Magnetic resonance study of -Fe$_2$O$_3$-betaine-MnCl$_4$ system

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A novel class of compounds combining molecular magnets with ferrimagnetic iron oxide nanoparticles was synthesized. The purpose was to examine the effect of the magnetic properties of -Fe$_2$O$_3$ on the magnetic properties of its partner. In this report we describe the magnetic resonance behaviour of Mn^{2+} bound as an $MnCl_4^{2-}$ an ion to -Fe$_2$O$_3$ through a betaine (Me_3N^+−CHCOO$^-$) spacer. Nanosize -Fe$_2$O$_3$ was prepared according to the precipitation method using $FeCl_3$ 6H_2O and $FeSO_4$ 7H_2O in the 2:1 mole ratio. After isolation and washing the -Fe$_2$O$_3$ nanoparticles were dispersed in water and treated with betaine. The solid -Fe$_2$O$_3$ -betaine was dispersed in ethanol containing a few drops of HCl. $MnCl_2$ was added to this solution. The obtained sample was investigated by using an X -band electron paramagnetic resonance (Bruker E 500) spectrometer in the 90-300 K temperature range. The registered spectra are presented in Figure 1.

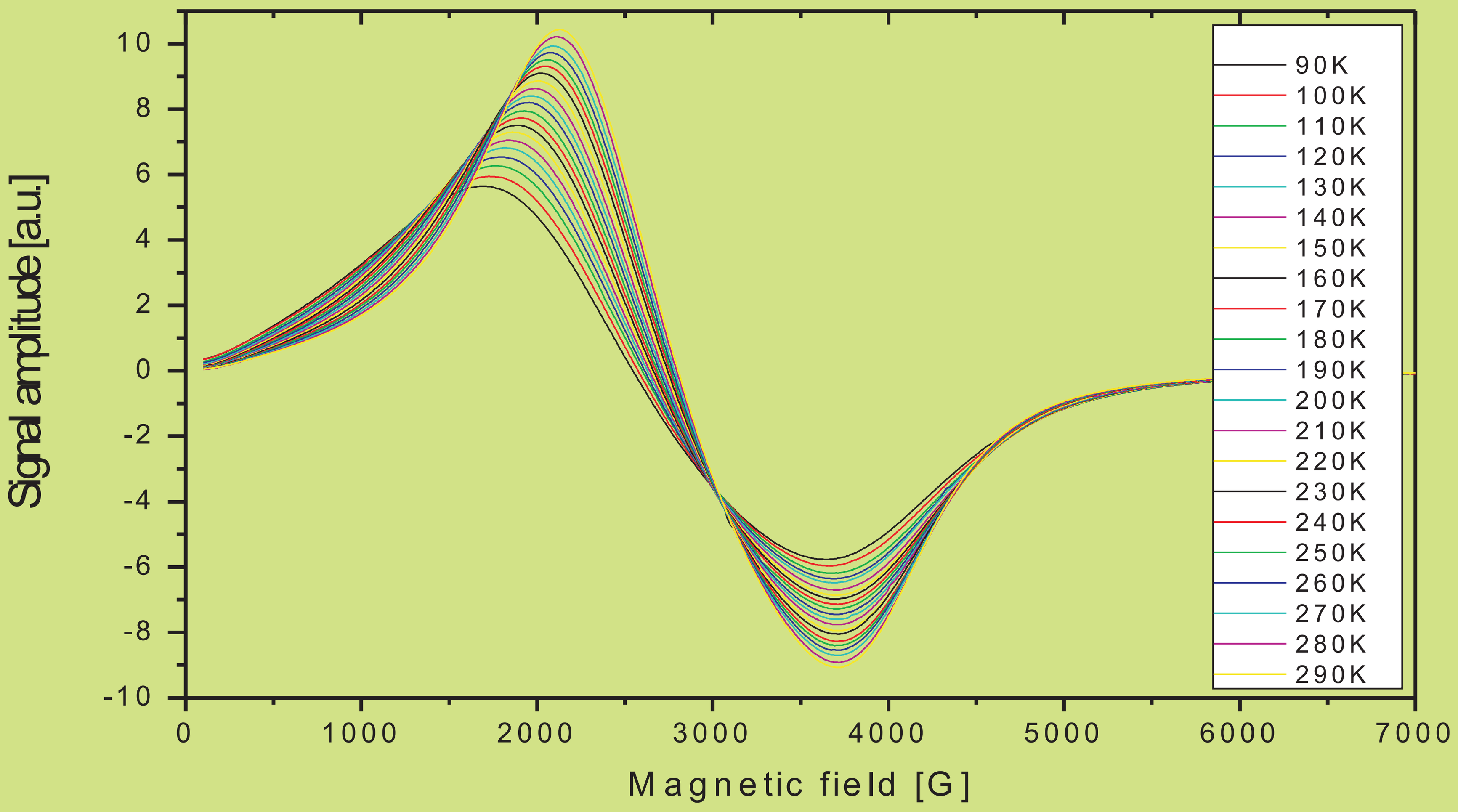

Figure 1: Magnetic resonance spectra of the investigated sample registered at different temperatures in the 90-300 K range.

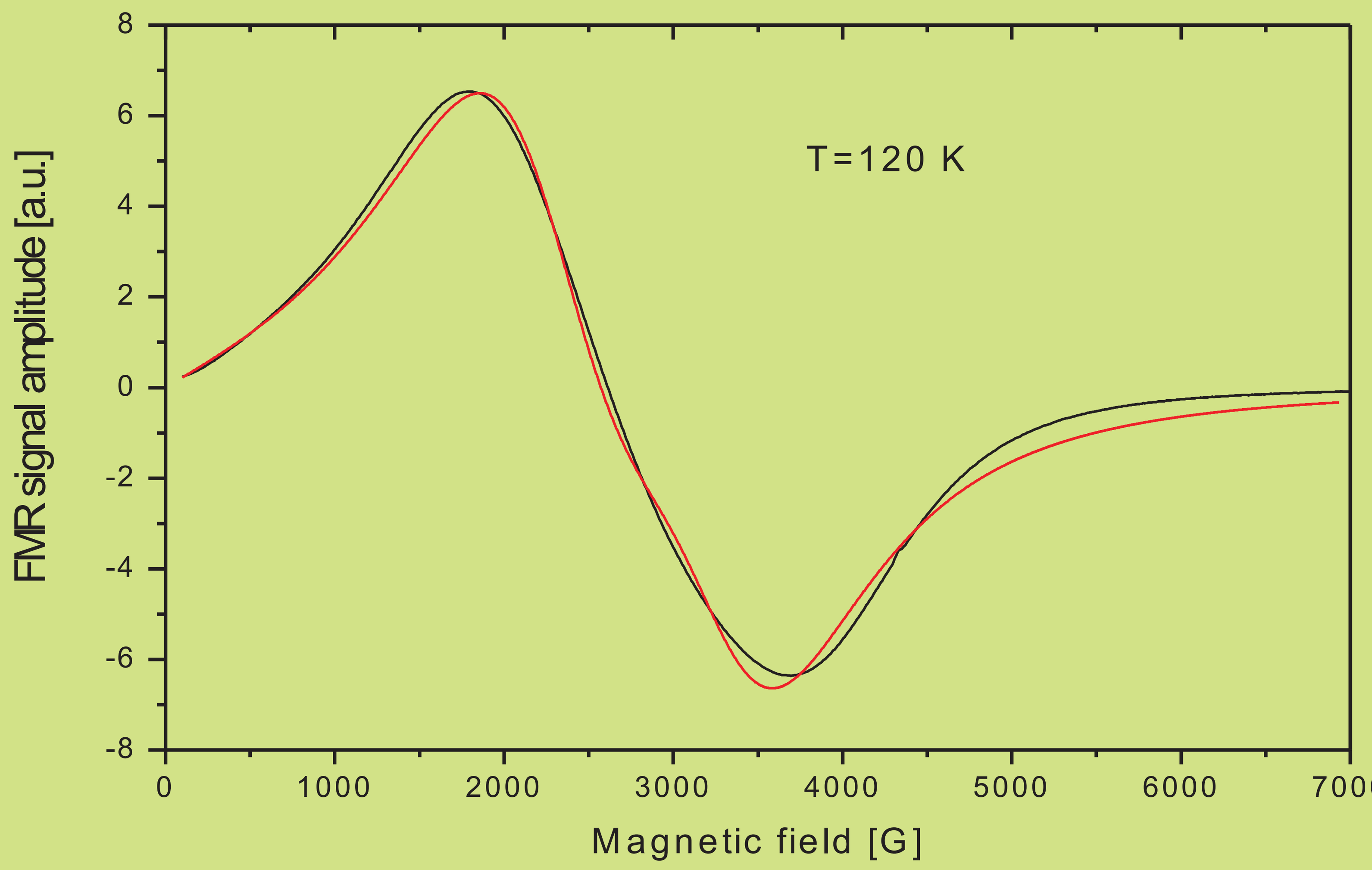

Figure 2: Experimental (black) and fitted (red) spectra of the investigated sample at T= 120 K.

The spectral lines were slightly asymmetric and they were attributed to the - Fe$_2$O$_3$ nanoparticles in a superparamagnetic state. Following the method proposed by Kliava, the registered spectra were fitted by two lines with lineshapes obtained from the solution of the Landau − Lifshitz equation. These two component lines were a result of magnetic anisotropy of the -Fe$_2$O$_3$ nanoparticles. As an example, a comparison of the experimental and fitted spectra at T =120 K is presented in Figure 2. The fitting allowed to determine the intrinsic resonance fields, linewidths and integrated intensities of both spectral components at different temperatures. The two obtained resonance fields (280 and 345 mT) did not vary in the studied temperature range (Fig. 5). This behaviour was in contrast to the usually observed decrease in the resonance field with lowering temperature for typical nanoparticles embedded in a non −magnetic matrix. On the other hand, two linewidths showed a pronounced temperature variation (Figure 3). On lowering the temperature the linewidths increased significantly.

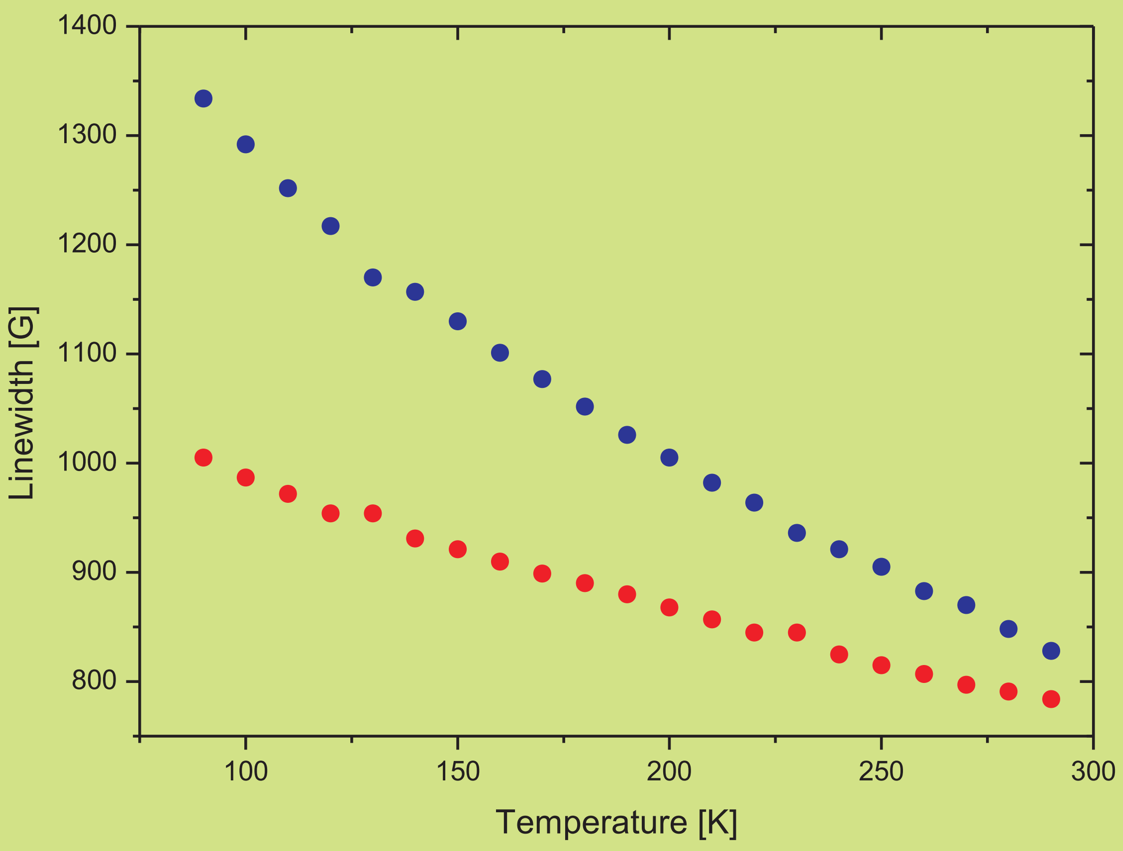

Figure 3: Temperature dependence of linewidths of two fitted components

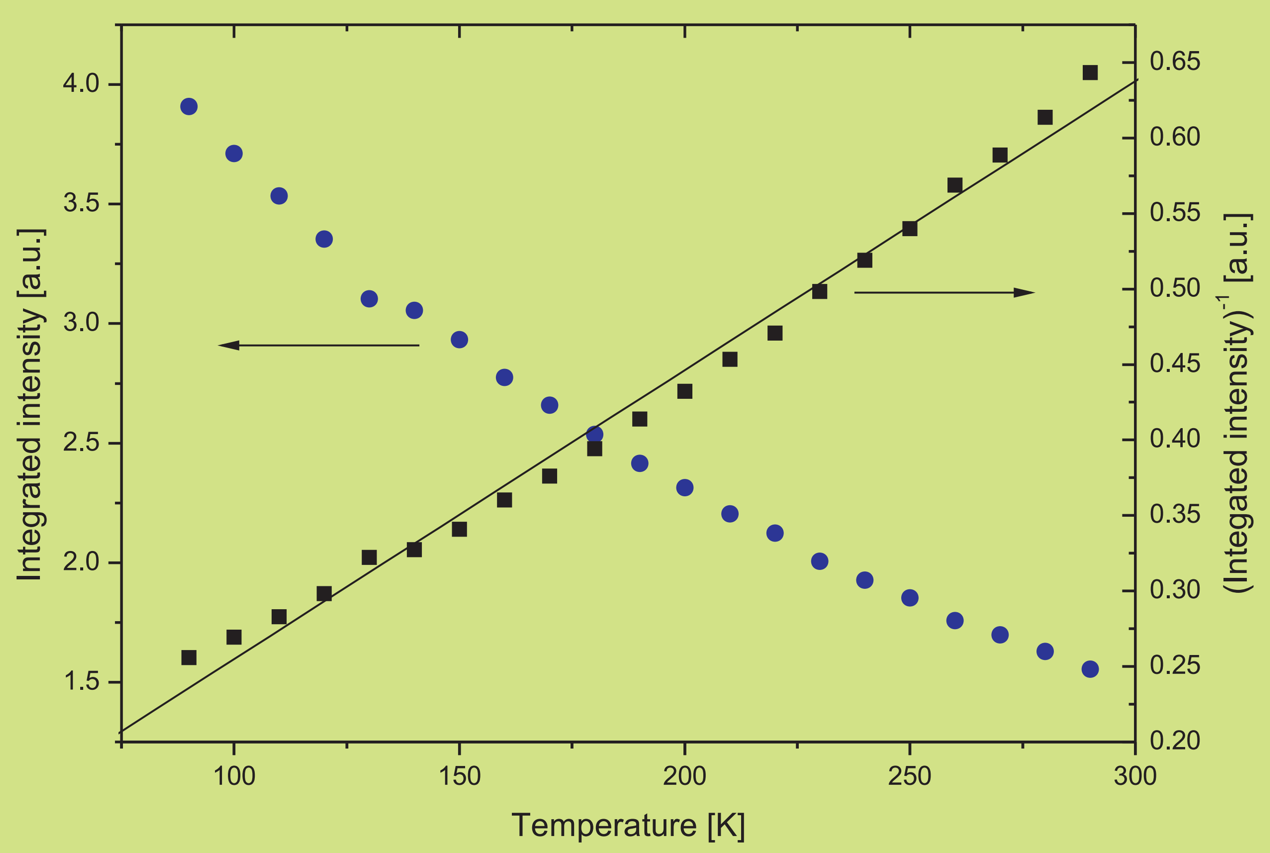

Figure 4: Temperature dependence of integrated intensity (left axis) and reciprocal of integrated intensity (right axis) for investigated sample

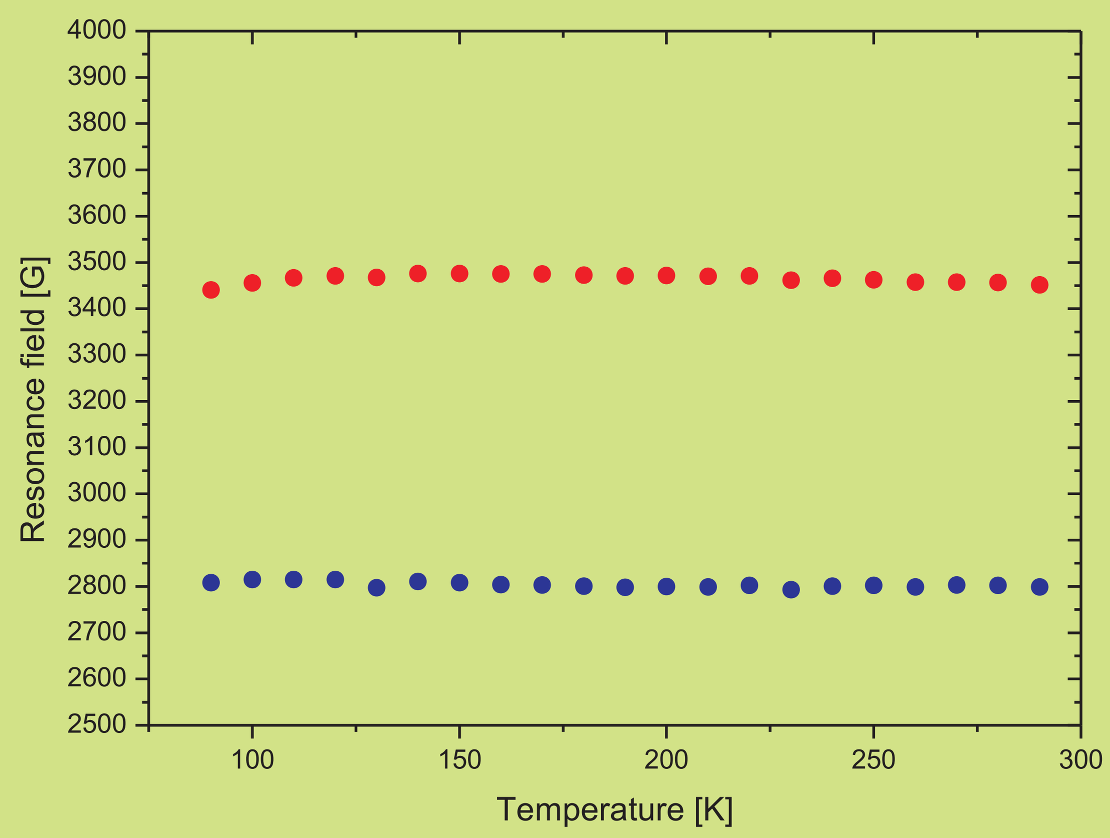

Figure 5: Temperature dependence of the resonance field for two components of the FMR spectrum.

The temperature dependence of integrated intensity (calculated as an area under the absorption curve) displayed the Curie −Weiss −type of behaviour, $I(T)=C/(T-T_0)$, with $T_0 = -33.2$ K. This indicates on the existence of strong antiferromagnetic interactions in the studied sample.