between ray and normal to the layer; I, energy brightness of radiation; Q, energy liberation in medium; M, liquid mass; S, area of illuminated surface; η, spectral efficiency of radiation source; Ω, solid angle; φ, azimuthal angle; λ, heat of phase transition; Λ, optical thickness; V, liquid-filled volume; h, grid step; δ, thickness of liquid layer in the direction perpendicular to propagation of the radiation; F, universal function calculated within the framework of similarity theory, Indices: c, critical area.

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INTENSIFICATION OF MASS-EXCHANGE PROCESSES BY AN ELECTRIC FIELD IN A CAPILLARY POROUS SOLID—LIQUID SYSTEM

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An experimental study is performed of mass-exchange processes during extraction in a capillary porous solid—liquid system in an electric field. The experimental data are generalized to a critical function.

Electrical fields are widely used to intensify heat and mass exchange in various chemical and technological processes such as absorption, drying, etc. [1, 2]. Moreover, they can be used in the production of sugar, plant oils, and other extraction processes which remove organic substances from plant materials. In this case use of the field can improve the quality of the product obtained [3].

It is well known that internal molecular mass transfer (within the capillary porous body) to the body—liquid boundary in the case of sucrose extraction is characterized by the sucrose diffusion coefficient in the plant tissue, the value of which depends on the physicochemical properties of the body and the temperature. Transfer of material from the surface of the capillary porous body into the flow of liquid being extracted is characterized by a mass-transfer coefficient, the value of which is dependent on hydrodynamic conditions of the process. We have experimentally established the value of the sucrose diffusion coefficient in a capillary porous body during extraction in an electric field in a previous study [4].

Below we will present the results of a study of mass exchange in extraction of sugar from a layer of capillary porous body into a liquid over various ranges of electric field intensity and temperature to clarify the effect of the hydrodynamic factor. To do this a device was created (Fig. 1) which generated a specific extraction rate through the layer of capillary porous substance with the quantity and concentration of extractant being measured at various times. The apparatus consisted of a thermostat, extractor, regulating valves, and measurement vessels.

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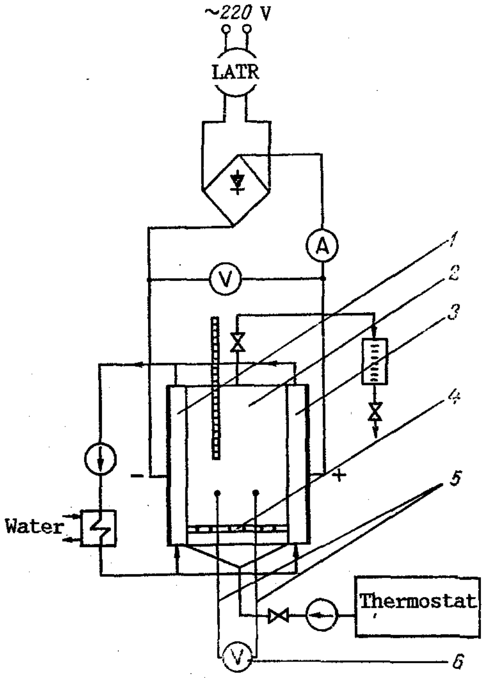

Fig. 1. Diagram of laboratory extraction device.

The thermostat maintains a specified extractant temperature. The extraction process was carried out in an electrolytic cell, divided by ion-exchange membranes into electrode chambers (anode 3 and cathode 1 and a middle electroextraction chamber 2).

The electrode chambers reduce the polarization of the electrodes and maintain the specified temperature in the extractor 2. Electrical values were monitored by instrumentation of the 0.5 accuracy class. The field intensity in the layer of capillary porous body was measured by a high resistance potentiometer 6 with comparison electrodes 5 installed in the electroextraction chamber. A distributor 4 was located in the lower portion of the apparatus and held the layer of particles. Parallel experiments with no electric field applied were also carried out.

In [5] equations were obtained for the dynamics of extracting substances from capillary porous materials and presented in a form which allows determination of the kinetic coefficients of the extraction process from the concentration of the extraction liquid leaving the layer. Constructing a graph of the dimensionless concentration of the liquid being extracted vs time in semilogarithmic coordinates for the regular period of the process, we find the slope of the averaging straight line tan α and define the value of the first root of the characteristic equation [5]

$$\mu_1 = \sqrt{\frac{\operatorname{tg}\alpha \cdot R^2}{D \cdot 0{,}4343}} \tag{1}$$

and the value of the Biot diffusion number. The intensity of mass exchange, which is characterized by the mass-transfer coefficient, is defined from the expression

$$\beta = \frac{\mathrm{Bi} \cdot D}{R}. \tag{2}$$

The dependences of mass-transfer coefficient on field intensity and time are shown in Figs. 2 and 3. In the range 0-1000 V/m with increase in field intensity the mass-transfer coefficient changes linearly. The character of the change in β with electric field is analogous to the dependence of the diffusion coefficient on field intensity. With increase in temperature the intensity of mass exchange increases in either the presence or absence of a field. But the effectiveness of the field's action decreases somewhat with temperature increase (Fig. 3b), since the viscosity of the sucrose solution decreases and the intensity

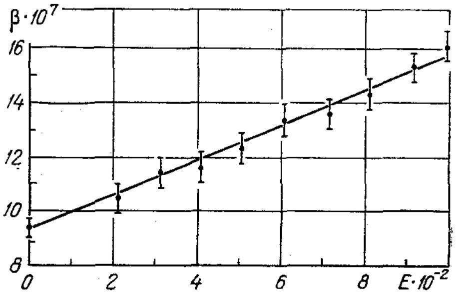

Fig. 2. Mass-transfer coefficient β (m/sec) vs electric field intensity E, (V/m).

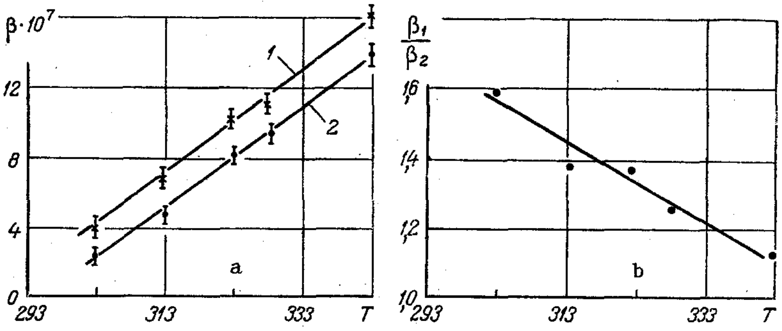

Fig. 3. Temperature T (°K) dependence of: a) mass-transfer coefficient β(m/sec) (1, with electric field applied; 2, without field); b) mass-transfer efficiency.

of the motion within the pores increases.

The conditions under which the particles are washed by the extraction agent, which have a most significant effect on the process, can best be described by comparing the hydrodynamic and mass exchange characteristics of the process.

The effect of velocity of the extraction liquid on the mass transfer coefficient was studied in a diffusion battery in the single counterflow regime. The battery was composed of nine identical electrodiffusors [3]. The experiments were performed at a temperature of 333°K, field intensity of 750 V/m, and extraction agent flow rate of 0.009-0.017 m/sec. The experimental data were generalized as a criterial equation

$$\mathrm{Nu} = f(\mathrm{Re},\ \mathrm{Pr}). \tag{3}$$

The number Nu describes mass exchange in sucrose extraction from a layer of capillary porous material in an electric field:

$$\mathrm{Nu} = \frac{\beta R}{D}. \tag{4}$$

The equivalent channel diameter between particles

$$d_e = \frac{4f(\gamma - q)}{Pq}; \tag{5}$$

the Reynolds number

$$\mathrm{Re} = \frac{wd_e}{\nu}; \tag{6}$$

the mean velocity of the extraction liquid in the interparticle channel

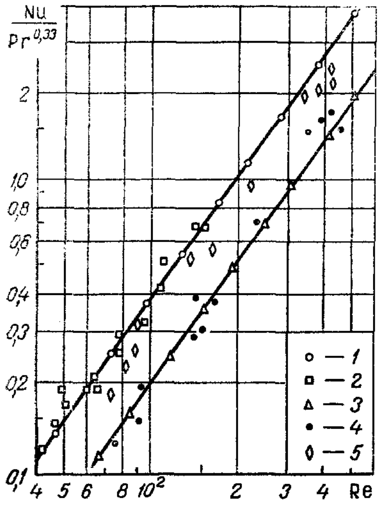

Fig. 4. Comparison of calculation with Eqs. (9), (10) with experimental data: 1) calculated; 2) experimental with Eq. (9); 3) calculated; 4) experimental with Eq. (10); 5) Eq. (10) with consideration of electric field application.

$$w = \frac{V}{F_\ell \, 60}; \tag{7}$$

the total area of interparticle channels

$$F_\ell = \frac{F_0 (\gamma - q)}{\gamma}. \tag{8}$$

The values of the auxiliary quantities required for calculating Nu, Re, and Pr are defined in accordance with [6, 7].

As a result, the criterial equation

$$\mathrm{Nu} = 6{,}95 \cdot 10^{-4}\, \mathrm{Re}^{1{,}38} \mathrm{Pr}^{0{,}33} \tag{9}$$

were obtained. The correlation coefficient of the dependence $K_r = 0.8$. Figure 4 compares calculations with Eq. (9) to the experimental data. The mean relative correlation error is 8%, which is close to the accuracy of the mass-transfer coefficient measurements.

An experimental dependence was presented in [5, 7] which describes mass exchange in a layer of capillary porous colloidal bodies during sucrose extraction without application of an electric field:

$$\mathrm{Nu} = 3{,}8 \cdot 10^{-4} \mathrm{Re}^{1{,}38} \mathrm{Pr}^{0{,}33}. \tag{10}$$

For comparison, Fig. 4 shows data on mass exchange calculated with this equation. Analysis of criterial equations (9), (10) shows that they have identical exponents for Re and Pr. Apparently, this is related to the fact that the electric field has no effect on the hydrodynamic situation during sucrose extraction.

The different values of the coefficients in these equations can be explained by intensification of the diffusion within the capillary porous body toward the body—liquid boundary upon application of the electric field. Figure 4 also shows experimental data of [7] processed by the authors with consideration of the change in the sucrose diffusion coefficient in a capillary porous colloidal body upon application of a 750 V/m field. They confirm the proposition of intensified mass exchange upon field application due to intensification of internal diffusion transport of sugar within the capillary porous colloidal body.

The data obtained are necessary for calculation of mass exchange electroextractors which could be used in the food and other industries.

NOTATION

μ, root of characteristic equation; tan α, tangent of averaging straight line; D, sucrose diffusion coefficient in capillary porous body with electric field applied; β, mass transfer coefficient; R, reduced particle radius; d_e, equivalent diameter of interparticle channel; f, particle cross-sectional area; P, particle cross section perimeter; γ, specific weight of particles; q, specific extraction chamber load; w, extraction liquid velocity in channel; V, volume of extraction liquid; F_1, total cross-sectional area of interparticle channels; F_0, cross-sectional area of extraction chamber.

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KINETICS OF COMBUSTION OF POLYDISPERSED COKE DUST

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A method for calculating combustion processes in self-similar systems of polydispersed solid fuel is developed, based on the kinetic equation for the particle distribution function over radius.

The study of combustion of polydispersed fuel is beset by difficulties related to the nonlinearity of the problem and the presence of the various temperature, combustion rate, and reagent concentration distributions, etc. In fuel combustion polydispersity of the particles is usually considered either by calculating the amount of fuel which remains unburned by a particular time, a quantity dependent only on the initial particle size distribution [1, 2], or by dividing the particle size spectrum into a number of fractions and performing calculations for each fraction [3]. These methods do not provide simple analytical expressions for calculation of combustion characteristics, and require use of numerical methods.

In [4], in a study of kinetics of mass exchange of a system of droplets with the surrounding medium polydispersity was considered by introducing a kinetic equation for the distribution function $f(r, \tau)$ of particles over radius. The present study will analyze solutions of this equation in detail, including self-similar systems, and generalize the result to a system with arbitrary initial distribution $f_0(r)$. It will be shown that the exact form of $f_0(r)$ affects only the initial stage of the process. The possibility of such an approach has been tested in a number of studies of heat—mass exchange of polydispersed systems with the surrounding medium [5-7], and generalized to some extent in [8].

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