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PHYSICS

EXPERIMENTAL DETERMINATION OF LONG-RANGE ATTRACTIVE FORCES

(*Provisional communication*)

BY

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Several phenomena, among them the flocculation of hydrophobic colloids [1]), point to the existence of long-range attractive forces. These attractive forces, which may be interpreted as LONDON–VAN DER WAALS forces, have now been measured between objects of macroscopic dimensions.

For the force between two parallel flat plates DE BOER [2]) and HAMAKER [3]) obtain:

$$F = \frac{A}{6\pi d^3} \tag{1}$$

where F = the force in dynes/cm², d = the distance between the plates in cm, $A = \pi^2 q^2 \lambda$, $\pi = 3.141\ldots$, q = number of atoms per cm³ and λ is the LONDON–VAN DER WAALS constant. For solid substances A is expected to be of the order of $10^{-13} - 10^{-11}$ dynes.cm.

Experiments

In our experiments two highly polished glass plates (refr. ind. D line 1.5209; $d_{15^\circ} = 2.556$) were very carefully adjusted over a surface of the order of 1 cm² at distances varying from 6000 to 15000 Å. NEWTON rings in white light were used to estimate the parallelism and the distance between the plates. One of the plates was attached to a rather stiff spring. The force F was obtained by determining the bending of this spring by an electrical capacity method capable of measuring the bending with an accuracy of 12 Å. In order to diminish the viscosity of the air and to remove water vapour the system was placed in a vacuum of 0.04 mm Hg. Dust particles and gel-layers formed in a wet atmosphere were the major causes of difficulties in the experiments.

In the following table some of our results are given. The values have been reproduced several times during a period of approximately one year.

[1]) E. J. W. VERWEY and J. TH. G. OVERBEEK, Theory of the stability of lyophobic colloids, Chapter 6 (Elsevier, Amsterdam 1948).
[2]) J. H. DE BOER, Trans. Faraday Soc., 32, 21 (1936).
[3]) H. C. HAMAKER, Physica, 4, 1058 (1937).

TABLE

Force F between parallel glass plates at a distance d, and the LONDON—VAN DER WAALS constant A calculated with eq (1).

d in Å	F in dynes/cm²	A in dynes.cm
∾ 200	7500—150000	$0.11 - 2.3 \times 10^{-11}$
6000	3.5 — 8.5	$1.4 - 3.5 \times 10^{-11}$
8000	1.8 — 3	$1.7 - 2.9 \times 10^{-11}$
10000	0.8 — 1.5	$1.5 - 2.8 \times 10^{-11}$
12000	0.25 — 1	$0.8 - 3.3 \times 10^{-11}$
15000	0.15 — 0.3	$1.0 - 1.9 \times 10^{-11}$

In the range from 6000—15000 Å the glass plates were completely free from one another. The distance between them could be changed continuously. At 200 Å a strong cohesion existed and a different measuring technique had to be used, in which the force necessary to draw the plates suddenly apart was measured. The difficulty in measuring these small distances with precision explains the wide spread in the values of the force.

Conclusion

Attractive forces of the expected order of magnitude exist, although the force constant A is somewhat larger than expected. This might be due to a certain roughness of the plates, which would tend to make the force larger than corresponds to the average distance measured.

It seems very unlikely that electrostatic effects are responsible for our results. Electrostatic forces would be expected to depend only slightly upon the distance, and very strongly upon the treatment of the glass plates, whereas the reverse was found to be the case.

Moreover the air inside the measuring apparatus was made conducting by the presence of a radioactive preparation.

The investigations are being continued.