ABSTRACTS OF ARTICLES DEPOSITED AT VINITI*

EXPERIMENTAL INVESTIGATION OF THE VISCOSITY OF PROPIONATES AT VARIOUS TEMPERATURES AND PRESSURES

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and N. M. Bairamov

UDC 536.2

The dynamic viscosity of amyl and isoamyl propionates in the liquid and gaseous phases has been investigated for temperatures from 300 to 500°K and pressures of $(0.1 \text{ to } 50) \cdot 10^{-3}$ N/m^2. Using a Tsvet-4 chromatograph it was found that the amyl and isoamyl propionate base materials used had purities of 99.8 and 99.9 wt.%, respectively.

The viscosity of the ethers was studied by the viscometric method developed at the State Scientific-Research Institute of the Nitrogen Industry. The capillary viscometer used had the following characteristics: radius of capillary $r = 0.0926$ cm, length of capillary $l = 5.1093$ cm, and volume of measuring vessel $v = 1.5728$ cm^3.

The viscosity measurements were performed along isotherms at 25-30° intervals. The values of η for amyl and isoamyl propionates are shown in Table 1. Basic corrections were taken into account in calculating η from the experimental data. We determined the values of the density necessary to calculate the dynamic viscosity by the method of hydrostatic weighing with an error of 0.1%. We estimated the error in determining η, taking account of the reference, as ±1.1%.

The experimental data confirmed the practicability of the Frenkel formula for the ethers studied. The constants of this formula and the temperature range in which it satisfactorily describes the experimental data were determined. Using the Golubev equation the functional dependence of the viscosity on the density and thermal properties of the ethers was established.

TABLE 1. Dynamic Viscosity of Amyl Propionate and Isoamyl Propionate $\eta \cdot 10^6$ (N · sec/m^2)

Temp. T, °K	Pressure P, 10^{-3} N/m^2						
	0,1	5	10	20	30	40	50
			Amyl propionate				
300	930	981	1040	1129	1244	1343	1455
325	678	715	752	826	901	974	1048
350	475	517	559	618	678	736	801
375	378	402	425	411	523	565	619
400	291	312	333	378	420	462	504
425	236	252	270	306	342	380	417
450	9,0	200	217	250	282	315	349
475	9,8	167	180	208	237	264	295
500	10,4	142	153	178	203	228	256
			Isoamyl propionate				
300	860	973	949	1039	1129	1220	1310
325	633	670	706	778	850	921	994
350	510	527	556	613	673	726	780
375	406	418	446	491	536	585	632
400	330	342	363	405	442	486	523
425	275	286	304	338	371	408	441
450	11,5	244	259	290	319	350	379
475	12,4	209	221	249	275	301	327
500	13,4	173	185	210	233	258	283

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DEPENDENCE OF DIELECTRIC PROPERTIES OF CELLULOSE ON MOISTURE CONTENT IN THE MICROWAVE REGION

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53.093:621.3.029.6

Results are presented of an experimental study of the dependence of the permittivity ε' and the tangent of the dielectric loss angle $\tan\delta$ of cellulose on moisture content. The values of ε' and $\tan\delta$ were measured at the maximum of a 10,000-MHz electric field. The permittivity ε' increases with moisture content W at different rates in different regions. For low moisture contents ε' increases slowly and linearly with W, and then for moisture contents above 5% it increases considerably more rapidly. The tangent of the loss angle is maximum for a moisture content of 15% which, according to data determined by other independent methods (drying thermograms, wetting heats, NMR method), corresponds to the maximum amount of water which can be adsorbed by cellulose.

The construction of a measuring cell for studying the dependence of dielectric parameters of capillary porous materials on moisture content is described.

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TEMPERATURE COMPENSATION AND ESTIMATE OF SENSITIVITY OF RESONATOR METHOD OF MEASURING MOISTURE CONTENT OF LIQUID DIELECTRICS

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UDC 617.621:533.275

The permittivity of nonpolar and weakly polar liquids and their aqueous emulsions decreases with increasing temperature, leading to an increase in the resonant frequency of a resonator. A simultaneous increase in the length and diameter of a resonator decreases its resonant frequency. If the change in the resonant frequency of the resonator arising from the change in permittivity is the same as that from the change in its dimensions, the temperature of the liquid will not affect the value of the resonant frequency.

Taking account of the linear nature of the temperature dependence of the permittivity of a liquid, we have used the method of small perturbations to derive an expression for calculating the necessary structural dimensions of a resonator and choosing the material for its construction so as to ensure temperature compensation. Relations were obtained for a cylindrical resonator with oscillations of the H_{01T} type with its cavity partially filled with the material under investigation.

The results obtained show that complete compensation is possible only for a definite moisture content of the emulsion. The temperature error increases with increasing temperature and as the moisture content exceeds the nominal value. The temperature error increases with increasing relative sensitivity of the method and is maximum for the method using complete filling of the resonator cavity with the liquid under investigation. To decrease the temperature error it is expedient to measure small moisture contents by partially filling the resonator cavity with the liquid under investigation.

To estimate the effect of the position and thickness of the membrane on the measurements of moisture content, a coefficient is introduced to characterize the sensitivity of the resonator method with partial filling relative to the sensitivity of the method with complete filling. The relative sensitivity increases if the air–dielectric boundary (in the presence of a dielectric membrane and without it) is at an antinode of the electric field. The highest sensitivity can be obtained by using a quarter-wave dielectric membrane.

Measurements showed that the sensitivity of the resonator method with partial filling is high, reaching 15 MHz per 1% moisture content for moisture contents up to 0.5%. The relative error in measuring moisture content in this same range of moisture contents does not exceed 5% for temperature changes from 20 to 50°C.

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DETERMINATION OF ADIABATIC EXPONENTS OF REAL GASES AT HIGH PRESSURE.

II. ADIABATIC EXPONENTS AND DEPARTURE COEFFICIENTS OF AIR AT PRESSURES UP TO 1000 BAR

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UDC 536.711

We present calculated values of the temperature and volume adiabatic exponents and graphs of the specific heats c_p and c_v, the departure coefficients μ_p and μ_T, and the adiabatic exponents K_v and χ as functions of the pressure and temperature for air.

Choosing as the most reliable the equation given in [1],

$$\sigma = \alpha_0 + \alpha_1\tau + \beta\psi + \gamma\psi^2,$$

where α_0, α_1, β, and γ are elementary functions depending only on the reduced density and the reduced temperature:

$$\psi = 1/\tau;\ \tau = T/T_{cr};\ \omega = V_{cr}/V;\ \sigma = Z\tau;\ Z = PV/RT,$$

after some simple transformations we obtained an equation in the form of a virial series in inverse powers of V and T in a form most convenient for machine calculations:

$$Z = \frac{PV}{RT} = 1 + \sum_{i=1}^{r}\sum_{j=0}^{S_i}\frac{b_{ij}}{V^i T^j}$$

Starting from this equation relations were derived and calculations were made of the departure coefficients μ_p, μ_T, μ_v, K_{TT}, and K_{pp} for temperatures T = 240-600°K and pressures P = 25-1000 bar. The volume and temperature adiabatic exponents K_v and $\varkappa$ calculated from the expressions [2]

$$K_v = \frac{c_p}{c_v K_{TT}} = \frac{c_p Z}{(c_p - AR\mu_v\mu_p)\,K_{pp}},\quad \varkappa = \frac{c_p}{c_{v_{id}}} = \frac{c_p}{c_p - AR\mu_p},$$

are tabulated and shown graphically. It is clear from Fig. 1 that the values of K_v increase substantially with increasing pressure and the isotherms become steeper as the critical region is approached. This indicates that at high pressures the compressibility of the gas decreases and its properties approach those of a liquid.

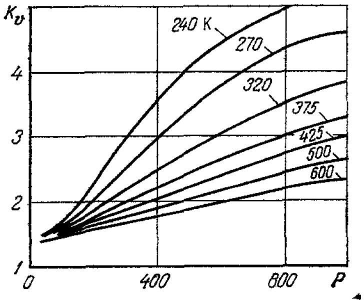

Fig. 1. Volume adiabatic exponent K_v as a function of pressure P, bar.

The temperature adiabatic exponent $\varkappa$ is relatively close to the ideal value for pressures up to 200 bar; at higher pressures it decreases appreciably with decreasing temperature. Small changes of the temperature adiabatic exponent with pressure make this quantity very convenient for thermodynamic calculations.

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INVESTIGATION OF THE P – ρ – T RELATION FOR METHYL HEXYL KETONE OVER A WIDE RANGE OF TEMPERATURES AND PRESSURES

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UDC 536.2

We present experimental P–ρ–T data on liquid methyl hexyl ketone for temperatures from 270 to 670°K and pressures from 1 to 800 bar obtained for the first time by the method of hydrostatic weighing. The probable error is estimated as ± 0.1%.

Some of the experimental values of the density of methyl hexyl ketone are listed in Table 1.

Starting from the fact that sections of isotherms in ρ – P coordinates at constant densities ρ are rectilinear to within ± 0.12% in density over the whole range of temperatures and pressures encountered in the experiment, the P–ρ–T data for methyl hexyl ketone were described by an equation of state of the form

$$P = A(\rho) + B(\rho)\,T,$$

where A and B are functions of ρ; P is the pressure on the liquid, bar; T is the temperature, °K.

The coefficients A and B were found separately for each line ρ = const by the method of least squares. Graphs of the functions $A = f(v)$ and $B = f(v)$, where $v = 1/\rho$ is the specific volume, have the shapes of a potential curve and a hyperbola, respectively. This behavior of the functions $A = f(v)$ and $B = f(v)$ becomes clear if their physical meaning is taken into account. As a matter of fact, it is easy to show that $A = -(\partial\varphi/\partial V)_T$, where φ is the intermolecular interaction energy, $V = \mu v$ is the molar volume, μ is the molecular mass, and $B = (\partial p/\partial T)_V$.

Having an analytic expression for the function $A = f(v)$, and taking account of the fact that the graph of this function approaches the axis of specific volumes asymptotically, the intermolecular interaction energy for a given v can be found from

$$\varphi = -\mu \int_{v_0}^{\infty} A(v)\,dv,$$

which permits the checking of other thermodynamic quantities.

TABLE 1.

P, bar	$\rho \cdot 10^{-3}$, kg/m³					
	T=273,15°K	313,15	374,31	476,15	566,08	673,15
0,98	0,8338	0,8013	—	—	—	—
50,06	0,8367	0,8050	0,7557	0,6621	—	—
99,11	0,8396	0,8085	0,7605	0,6736	0,5836	0,4452
197,21	0,8453	0,8150	0,7694	0,6915	0,6134	0,5182
295,31	0,8498	0,8218	0,7784	0,7061	0,6378	0,5550
393,41	0,8545	0,8278	0,7868	0,7182	0,6557	0,5825
491,51	0,8602	0,8340	0,7950	0,7290	0,6710	0,6048
589,61	0,8653	0,8403	0,8025	0,7393	0,6845	0,6220
687,71	0,8703	0,8462	0,8100	0,7491	0,6978	0,6370
785,81	0,8751	0,8520	0,8169	0,7581	0,7084	0,6510

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Original article submitted June 13, 1977.

NUMERICAL INVESTIGATION OF CERTAIN BASIC LOCAL RADIATIVE HEAT-TRANSFER CHARACTERISTICS IN A PRISMATIC CHAMBER OF RECTANGULAR CROSS SECTION (RATIO OF SIDES OF BASE $a : b = 1.5$)

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UDC 536.241

To obtain high-quality food products which are subjected to heat treatment in the manufacturing process, it is important to know local as well as average values of radiative heat-transfer characteristics.

Local radiative heat-transfer characteristics were investigated numerically by the Yu. A. Surinov generalized zonal method.

The widespread use of the generalized method of determining local radiative heat-transfer characteristics is deterred by the necessity of performing voluminous calculations with very cumbersome and complicated formulas.

We have calculated radiative heat transfer in a chamber with a rectangular base. The height of the chamber was varied from 0.1 to 10.0 (22 values) in relative units. Each side of the chamber was divided into 121 local portions.

A mixed formulation of the problem was considered: The net radiant flux on the lateral surfaces of the chamber and the temperatures and emissivities of the upper and lower bases of the chamber were specified, and the local distributions of radiant fluxes over the upper and lower bases of the chamber and the temperature over the lateral surface were determined. The emissivity of the bases was varied from 0.01 to 1.0 (six values for each base).

The results obtained are presented in tables and graphs which can be used in engineering practice.

It can be seen from Eqs. (1)-(3) that the main difficulty in the numerical computation of local energy characteristics is the determination of the local angular resolving coefficients. Figure 12 shows the dependence of the local angular resolving coefficients from points of the lower base to points on the upper base as a function of the emissivity of the lower base.

The six calculated curves of Fig. 12 can be used to determine local angular resolving coefficients $\Phi(M_1, F_3)$ for radiating systems having $N=1.0$, 1.25, 1.5, 2.0 and $L=0.5$, 0.75, 1.0, 1.5, 2.0, 3, 4, 5, 6, 7, 8, 9, 10 with an error of no more than 1.5-10%. It turned out that the error in using Fig. 12 is smaller, the smaller A_1 and A_3.

Thus, it can be stated that for the indicated values of N and L, $\Phi(M_1, F_3)$ is a function only of the emissivity as is clear from the values of the dimensionless local density of the net radiation of zone 1 given in Table 6.

The constancy of $\Phi(M_1, F_3)$ for constant values of the emissivity appreciably simplifies the computation of radiative heat transfer in a prismatic chamber of rectangular cross section.

The work is designed to supply reference material for the engineering solution of radiative heat-transfer problems in a chamber of rectangular cross section.

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SOLUTION OF A SYSTEM OF DIFFERENTIAL EQUATIONS FOR MOLECULAR TRANSPORT WITH N COUPLED FLUXES

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UDC 536.24:681.3

We present the solution of a system of transport differential equations with N coupled fluxes:

$$\gamma_k c_k \frac{\partial \vartheta_k}{\partial \tau} = \sum_{i=1}^{N} a_{ki}^2 \Delta \vartheta_i + f_k, \; k = 1, 2, \ldots, N,$$

$$\vartheta_k(\tau, x)|_{\tau=0} = \eta_k(x), \; x \in G; \; M[\vartheta_k(\tau, x)]|_\Gamma = \varphi_k(y, \tau), \; y \in \Gamma,$$

where

$$M[\vartheta_k(\tau, x)]|_\Gamma = \alpha \frac{\partial \vartheta_k}{\partial \nu} + \beta \vartheta_k, \; \alpha\beta = 0, \; \alpha^2 + \beta^2 \neq 0.$$

Using specially constructed functions which satisfy the conditions for the expansion of an arbitrary function in a series of eigenfunctions of the Laplacian operator [1] which is uniformly and absolutely convergent in a closed interval $\bar{G}$, and using [2], we obtain an explicit solution of the problem.

The coefficients in the series giving the solution contain all the parameters of the problem explicitly, and the series have the maximum possible rate of convergence for a given smoothness of the functions f_k, η_k, and φ_k.

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HEAT CONDUCTION FOR A HALFSPACE WITH VARIABLE COEFFICIENTS AND MIXED BOUNDARY CONDITIONS OF THE SECOND AND THIRD KINDS

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UDC 536.21

We consider the heat-conduction equation

$$\theta_t = \omega \Delta \theta + \beta \theta_x + \alpha \theta_y + \gamma \theta + \frac{\omega}{\lambda} \Psi, \; M \in u, \; t > 0 \tag{1}$$

with mixed boundary conditions

$$-\lambda \theta_z(N, t) = q(N, t), \; N \in \bar{S} = \Omega - S, \tag{2}$$

$$-\lambda \theta_z(N, t) = \alpha(N, t)[\delta(N, t) - \theta(N, t)], \; N \in S \tag{3}$$

and initial conditions $\theta(M, 0) = \mu(M)$, $M \in u$, where u is the halfspace $z \geq 0$; Ω is the plane $z = 0$; S is a certain domain on the boundary of the body Ω; $M = (x, y, z)$; $N = (x, y, 0)$; ω, λ, α, and β are constants; $\gamma = \gamma(t)$ is an arbitrary function of time; Δ is the Laplacian operator. We define a new unknown function v by the relation

$$\theta = v \exp[H(N, t)]; \tag{4}$$

$$H(N, t) = -\frac{1}{2\omega}[\beta x + \alpha y] + \int_0^t \left[\gamma(\tau) - \frac{\beta^2 + \alpha^2}{4\omega}\right] d\tau.$$

Then Eq. (1) takes the form

$$v_t = \omega\Delta v + \frac{\omega}{\lambda}\Psi e^{-H};\ v(M,\ 0) = \mu(M)\,e^{-H(N,0)}. \tag{5}$$

The heat flux on the boundary of the region Ω

$$-\lambda\theta_z(N,\ t) = q(N,\ t),\quad -\lambda v_z(N,\ t) = q(N,\ t)\,e^{-H(N,t)}$$

is known only in the domain S; it is to be determined in the domain $\bar{S}$.

On the basis of the theory of heat potentials we first write the general solution of Eq. (5) in terms of the heat flux q(N, t), and then use (4) to find the general solution of Eq. (1):

$$\theta(M,\ t) = \Phi(M,\ t) + \frac{\omega}{\lambda}\int\limits_0^t d\tau \int\limits_S q(N_0,\ \tau)\,G(M,\ N_0,\ t,\ \tau)\,dS. \tag{6}$$

Here $\Phi(M, t)$ is a known function; $N_0 = (x_0, y_0, 0) \in S$; $G(M, M_0, t, \tau) = G^*(M, M_0, t-\tau)\exp[H(N, t) - H(N_0, \tau)]$; $M_0 = (x_0, y_0, z_0) \in u$; $G^*(M, M_0, t, \tau)$ is the Green function of the second kind for the halfspace $dS = dx_0dy_0$. Setting M = N in Eq. (5) and using boundary conditions (2) and (3), we obtain an integral equation of the Volterra type in the time and of the Fredholm type in the coordinates for the heat flux of q(N, t)

$$q(N,\ t) = F(N,\ t) + \frac{\omega}{\lambda}\alpha(N,\ t)\int\limits_0^t d\tau \int\limits_s q(N_0,\ \tau)\,G(N,\ N_0,\ t,\ \tau)\,dS. \tag{7}$$

The kernel of this integral equation has a removable singularity in the time and consequently can be solved by the method of successive approximations. The method of successive approximations involves multiple integration which severly limits the computational possibilities of the method. We use a more convenient approximate method of solving Eq. (7) which leads to triangular type recurrence relations.

The method presented for solving heat-conduction problems for a halfspace with variable heat-transfer coefficients and mixed boundary conditions can be extended to other bodies for which the Green function is known.

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ESTIMATE OF ACCURACY OF NUMERICAL COMPUTATION OF ANALYTIC SOLUTIONS OF UNSTEADY HEAT-CONDUCTION PROBLEMS

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UDC 536.2.02

Using the asymptotic formulas for Bessel functions of large argument, and applying the methods of differential calculus, we have estimated the absolute magnitude of the remainder of the functional series appearing in the analytic solutions of heat-conduction problems for unbounded plates and cylinders (including the asymmetric heating of a plate for boundary conditions of the third kind and the heating of a hollow cylinder) for boundary conditions of the first, second, and third kinds.

For a boundary condition of the fourth kind the numerical computation of the solution for an unbounded plate is reduced to the use of tabulated functions. For an unbounded cylinder in an unbounded medium the improper integral appearing in the solution [1] is broken up into three integrals:

$$\int\limits_0^\infty \frac{J_0\left(\mu\frac{r}{R}\right)J_1(\mu)}{\mu^2[\varphi^2(\mu) + \psi^2(\mu)]}\exp\left(-\mu^2\frac{a_1\tau}{R^2}\right)d\mu = \int\limits_0^\infty = \int\limits_0^p + \int\limits_p^P + \int\limits_P^\infty.$$

Since the limits of integration of the original integral are singular points, the problem is reduced to choosing p and P so that the absolute magnitude of the first and third integrals of the sum does not exceed a preassigned value.

The relations obtained permit the determination of the number of terms of the corresponding functional series or the choice of the limits of integration for the improper integral so as to ensure the required accuracy of the numerical computation.

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Original article submitted February 4, 1976.