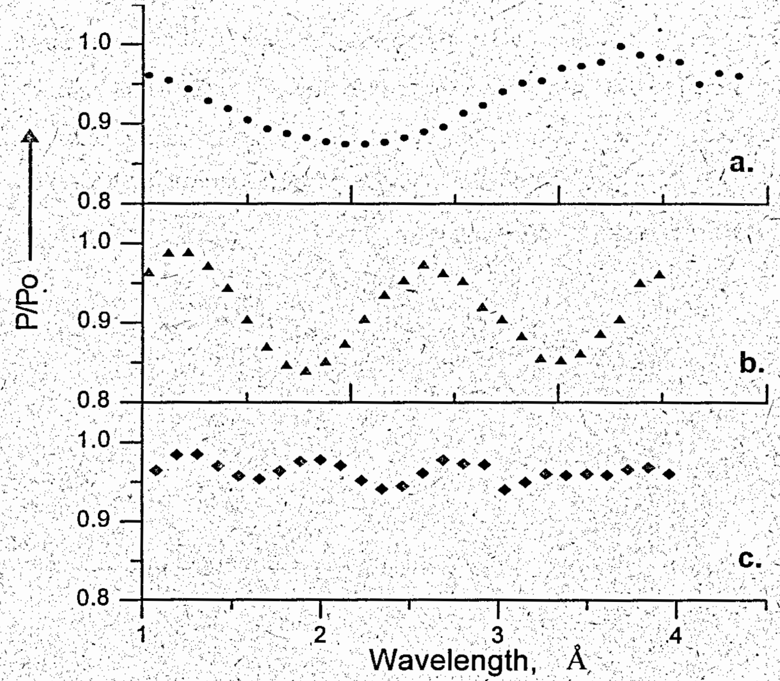

Fig.2. $P_s(\lambda)$ dependence for the concentration $c = 20\%$ at magnetic field:

a)-H=15 Oe; b)-H=45 Oe; c)-H=130 Oe

The picture of a neutron passing through the sample appears to be as follows. At the sample boundary, neutron spin precession arises around the induction vector in the sample because of a jump in induction direction. Inside the induction vector turns slowly, and the precessing spin follows adiabatically. The $P_s(\lambda)$ oscillation period determines the mean magnetic induction within the sample, which allows the elementary magnetic dipole parameters to be evaluated. To do this, we use the Langevin formula for the magnetization, J, of a paramagnet:

$J = J_0 \cdot c \cdot (cth(X) - 1/X)$, where $X = mH_{loc}/kT$, m is the magnetic moment of the dipole, H_{loc} is the local magnetic field, J_0 is the saturation magnetization, and c is the spatial concentration. Assuming $H_{loc} = H + (\gamma - N) \cdot J$, where N is the sample demagnetization factor and γ is the factor taking into account the spatial distribution of the magnetic dipoles, we obtain $4\pi \cdot J_0 \cdot c \cdot (1 - N) = 1.176\ kOe$, $\gamma - N = 0.95$, and $m = 0.95 \times 10^{-16}\ Gs \cdot cm^3$. These parameter values are in good agreement with the parameters of colloid elementary particles. Thus, for the colloid with a concentration of $c = 20\%$, no clustering was observed for $H = 15 \div 130\ Oe$. For $c = 10\%$ (Fig. 1b), the polarization exceeds 1 as the field increases, which seems to be connected with neutron scattering in the lattice formed by dipole chains [7].

The work was performed within the framework of the RFFI project № 94-02-04011.

References

1. P.H. Hess, P.H. Parker. J. Appl. Polym. Sci., **10** (1966), 1915

2. R.E. Rosensweig, M. Zahn, R. Shumovich, J.M.M.M., **39** (1983), 127

3. D.J. Cebula, S.W. Charles, J. Popplewell. Colloid & Polymer Sci., **259** (1981), 395

4. R. Pynn, J.B. Hayter, S.W. Charles. Phys. Rev. Lett., **51** (1983), 710

5. L.A. Akselrod et al. JETP, **91** (1986), 531 (in Russian)

6. S.V. Maleyev. J. Physique, **43** (1982), 7

7. P.G. de Gennes, P.A. Pincus. Phys. Kondens. Mater. **11** (1970) 189

Received by Publishing Department on July 27, 1994.