MASS TRANSFER BETWEEN SOLID PARTICLES AND A ROTATING STREAM OF LIQUID

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The mass transfer between a solid particle of a diffusively dissolving substance and a rotating stream of the solvent is studied here, with the liquid flowing in the direction normal to its axis of rotation. Formulas are obtained for calculating such a mass transfer.

We consider the kinetics of mass transfer in a centrifugal solid–liquid system. For the study of the mass-transfer kinetics, a tubular rotor was used as the principal operating part of a test apparatus (Fig. 1). Cylindrical particles with a 0.5-1.0 diameter-to-height ratio made of diffusively dissolving resorcin $C_6H_4 \cdot (OH)_2$ (ρ_S = 1.283 g/cm^3), ammonium sulfate $(NH_4)_2SO_4$ (ρ_S = 1.695 g/cm^3), and sylvite KCL (ρ_S = 1.93 g/cm^3) served as the solid phase. Water at a temperature of 15-17°C served as the liquid phase.

The rotor according to the schematic diagram in Fig. 1 consisted of a hollow shaft with two conical test cells glued to it radially, the entire assembly rotating at n = 200-500 rpm (a detailed description of the experimental setup was given earlier in [2]).

The test procedure was as follows. A test specimen molded from fine-grain powder of a given substance was placed in the tubing with the solvent, to be carried into one revolving cell. As soon as a test specimen entered the test zone of the cell, its further motion ceased by the action of a centrifugal force field. The test specimen remained in the test zone of the conical cell until the hydrodynamic force of the solvent stream exceeded the centrifugal force. The residue of specimen material was then carried away from the test cell and collected in a filter mesh.

During the test we recorded: the dissolving time of a specimen in the rotating solvent; the solvent flow rate in order to determine its linear velocity by means of an inductive flow meter; and the initial and final weights of the test specimen to determine the loss of weight by dissolution.

An important step in the test procedure was the adjustment of the apparatus to attain the necessary hydrodynamic conditions. The velocity of the liquid w_{cr} flowing into the conical cell of the rotor had to satisfy the condition of temporary equilibrium of a particle acted on by centrifugal and hydrodynamic forces [3]. This velocity had to be matched to the angular velocity of the rotor. Otherwise, the particle would have been promptly ejected from the conical cell. At some definite ratio of flow velocity to rotor speed a particle could lose here 80-90% of its weight before being ejected by the hydrodynamic forces.

The flow velocity of the solvent satisfying this requirement was determined experimentally and was found to vary from 3.2 to 7.6 m/sec, depending on the density of the specimen material.

From the test data we could determine the mass-transfer coefficients k according to the formula

$$k = \frac{3G_0\left(1 - \sqrt{\frac{G_f}{G_0}}\right)}{\Pi d_0^2 C_s \left(\frac{h_0}{d_0} + \frac{1}{2}\right)\tau}. \tag{1}$$

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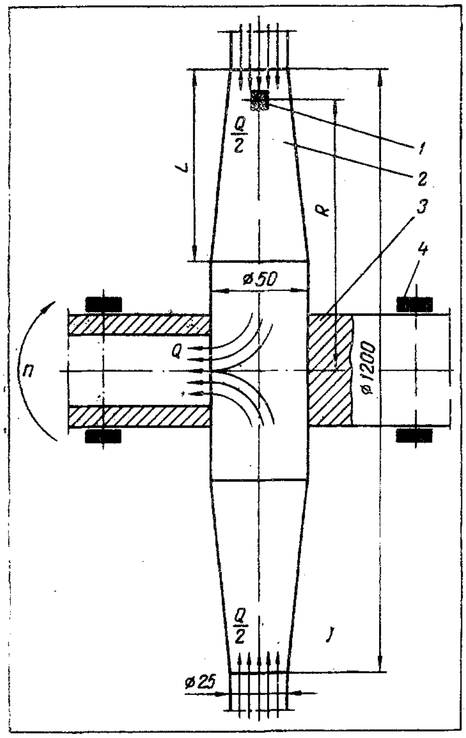

Fig. 1. Rotor of the test apparatus: 1) specimen of tested solid substance; 2) conical test cell; 3) hollow shaft; 4) bearing.

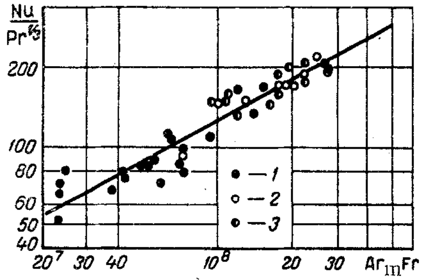

Fig. 2. $Nu/Pr^{1/3}$ as a function of Ar · Fr (Pr = 597-1150, Fr = 28-172) for resorcin (1), ammonium sulfate (2), and sylvite (3).

It is interesting to compare the mass-transfer coefficients k under nominal conditions in a centrifuge with the coefficients obtained by simple gravity weighing. We refer to Zdanovskii's data on the dissolution of sylvite [4], according to which k = 0.0093. At a Froude number Fr = 200, we obtained for this coefficient the value 0.055 (six times higher).

The results obtained by an analysis of mass transfer between solid particles and a rotating stream of liquid solvent can be summarized with the following equation:

$$\frac{Nu}{Pr^{1/3}} = f(ArFr). \tag{2}$$

The extent to which the experimental data agree with the theoretical formula

$$\frac{Nu}{Pr^{1/3}} = 0.013\,(ArFr)^{0.54} \tag{3}$$

is indicated in Fig. 2.

NOTATION

w_{cr}	is the critical velocity of the stream, m/sec;
d_0	is the initial diameter of the particle, m;
d_m	is the mean diameter of the particle, m;
ρ_S, ρ_L	are the density of the solid and of the liquid phase respectively, g/cm^3;
g	is the acceleration due to gravity;
r	is the radius of the particle orbit, m;
k	is the mass-transfer coefficient, cm/sec;
D	is the diffusivity, m^2/sec;
G_0	is the initial weight of the specimen, g;
G_f	is the final weight of the specimen, g;
h_0	is the initial height of the specimen, cm;
C_S	is the saturation concentration of the solution, g/cm^3;
ω	is the angular velocity, sec^{-1};
ν	is the kinematic viscosity, m/sec;
τ	is the time, sec;
$Ar_m = (gd_m^3/\nu^2)(\rho_S-\rho_L)/\rho_L$	is the Archimedes number;
$Fr = \omega^2 r/g$	is the Froude number;
$Pr = \nu/D$	is the Prandtl number;
$Nu = kd_m/D$	is the Nusselt number.

LITERATURE CITED

1. G. A. Aksel'rud, Theory of Diffusive Extraction of Substances from Porous Media [in Russian], Izd. L'vovsk. Politekh. Inst., L'vov (1959).

2. G. A. Aksel'rud and D. D. Dragomiretskii, Inzh.-Fiz. Zh., 16, No. 3 (1969).
3. G. A. Aksel'rud, B. N. Guberman, and D. D. Dragomiretskii, Heat and Mass Transfer [in Russian], Vol. 4, Nauka i Tekhnika, Minsk (1968), p. 126.
4. A. B. Zdanovskii, Proceedings of the All-Union Scientific-Research Institute of Metallurgy [in Russian], No. 33, Goskhimizdat (1956).