A NEW METHOD OF ESTIMATING CATAPHORETIC VELOCITY IN A CONCENTRATED SUSPENSION.

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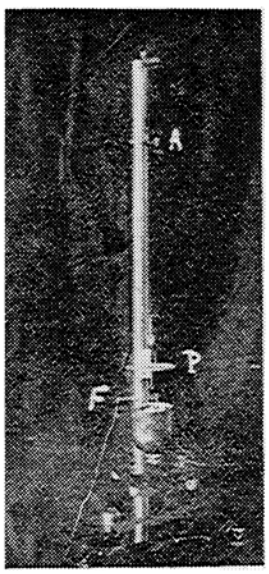
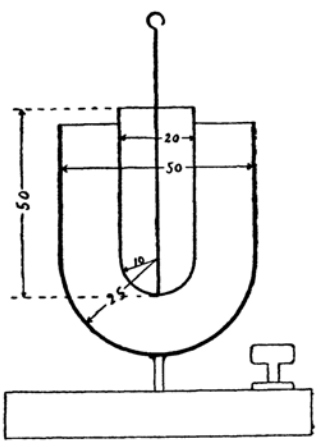
Among the methods hitherto known, the U-tube method is only applicable for the measurement of cataphoretic velocity in a concentrated suspension. The author has recently deviced a new method which may be called the *weight method.* In the present paper, the general outline of this new method is briefly described.

Apparatus. When a suspension is placed under the influence of an electric field, the cataphoresis occurs and causes the particles in the suspension to gather on the surface of the electrode. It is the necessary condition for the applicability of the weight method to be the sample unidisperse and so concentrated that the weight increase of deposition is measurable.

The present apparatus used is as shown in Fig. 1. The upper electrode used as collecting electrode is hung at the end of the spring and the other



(a)



(b) Electrode-configuration (scale in mm.)

Fig. 1.

is fixed against it. When the electromotive force is applied between them, the cataphoresis occurs which would cause the suspended system to descend gradually. But at this moment, the system is adjusted so as to keep itself in the original position by the mechanism of rack and pinion (A) attached to the apparatus. The displacement of rack on this adjustment is read by the scale, indicating the quantity relating to the increased weight of deposition. To avoid to flow current in the spring, the ebonite piece is connected between the electrode and the spring, which makes inconvenient to feed current to the electrode. But, in the present case, the feeding is made by mean of the 2 amp. fuse connected directly with the electrode and the calibration of spring is obtained under such condition. The connection diagram is as shown in Fig. 2.

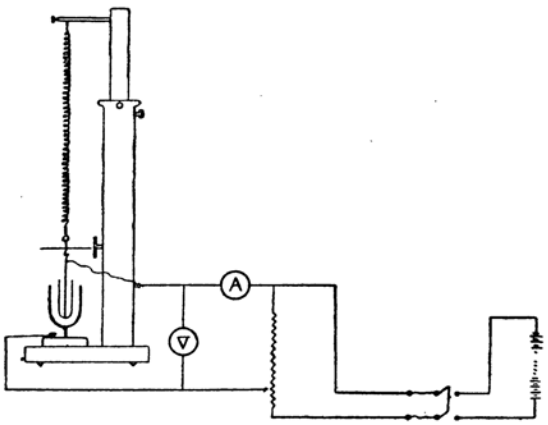


Fig. 2.

Principle. Let W (gr.) be the increase of reading of spring balance i. e. the weight of deposition in suspension and W_a (gr.) the weight of deposition in air, then the difference between W_a and W is equal to the weight of suspension occupied by the deposition i. e. the buoyancy W_b.

$$W_b = W_a - W \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

And, let v (cm./sec.) be the rate of increase of deposition, d the specific density of suspension, A the effective area of electrode and t the time, then we have

$$v = \frac{1}{d}\frac{1}{A}\frac{dW_b}{dt} = \frac{1}{d}\frac{1}{A}\frac{d(W_a - W)}{dt} \quad \ldots\ldots\ldots\ldots \quad (2)$$

But it occurs in general that the distribution of particles, accordingly, that of voltage change with the lapse of time. Furthermore, the part of voltage impressed for the deposition and the effects of electrolysis appear and increase seriously with time. Therefore, it is impossible to obtain the time-relation of equation (2) experimentally. To eliminate such difficulties, the limiting state at $t = 0$ must be considered as follows:

$$(v)_{t=0} = \frac{1}{d_0}\frac{1}{A}\left\{\frac{d(W_a - W)}{dt}\right\}_{t=0} \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (3)$$

where d_o is the specific density of sample itself. As the distribution of voltage is uniform G at this very case, the velocity $(v)_{t=0}$ for unit voltage gradient is given by

$$v_0 = \frac{(v)_{t=0}}{G} = \frac{1}{d_0}\frac{1}{A}\frac{1}{G}\left\{\frac{d(W_a - W)}{dt}\right\}_{t=0} \cdot \quad \cdots\cdots\cdots\cdots \quad (4)$$

Now let P_0 (%) be initial weight percentage of particles in sample and P_0' be the limiting value of weight percentage of particles in deposition at $t = 0$, then we have

$$v_0 p_0' GA = u_0 p_0 GA$$

Therefore, cataphoretic velocity u_0 is given by

$$u_0 = \frac{p_0'}{p} v_0 = \frac{1}{d_0}\frac{1}{A}\frac{1}{G}\frac{p_0'}{p_0}\left\{\frac{d(W_a - W)}{dt}\right\}_{t=0} \quad \cdots\cdots \quad (5)$$

The factors given in above equation (5) can easily be determined by the use of the author's apparatus :—

(i) A : The KCl solution having known conductivity κ is put into the vessel and the resistance R is measured by the Kohlrausch Bridge. Then A, the effective area of electrode, is obtained by

$$A = \frac{l}{R\kappa} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (6)$$

where l is the distance between the electrodes.

(ii) G : The correction for the polarisation on the electrode, the voltage drop in the feeding wire and so on must be considered in this case. For

this purpose, the several measurements are carried out under the various impressed voltages. The relation between W and the applied voltages V, its parameter being time, is obtained such as shown in Fig. 3. The intersection of the group of curves and the abscissa gives the required correction by the following relation.

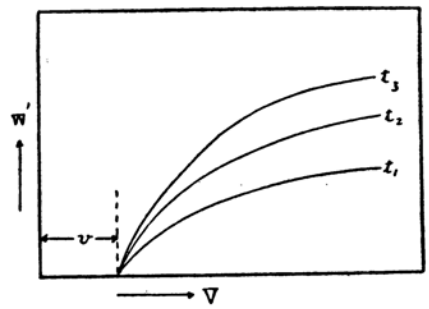


Fig. 3.

$$G = \frac{V-v}{l} \quad \cdots\cdots\cdots \quad (7)$$

(iii) p_0' : p_0' is obtained by the extrapolation of p'-t curve. (p' = weight percentage of particles in deposition)

(iv) $\left\{\frac{d(W_a-W)}{dt}\right\}_{t=0}$: Drawing out carefully the suspended system into air, W_a is measured by the apparatus. $\{d(W_a-W)/dt\}_{t=0}$ is obtained by the tangent of (W_a-W)-t curve at $t=0$.

Experimental Results : 250 Gr. of clay is mixed with l liter of 1/250 N.—NaOH aqueous solution and the mixture is shacken for five hours and is left at one night long. The upper part of this mixture is taken out as sample. The experimental data are tabulated as follows :

(1) Ball clay :

W' = reading of spring balance (cm.)
W_a = weight of deposition in air (gr.)
W_d = weight of deposition in dry state (gr.).
p' = $(W_d/W_a)\times 100$ (%)

Applied voltage	W' \ t	1 min.	2	3	4	5	W_a	W_d	p'
(a) 6	I	0.50 cm.	—	—	—	—	1.77	0.48	27.12
	II	0.50	1.00	—	—	—	2.90	0.85	29.31
	III	0.50	1.00	1.30	—	—	3.94	1.17	29.69
	V	0.50	0.90	1.25	1.50	1.75	5.25	1.68	32.06
	mean	0.50	1.00	1.28	1.50	1.75			

(*Concluded*)

	W' \ t	1 min.	2	3	4	5	W_a	W_d	p'
(b) 12	I	0.80 cm.	—	—	—	—	3.07	0.94	30.62
	II	0.75	1.40	—	—	—	4.51	1.55	34.25
	III	0.75	1.40	2.00	—	—	6.33	2.30	36.33
	V	0.75	1.40	2.02	2.67	3.22	8.77	3.40	38.77
	mean	0.76	1.40	2.01	2.67	3.22			
(c) 18	I	1.05 cm.	—	—	—	—	3.65	1.18	32.33
	II	1.07	2.05	—	—	—	5.95	2.18	36.72
	III	1.03	2.03	2.97	—	—	8.25	3.20	38.81
	V	1.05	2.07	3.03	4.02	4.90	13.42	5.80	43.22
	mean	1.05	2.05	3.00	4.02	4.90			

Then, we have

	V volt	G volt/cm.	$\left(\frac{d(W_a-W)}{dt}\right)_{t=0}$ gr./sec.		v_0 (cm./sec. / volt/cm.)	p_0' %		u_0 (cm./sec. / volt/cm.)
a	6	2.67	0.0167		16.3×10^{-5}	22.8		28.8×10^{-5}
b	12	6.67	0.0317	$A=35.6$ cm.	12.3×10^{-5}	24.8	$p_0=12.87$	23.7×10^{-5}
c	18	10.67	0.0433	$d_0=1.076$	10.6×10^{-5}	26.8		22.1×10^{-5}
	$v=2.0$			(mean)	12.7×10^{-5}		(mean)	$\mathbf{24.8\times10^{-5}}$

(2) China clay :

Applied voltage

W' = reading of spring balance (cm.)
W_a = weight of deposition in air (gr.)
W_d = weight of deposition in dry state (gr.)
p' = $(W_d/W_a)\times100$ (%)

	W' \ t	1 min.	2	3	4	5	W_a	W_d	p'
(a) 6	I	0.35 cm.	—	—	—	—	1.90	0.70	31.69
	II	0.45	0.80	—	—	—	2.85	1.02	35.83
	III	0.35	0.70	1.05	—	—	4.00	1.45	38.32
	V	0.45	0.78	1.05	1.45	1.75	5.88	2.44	41.49
	mean	0.40	0.76	1.05	1.45	1.75			

(Concluded)

(b) 12	W' \ t	1 min.	2	3	4	5	W_a	W_d	p'
	I	0.70 cm.	—	—	—	—	3.05	1.17	38.36
	II	0.70	1.40	—	—	—	5.00	2.21	42.20
	III	0.60	1.35	1.87	—	—	6.61	2.95	44.63
	V	0.60	1.30	1.95	2.55	3.00	9.80	4.62	47.19
	mean	0.65	1.35	1.91	2.55	3.00			

(c) 18	W' \ t	1 min.	2	3	4	5	W_a	W_d	p'
	I	1.10 cm.	—	—	—	—	4.33	1.74	40.18
	II	1.10	2.20	—	—	—	7.42	3.27	44.02
	III	1.00	2.10	3.00	—	—	10.14	4.80	47.33
	V	1.00	2.00	3.10	4.10	5.05	14.87	7.49	50.38
	mean	1.05	2.10	3.05	4.10	5.05			

Then, we have

	V volt	G volt/cm.	$\left(\frac{d(W_a-W)}{dt}\right)_{t=0}$ gr./sec.		v_0 (cm./sec. / volt/cm.)	p_0'		u_0 (cm./sec. / volt/cm.)
a	6	2.27	0.0180	$A=35.6$ cm.	20.1×10^{-5}	23.0	$p_0=16.23$	28.4×10^{-5}
b	12	6.27	0.0350	$d_0=1.108$	14.1×10^{-5}	33.6		29.1×10^{-5}
c	18	10.27	0.0533		13.1×10^{-5}	35.6		28.8×10^{-5}
	$v=2.6$			(mean)	15.6×10^{-5}		(mean)	28.7×10^{-5}

U-tube Method: For the purpose of comparison, the U-tube method is also carried out for the same samples. The apparatus used is as shown in Fig. 4. The method of measurement is, in almost all the parts, same as that of H.R. Kruyt and P. C. van der Willigen[1]. The results obtained are given in the following table, which coinside well with those obtained by the weight method :—

	u_0	
Ball clay	22.0×10^{-5}	cm. / sec. / volt / cm.
China clay	28.0×10^{-5}	,,

(1) *Kolloid. Z.*, **44** (1928), 22.

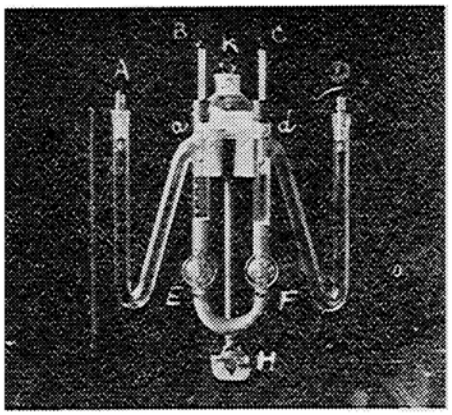


Fig. 4.

Lastly, the author expresses his hearty thanks to Mr. Iwasaka for his assistance in carrying out the experiments.

Summary: The results of the weight method coinside well with those of U-tube method. Although there are many points to be improved in the present apparatus, the author believes that the method is of some value, as it is, for the reason that there are few methods for the measurement of cataphoretic velocity in a heavily concentrated suspension. The author has designed the apparatus operating automatically under the same principle, results of which will be reported in a near future.

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