On the Limiting Size of Colloidal Particles in a Brownian Motion

By

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When minute particles are in suspension in water, they are bombarded by molecules of liquid moving in very irregular ways. The force due to the impacts is resisted by inertia of the particles and viscosity of the medium. Brownian motion takes place when the former overcomes the latter, and the motion becomes less pronounced as the size of the particle gets larger and the viscosity increases. In his book on colloidal solution, Burton[1] states that particles cease to move when the diameter exceeds about $4\,\mu$, but as to the nature of the solution and the viscosity of the medium nothing is stated. In one of our experiments with silver, particles about $2.5\,\mu$ in diameter were found to be in a state of rest, while in gamboge sol, vivid motions were observed even in greater particles. This led us to study the subject more minutely.

An ultra-microscope used in the present experiment was one provided with a cardioid condenser, and rays from a carbon arc were sent through a water chamber to the condenser. The apparent sizes of the particles were measured on an ocular micrometer scale whose one division was found to be $2.25\,\mu$ in the object plane of the microscope. The colloidal solutions used in this experiment were prepared by Bredig's method, the metals pulverized being gold, silver, copper, cadmium, zinc, tin, magnesium, nickel, aluminium, and tungsten; beside these, mercury suspension in water was also used. A drop of

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1. The Physical Properties of Colloidal Solutions. p. 66.

sols thus prepared was put between a pair of clean microscope cover glasses, and the microscope was focussed on a certain plane midway between them, the room temperature being about 10°C. throughout the experiment.

Of the particles in a state of rest, the smallest one was sought for, and this was then brought by centering the objective into such a position as to be measured by the ocular micrometer scale. This was then watched carefully and if any measurable displacement was noticed within a few minutes, this particle was rejected and another was again sought for. If no displacement could be detected within a few minutes, the diameter of the particle was measured, and then another particle was taken up, and the process repeated *ad lib.* For each sol about thirty such particles were measured and an example of such a measurement is given below:

For Au-sol (in μ).

2·5	2·7	2·7	2·7	2·6	2·9	2·5	2·7	3·0
2·7	2·5	2·5	2·7	2·7	2·3	2·5	2·7	2·9
2·9	2·5	2·7	2·5	2·5	2·7	2·7	2·5	2·7
2·7	2·7	2·9						

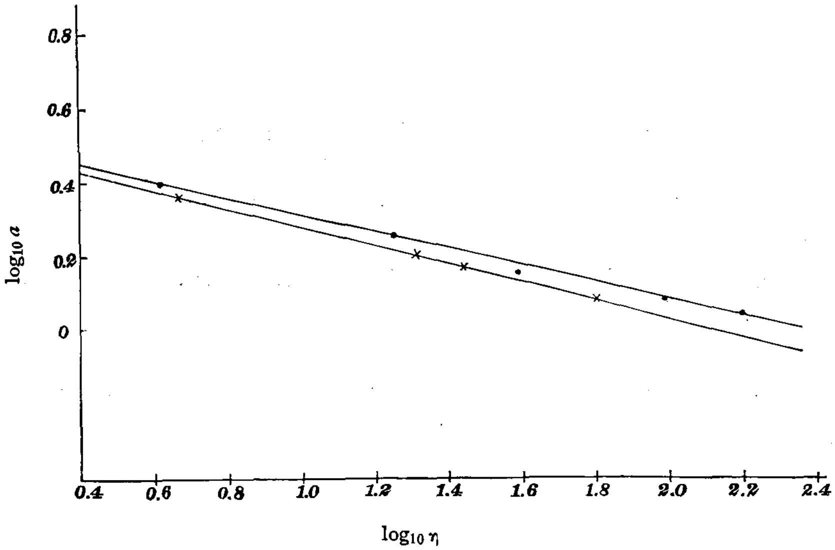
Thus 2.7 μ seems to be the limiting size for gold sol.

With other sols such as platinum, silver etc. limiting sizes were found to be almost the same as that for a gold. The following table shows these values for each sol thus measured.

Metals	Wo	Pt	Au	Ag	Cu	Al	Ni	Hg
Diameter in μ	2·7	2·5	2·7	2·5	2·7	2·7	2·5	2·3

The mean of these values is 2·6 μ. For Cd, Zn, Sn and Mg particles were generally small and no measurement could be effected. So far as this experiment is concerned, metallic particles, whatever be their nature, placed in suspension in water, will take the Brownian motion, provided their sizes are less than about 2·6 μ. This value, however, depends, of course, upon the viscosity of the continuous phase.

The relation of this limiting size of particles to the viscosity of the continuous phase was studied in the following way. It is known that sols have viscosities very slightly higher than those of the media, so that viscosities of sols may, at a close approximation, be taken to be those of the media. In our experiments viscosity was varied by adding a concentrated solution of sugar or glycerin into the sol and the viscosities of the sols thus treated were measured by a viscosimeter. A drop from such a solution was examined under the ultra-



microscope and the limiting size was determined in the way described above.

The sols used in this experiment were of gold and copper and the result obtained is given in the following table.

Gold sol.			Copper sol.		
Viscosity: η	Limiting size: a	$a\eta^{0.229}$	Viscosity: η	Limiting size: a	$a\eta^{0.249}$
4·2	2·5 μ	3·5	4·7	2·3 μ	3·4
17·7	1·8 "	3·5	20·2	1·6 "	3·4
38·8	1·4 "	3·3	27·5	1·5 "	3·4
97·3	1·2 "	3·4	62·5	1·2 "	3·4
155·0	1·1 "	3·5			

In the annexed figure the logarithm of a was plotted against the logarithm of η, the mark • representing the values for gold sol and × for copper sol; thus fine straight lines are obtained, and consequently, so far as the present experiment is concerned, we get the following relations for gold and copper respectively.

$$a\,\eta^{0.229}=3.5,$$
$$a\,\eta^{0.249}=3.4.$$

Summary.

1. The limiting sizes of colloidal particles performing a Brownian motion were studied for various metal sols.

In Bredig's colloids, this size is about $2.6\,\mu$ for all the metals examined.

2. The relation between the viscosity of the sol and the limiting size was studied.

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