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A SIMPLE ACCURATE METHOD FOR MEASURING THE DIAMAGNETIC SUSCEPTIBILITY OF DISSOLVED SUBSTANCES

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Abstract

A quasi-null method has been developed for determining very accurately the diamagnetic susceptibility of dissolved substances. Two independent runs with 2.521 M. sodium iodide agreed easily within ±0.06 percent. Its advantages over other methods are discussed. Several other kinds of investigations to which this method may be applied are pointed out.

THE need of an accurate method for measuring the diamagnetic susceptibility of dissolved substances has long been recognized.

The present method is a simple modification of the standard method of Gouy. The modification resides in the elimination of the effect produced by almost all of the solvent, a procedure which can take advantage of the sensitivity of a micro-balance. Hitherto, the susceptibilities of the solutions were measured against air or vacuum and all the errors in the measurements had to be borne by the solute alone. The new method measures the susceptibility of the solute almost directly and it measures the solute against the solvent.

In this way, the actual pull suffered by the solution in the magnetic field is slight, it is less sensitive to the fluctuations in the current going through the coils (highly sensitive ammeters are unnecessary), the tube is not urged out of its position in the field by the dissymmetries which exist there, and indeed almost all the advantages of a null method are realized.

The method shall be illustrated with a run on a solution of sodium iodide, 2.521 M (vol.).

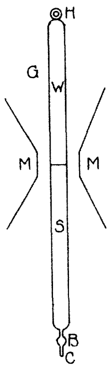

Fig. 1.

MM are the pole pieces of an electromagnet. *G* is a glass tube with a glass partition *P* in the center of the pole gap and *G* extends on both sides to fields of negligible intensity. The upper part of the tube *W* contains the solvent, in this case water, and the lower half contains the solution, that of sodium iodide. By employing a little bulb *B* with constrictions on both sides and by having the end *C* drawn into a capillary, no trouble is experienced in keeping the air bubble (the space present above the solution when the tube is sealed off) from rising to the top of *S*. The tube *G* is suspended by braided silk thread at the hook *H* from the stirrup of a Sartorius micro-balance having a capacity of 20 gm and a sensitivity of ±0.001 mg.

In this work a sensitivity of ±0.01 mg was usually obtained. Finer reproducibility than this was reached in the measurements with the sodium iodide solution.

TABLE I. *Diamagnetic susceptibility of sodium iodide.*

Amperes	Pull in mg	Calibration in mg (against air)	$X_{gr.}$[a]
35	1.238	11.31	0.3941
40	1.362	12.48	0.3937
45	1.466	13.43	0.3938
50	1.558	14.23	0.3943

(a) The results show an average deviation of 0.06 percent.

An independent determination gave a result equal to the one above within the limits stated. All of the pulls had a slight correction for the non-uniformity in the glass of the tube. The correction was found by measuring the change in weight when both the upper and lower parts of the tube were filled with water.

The same sample of water was employed for both the standard and the solutions. An absolute accuracy of ±0.06 percent cannot be claimed for the determination. It is merely a measure of its reproducibility. If the calibration had been made with a solution of nickel chloride in the lower portion of the tube *G* instead of air, the reproducibility in the calibration would have been as good as that with sodium iodide. (The pull in the calibration against air was about ten times that with sodium iodide and a fluctuation in the current, for example, effects a proportionate change in the total pull. The absolute change then in the calibration is about ten times that in the run, and it is the absolute change which determines the accuracy of the susceptibility.) The use of nickel chloride would then have permitted an absolute determination of the diamagnetic susceptibility to within 0.2 percent[1] the accuracy with which the susceptibility of nickel chloride is known.

However, if the susceptibility of a diamagnetic salt is once accurately determined, the susceptibility of other diamagnetic salts can be determined relative to it with even greater precision, since the full advantages of a null method can be more nearly realized.

The sample of sodium iodide which we employed to test the reproducibility of the method was as pure as we could obtain. We did not analyze the salt, for it was not our purpose to find its absolute susceptibility. It still may be worth while to compare the result with the reliable determination of Ikenmeyer[2] who recently perfected a torsion method employing a non-homogeneous field.[3] Ikenmeyer did not analyze his material for impurities.

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[1] Brant, Phys. Rev. **17,** 678 (1921).

[2] Ikenmeyer, Ann. d. Physik **5,** 1, 169 (1929).

[3] The torsion methods in the past have been subject to many inaccuracies, although their sensitivity leaves nothing to be desired. The difficulty seems to lie in placing the bob exactly in the same field gradient. And again, the inaccuracy incurred by the total solution is assumed by the solute alone.

He obtained -60.4×10^{-6} per mol, while our value is -59.1×10^{-5}. Under the circumstances the agreement is satisfactory. Several other determinations are recorded in the literature, but they differ from the above by about 15 percent.

The quasi-null method just described is applicable to many problems. It may be employed in order to determine accurately the susceptibility of paramagnetic substances in great dilution. It may also serve to measure accurately diamagnetic as well as paramagnetic substances in non-aqueous solvents, for the susceptibility of the solvent itself need not be known to the extreme precision which previous methods have required.