Physical Chemistry

L. A. Shchits and E. M. Aleksandrova

1962

SovietRxiv

Abstract

Full Text

Physical Chemistry

L. A. Shchits and E. M. Aleksandrova

On the Question of Estimating the Aggregative Stability of Synthetic Latexes

(Presented by Academician P. A. Rebinder on 27 VI 1961)

The aggregative stability of synthetic latexes is determined mainly by the structural-mechanical factor of stabilization ([1,2]). The structured protective shells of polymer globules in a latex, formed by a surface-active stabilizer, possess a high effective viscosity and hinder aggregation of the particles upon their collision ([2,3]).

Thus, the aggregative stability of the system is determined by the strength of the protective adsorption layer of the polymer particle. This strength can be estimated from the force required to destroy the protective shell, which is associated with the expenditure of a certain amount of energy. Mechanical destruction of the protective shells during mixing, leading to coagulation of the latex, is possible only at sufficiently high (exceeding a certain critical value) velocity gradients $g > g_k$, arising within the thickness of the protective layer.

Mechanical coagulation of latexes during mixing has been carried out in studies by a number of authors ([4–6]). The power N consumed during mixing is expended in overcoming inertial forces as a result of vortex formation (N_{in}) in the case of nonstationary flow, in dissipation in the dispersion medium (N_{sr}), and in destruction of the protective shells (N_{ob}):

$$N = N_{\text{in}} + N_{\text{sr}} + N_{\text{ob}}. \quad (1)$$

The measure of the aggregative stability of the system should be taken as the amount of energy expended on destruction of the shell and determined by the complex

$$N_{\text{ob}}\tau, \quad (2)$$

where τ is the time of mixing the latex until a certain coagulation effect is reached as a result of the development of the autocoagulation process (in the absence of the phenomenon of "lump" coagulation). Taking equation (1) into account, we shall assume that

$$N_{\text{ob}} = K_1 N \quad (K_1 < 1), \tag{3}$$

where K_1 is a function of the Reynolds number Re and of the particle concentration.

High velocity gradients in a practically homogeneous field of shear stresses can be obtained by mixing the samples under study in the annular space between coaxial cylinders with radii R_1 and R_2, when

$$R_2 - R_1 \ll \frac{R_1 + R_2}{2} \quad (R_2 > R_1).$$

The power consumed in this case by the viscous liquid (referred to unit height of the cylinders) in the case of stationary flow is determined by the well-known formula ([7]):

$$N = 4\pi\eta \frac{(\omega_1 - \omega_2)^2 R_1^2 R_2^2}{R_2^2 - R_1^2}, \tag{4}$$

where ω_1 and ω_2 are the angular velocities of the corresponding cylinders.

From Newton' s formula* $p = \eta \frac{dU}{dx}$ we find the expression for the viscosity and substitute it into formula (4), taking

$$\frac{dU}{dx} \approx \frac{\Delta U}{R_2 - R_1} = \frac{R_2\omega_2 - R_1\omega_1}{R_2 - R_1}$$

(ΔU is the linear velocity of motion of the inner cylinder relative to the outer one).

For definite and constant values of R_1, R_2, ω_1, and ω_2, formula (4) takes the form:

$$N = K_2 p, \tag{5}$$

where the dimensional factor K_2 combines all constant quantities. In other words, the consumed power, or the intensity of the mechanical action on the latex, is characterized by the shear stress.

Taking formula (5) into account, (3) may be rewritten as

$$N_{\text{ob}} = K_1 \cdot K_2 p = K_3 p. \tag{6}$$

This makes it possible, in evaluating the aggregative stability of latices, to replace complex (2) by the equivalent complex

$$p\tau. \tag{7}$$

We shall consider laminar motion of a liquid in an unsteady flow within one eddy. Then the shear stress in each eddy will be $p_i = \eta \left(\frac{dU}{dx}\right)_i$. The shear stress averaged over the whole flow is

$$p_{\text{av}} = \frac{\sum p_i}{i} = \eta \frac{\sum \left(\frac{dU}{dx}\right)_i}{i} = \eta G_{\text{av}}.$$

Under identical hydrodynamic mixing conditions, G_{av} will evidently be related in a definite way to the "conditional" velocity gradient G_{us}, calculated as though the flow were steady:

$$G_{\text{us}} = \frac{\Delta U}{R_2 - R_1} = K_4 G_{\text{av}},$$

where $K_4 = f(\text{Re})$.* If the conditional shear stress $p_{\text{us}} = \eta G_{\text{us}} = K_4 p_{\text{av}}$, then the equivalent replacement for complex (2) will be the complex

$$p_{\text{us}}\tau. \tag{8}$$

Instead of complexes (7) and (8), at constant gap width between the cylinders and an unchanged (or only slightly changing) value of Re, the complex

$$\eta\tau, \tag{9}$$

may be used to evaluate the aggregative stability of latices, since in this case η determines the values of p or p_{us}.

When testing one and the same sample ($\eta = \text{const}$) under identical hydrodynamic conditions ($\text{Re} = \text{const}$), but with different gap widths between the cylinders, the values of p or p_{us} are determined by the ratio $\frac{\Delta U}{R_2 - R_1}$. This ratio may serve as a measure of the mechanical action on the sample being tested, and the following condition must be maintained:

$$\frac{\Delta U}{R_2 - R_1}\tau = \text{const}. \tag{10}$$

Table 1 gives the results of an experimental verification of condition (10). The test was carried out on a polystyrene latex stabilized with sodium oleate. A special instrument (stabilometer) was used (8)

* The limiting shear stress of the stabilized systems considered is equal to zero or small in comparison with p.

with an external fixed cylinder (stator) and an internal moving cylinder (rotor). The tests were carried out in the absence of an air phase and under a turbulent mixing regime.

Table 1

Determination of the aggregative stability of polystyrene latex at different widths of the gap between the rotor and stator

$R_2 - R_1$, cm	U, cm/sec	$G_{us} = \frac{U}{R_2 - R_1}$, sec^{-1}	τ, sec	$S = \frac{G_{us}\tau}{1000}$
0.20	565	2825	63.0	178.0
0.15	581	3873	40.7	157.6
0.10	597	5970	28.9	172.5

As can be seen from Table 1, the average relative discrepancy of the values S, characterizing the aggregative stability of the sample, is only 4.6% (169 ± 8 conventional units).

The data obtained may serve as confirmation of the essential correctness of the views set forth above.

Moscow Institute of Chemical Technology
named after D. I. Mendeleev

Received
27 VI 1961

REFERENCES CITED

1. E. M. Aleksandrova, Yu. Kartes-Mureshan, DAN, **103**, No. 2, 269 (1955); Ch. P. Roe, P. D. Brass, J. Coll. Sci., **10**, No. 2, 194 (1955).
2. P. A. Rebinder, Kolloid. zhurn., **20**, No. 5, 527 (1958).
3. V. G. Levich, DAN, **103**, No. 3, 453 (1955).
4. V. N. Tsvetkov, E. M. Aleksandrova, Khim. prom., No. 5, 20 (1958).

5. S. M. Min, A. V. Lebedev, N. A. Fermont, in: *Latexes and Their Application*, L., 1961.

6. H. G. Dawson, *Anal. Chem.*, **21**, No. 9, 1066 (1949).

7. N. E. Kochin, I. A. Kibel, N. V. Roze, *Theoretical Hydromechanics*, part 2, Moscow, 1948.

8. L. A. Shits, E. M. Aleksandrova, *Bulletin of Technical and Economic Information*, No. 9 (1961).

Note: Figure translations are in progress. See original paper for figures.