Methods for Observing the Deformation of an Aqueous Paramagnetic Solution in a Magnetic Field

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(Received March 14, 1985)

Synopsis. Two methods have been worked out for the observation of the deformation of a paramagnetic aqueous solution in a magnetic field. The deformation was observed on: (1) a layer of a solution covered with a water-immiscible organic liquid and (2) a drop of the solution suspended in the liquid.

The paramagnetism of a solution of a heavy metal salt can be demonstrated by the deformation of the solution occurring in a magnetic field. If a test tube containing the solution is placed between the poles of an electromagnet, a distinct elevation of the surface takes places near the poles.[1] We have worked out two simple methods to magnify the deformation, so that a visual estimation of its magnitude is possible.

Our methods are based on the fact that the presence of a water-immiscible liquid in contact with the solution gives rise to an increase in the deformability of the solution in a magnetic field; this is a result of the reduction of the gravitational force acting on it. The experimental details are given below.

I. A JEOL JM-360 electromagnet (pole diam., 300 mm; pole distance, 60 mm, and maximum flux density, 1.4 tesla) was used. Three cm^3 of a paramagnetic salt solution (1 mol dm^{-3}) was poured into an acrylic plastic cell (10×60×60 mm) to a depth of 5 mm. Benzene was then added, forming an upper layer since the benzene and the solution do not mix with each other. The cell was then set between the poles of the electromagnet. The magnetic field was applied, and the resulting change in the form of the solution in the cell was photographed. Solutions of $CuCl_2$, $NiCl_2$ $CoCl_2$, and $FeCl_3$ were studied. Commercial reagents of a guaranteed grade were used without further purification.

Figure 1 shows the deformation of the layer of a $FeCl_3$ solution placed in magnetic fields of 0, 0.9, and 1.3 tesla. With an increase in the field intensity the solution is attracted towards the magnetic poles, finally splitting into two parts. The deformation of solutions of $CuCl_2$, $NiCl_2$, $CoCl_2$, and $FeCl_3$ in the field of 1.3 tesla is shown in Fig. 2. The change in the form of the solution layer in the magnetic field, as expressed by the difference in the height of the solution at its center and at its periphery, decreases in this order: $FeCl_3$, $CoCl_2$, $NiCl_2$, and $CuCl_2$. This is in line with the order of the number of unpaired electrons or Bohr magnetons in each metallic ion and enables a rough estimation of these numbers.

II. A straight-bar electromagnet (pole diam., 30 mm; maximum flux density, 0.18 tesla) was used. A single drop of a solution was suspended in a water-immiscible liquid with the same density as that of the drop, and its deformation in a magnetic field was observed. An acrylic cell (60×60×60 mm) containing the sample was set in contact with a pole of the magnet.

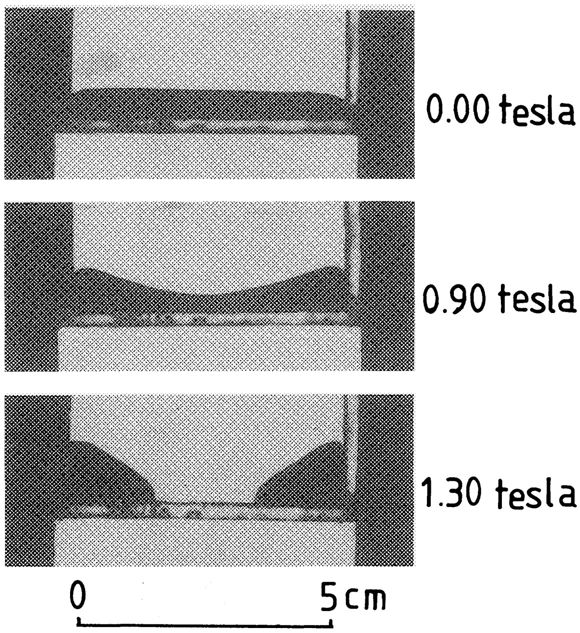

Fig. 1. Deformation of a $FeCl_3$ solutions in magnetic field.

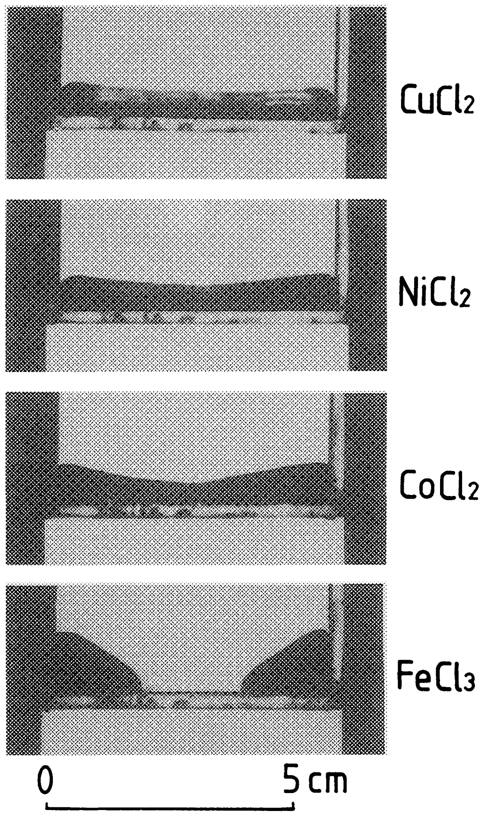

Fig. 2. Deformation of various solution in magnetic field of 1.3 tesla.

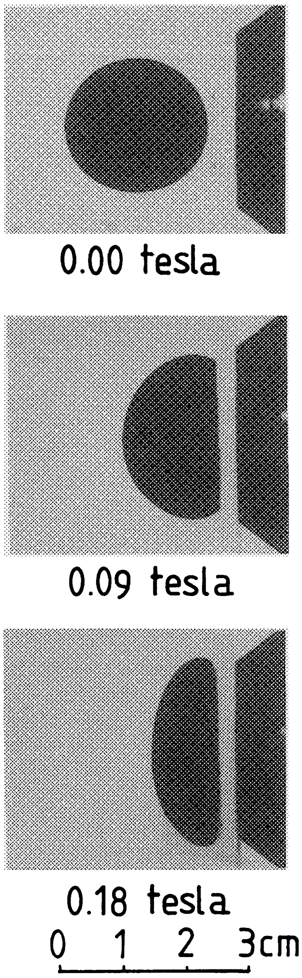

Fig. 3. Deformation of a drop of $FeCl_3$ solution in magnetic field.

The water-immiscible liquid of the desired density was prepared by adjusting the mixing ratio of benzene and carbon tetrachloride and was then poured into the cell. When 8 cm^3 of a $FeCl_3$ solution (3 mol dm^{-3}) was introduced into the liquid, it turned into a spherical drop. The deformation of the drop at 0, 0.9, and 0.18 tesla is shown in Fig. 3. The drop is spherical at 0 tesla, but it undergoes conspicuous deformation with an increase in the magnetic field. The deformation of the solution is far more marked in this case than in **I**.

These methods will be useful in demonstration experiments and also for a rough estimation of solution paramagnetism or magnetic-field strength.

The authors wish to thank Prof. Tsunetaka Sasaki for his kind interest in and suggestions for this work.

Reference

1) T. Katsurai, *Sci. Papers Inst. Phys. Chem. Reseach (Tokyo),* **35**, 224 (1939), Fig. 25.