Magnetic Susceptibility as measured by Gouy's Method with the Specimen in a Fixed Position.

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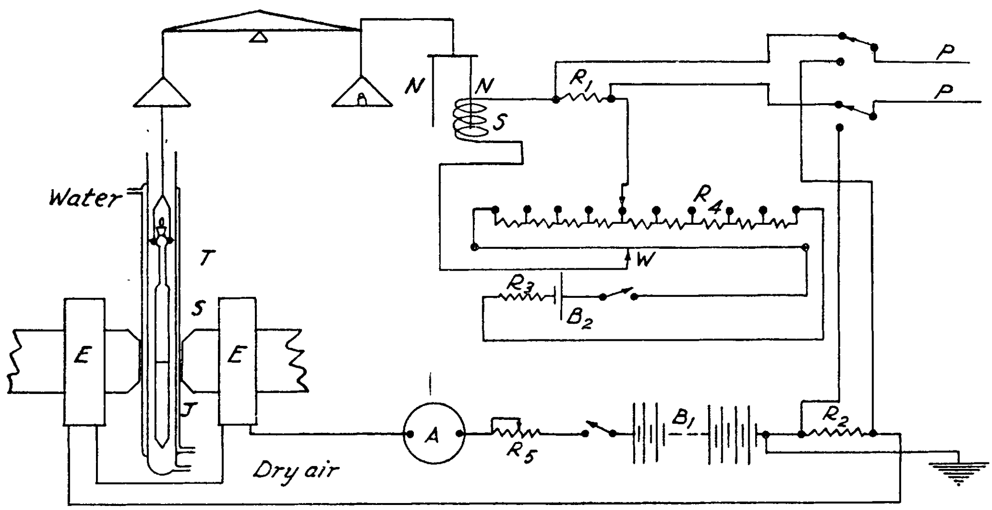
[Reprint Order No. 4124.]

A refinement of Gouy's method of measuring magnetic susceptibilities is described, the position of the specimen in the magnetic field being fixed. The value for benzene was determined at 20°, water being the reference standard. The results indicate a reproducibility of better than 0·04% and the value for benzene was $10^6\chi^{20} = -\ 0{\cdot}7012 \pm 0{\cdot}0002$.

WHILE making measurements with a standard type of semimicro-balance and a moderately strong electromagnet (cf. *Proc. Phys. Soc.*, 1933, **45**, 425), it was observed that the use of the method of swings, for determining the fourth and later decimal places, was not entirely dependable when the interpole distance was made large enough to accommodate a double-walled jacket *J* (see Figure), controlling the temperature of the specimen, for, unless



a very large electromagnet is used, the bottom of the tube swings out of the region in which the field is uniform. It therefore appeared desirable, both for reproducibility and for flexibility of the apparatus, to use a true balance and hence a fixed specimen position. The physical dimensions of any tubes, jackets, or other parts placed between the poles would then not be so restricted.

EXPERIMENTAL

With the above object, an electro-dynamic balancing device was added, consisting of two ordinary sewing needles (*N*, *N*, see Figure), a small solenoid *S*, and a means of adjusting and measuring a current in the solenoid. The two needles were magnetized in opposite directions. They were then rigidly mounted in a vertical position on an arm of stiff wire which was attached to the bar carrying the automatic riders and which rested on the right-hand knife edge. The position of the needles is thus not affected by the position of the weights on the right-hand pan. The two needles are parallel, one lying along the axis of the solenoid and the other just outside it. As the two needles are magnetized in opposite directions, the forces exerted on them by a current in the solenoid are complementary, but, if they are magnetically exactly alike, the system as a whole will be insensitive to stray fields from outside the balance case. Best results were obtained with needles selected from the same package and checked for equal length (61 mm.) and equal diameter (1·17 mm.). With these, the effect of the stray field from the electromagnet, *E* mounted below the balance, was less than 0·03 mg. This was eliminated completely by hanging a hook of fine steel wire, magnetized in the correct direction, on one of the pan supports. Its length was adjusted until there was no permanent deflection of the balance when the electromagnet was turned on.

The solenoid winding, 20 mm. long with an internal diameter of 13 mm., consists of 100 turns of 0·55-mm. D.S.C. copper wire. The current for the solenoid is provided by the battery B_2, and is controlled by the potential dividing action of the resistor R_3 and potentiometer $(R_4 + W)$, W being a slide wire. The solenoid is rigidly mounted, by means of a brass strap, on the inside of the balance case. Its vertical position is such that it exerts maximum force on the needles. With this arrangement, a current of 30 mA exerts a force of 10 mg. on the needles. This was selected as its maximum range so that it is used to indicate the third to the (estimated) sixth decimal place, the current being measured with a series resistance, R_1, and an accurate potentiometer connected at P,P. The same potentiometer, in combination with a shunt, R_2, is used to standardize the current through the electromagnet, supplied by the battery B_1 and controlled by the rheostat R_5 and ammeter A. For the indicated range, the force on the needles was found to be proportional to the solenoid current, to within the accuracy of measurements, which was better than 0·01 mg. The calibration was made with a set of certified standard weights.

A compensated Pyrex-glass specimen tube T was used to eliminate the temperature susceptibility coefficient of the glass and the air correction from the final calculations. The specimen chamber S was 1 cm. in diameter and 10 cm. long, with a neck of 2 mm. internal diameter. The lower chamber L had the same dimensions and was evacuated.

For a specimen in such a tube, the force, in dynes, produced by the field on the specimen is:

$$F = \tfrac{1}{2}A\kappa(H_1^2 - H_2^2) = 0{\cdot}981(f - f_1)$$

where A is the cross-sectional area of the specimen, κ its volume susceptibility, H_1 and H_2 are the field strength at the lower and the upper end of the specimen, respectively, f is the observed force (in mg.) on tube and specimen, and f_1 is a small force (in mg.) on the tube itself due to unavoidable imperfections.

From this equation, the mass susceptibility

$$10^6\chi = \frac{10^6\kappa V}{W} = \frac{2 \times 10^6 \times 0{\cdot}981 \times V}{A(H_1^2 - H_2^2)} \times \frac{f - f_1}{W} = \beta\frac{f - f_1}{W}$$

where W is the weight of the specimen filling the tube of volume V to the etched mark. Both β and f_1 are constants for a particular specimen tube and magnetic field; f_1 can be determined by measuring the forces (in mg.) on the specimen tube filled first with a substance (a) and then with a substance (b), where (a) and (b) have known but different volume susceptibilities. Then

$$f_1 = (\kappa_a f_b - \kappa_b f_a)/(\kappa_a - \kappa_b)$$

For the measurements recorded in this paper, water and air were selected for determinations of f_1, and water was used as a standard to evaluate β. The accepted values for these substances were used, *viz.*, $\kappa_{air} = 0{\cdot}029 \times 10^{-6}$, $\kappa_{water} = -0{\cdot}7187 \times 10^{-6}$, and $\chi_{water} = -0{\cdot}7200 \times 10^{-6}$, all at 20°. Three determinations of both the tube constant β and the mass susceptibility of benzene were made at 20° ± 0·02°. The benzene was purified by washing with concentrated sulphuric acid until colourless, then shaken with water. The product was dried ($CaCl_2$), shaken twice with mercury, twice recrystallised, and then dried and distilled over sodium. The results are listed in the following table:

	Tube constant, β	$-10^6\chi^{20}_{benzene}$
First filling	0·38263	0·7012
Second filling	0·38260	0·7014
Third filling	0·38266	0·7009
Mean value	0·38263	0·7012
„ deviation	±0·00003	±0·0002

French and Trew (*Trans. Faraday Soc.*, 1945, **41**, 437) found $-10^6\chi^{20}_{benzene} = 0{\cdot}7020 \pm 0{\cdot}0007$.

As the accuracy of the weights was ±0·01 mg., the above values are accurate to within 0·1%. The values indicate that the reproducibility of the apparatus is better than 0·04%.

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