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DENSITY DEPENDENCE OF POLYSTYRENE SOLUTIONS ON CONCENTRATION UNDER ISOBARIC CONDITIONS

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Annotation

Polystyrene is recognized as the most inexpensive material, finding application in all areas and spheres of human life. Even its waste is used as secondary raw material.

Chemical-grade benzene, dichloroethane, xylene, and bromoform were selected as solvents. These organic liquids were chosen because they dissolve polystyrene well and their thermophysical properties have been studied. These liquids do not react chemically with polystyrene; they dissolve the polymer as a result of physical interaction between the polymer molecules and the liquid. Most importantly, changes in the characteristic parameters of the solvents allow us, based on the experimental results, to assess the mechanism of interaction between the polystyrene macromolecule and the solvent molecules.

Keywords

thermal conductivity, macromolecules, experiment, concentration, density, pressure, temperature, solution, liquid, ethylene, benzene, polystyrene, parameter, molecules, properties, reaction, interactions, solvent.

As the object of study, we have chosen polystyrene solutions with molecular weights $6{,}6 \cdot 10^4; 3 \cdot 10^5; 2{,}3 \cdot 10^6$ and $15 \cdot 10^6$. The choice of polystyrene is due, on the one hand, to the fact that it is produced in large volumes and, due to its physical and chemical properties, is widely used in industry in various areas of the national economy in technology, technological and household devices.

Polystyrene produced by the industry is an amorphous, transparent, brittle substance and has a high degree of polymerization: 600 – 2500 [1-10-11]. Polystyrene is a good dielectric. Due to its unique properties, polystyrene is used as an injection molding structural material for the production of containers, pipes, tableware, toys, lighting fixtures, as a packaging material in the food and medical industries, for the production of cartridges, fountain pens, fittings, and in various other fields of technology and processes.

The choice of polystyrene, on the other hand, is also due to the fact that the thermophysical properties of this polymer are well studied. Information on some of the main physical, chemical and thermophysical characteristics of polystyrene is given in Table 1.

Table 1

Specifications	**Meaning**
Appearance	colorless
Refractive index of light n_D^{20}	1,59
Density at 20°C, g/cm³	1,05
Thermal conductivity, W/(m·K)	0,093
Specific heat capacity, kJ/(kg·K)	1,26
Temperature coefficient of linear expansion, $^0C^{-1}$	$6 \cdot 10^{-5}$
Tensile strength (Mpa) during bending	35 – 50
Dielectric constant	2,49 – 2,60

For industrial purposes, polystyrene is used, which has a molecular weight with critical values$\bar{M}_n \sim 120 \cdot 10^3, \bar{M}_\vartheta \sim 250 \cdot 10^3$. At the above values, the strength characteristics of polystyrene have a relatively small dependence on the molecular weight [2-3-8].

Polystyrene has low moisture absorption and good resistance to radioactive radiation. Its main characteristics are:

vapour resistance;

high density;

low operating temperature of -40 °C;

operating temperature of +75 °C;

heat capacity;

thermal conductivity;

good coefficient of thermal expansion;

lightness;
strength;
flexibility;
ease of processing;
resistance to acids and alkalis;
impact resistance;
is perfectly formed.

The material is considered a fire hazard because it contains a large amount of carbon. However, it does not ignite spontaneously, but rather ignites when directly exposed to fire. The gases emitted during combustion are toxic.

Polystyrene contains 92% carbon and 8% hydrogen by weight, and also contains sulfur, nitrogen, and oxygen. It becomes elastic at 80°C and begins to melt at 239°C.

Depending on the method of production, there are different types of polystyrene, but there are mainly three types based on their purpose:

- Shock-resistant (HIPS)
- General Purpose or Transparent (GPPS);
- extruded or foamed

Plexiglas is considered to be the main analogue of polystyrene. The only difference is that plexiglas is more resistant to ultraviolet rays, but polystyrene has a lower cost.

Polystyrene is recognized as the most inexpensive material that is used in all areas and spheres of life. Even the waste of this material is used as a secondary raw material in other industries and can be recycled [9-10].

Chemically pure benzene, dichloroethane, xylene, and bromoform were chosen as solvents. These organic liquids were chosen because they dissolve polystyrene well and their thermophysical properties have been studied and are known to a certain extent. These liquids do not react chemically with polystyrene; they dissolve the polymer as a result of physical interaction between the polymer molecules and the liquid. Most importantly, changes in the characteristic parameters of the solvents (for example, molar mass) allow us to, based on the experimental results, assess the mechanism of interaction between the polystyrene macromolecule and the solvent molecules.

The main physical and chemical characteristics of solvents are listed in Table 2.

Table 2.

Solvent	Chemical formula	Molar mass $M, 10^{-3}\frac{kg}{mol}$	Melting point$T_{пл}$, К
Benzene	C_6H_6	78,11	278,68

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Dichloroethane	CH_3CHCl_2	98,96	176,45
Xylene	$C_6H_4(CH_3)_2$	106,17	247,8
Bromoform	$CHBч_3$	252,73	281,65

Solvent	Boiling point $T_{кип}$, К	Critical temperature $Т_{кр}$, К	Critical pressure $Р_{кр}$, 10^5Па	Dielectric constant ε
Benzene	353,22	553,0	48,6	2,275
Dichloroethane	330,50	522	50	10,86
Xylene	417,55	632	36	2,226
Bromoform	423,65	-	-	4,49

Xylene is used as a solvent for paints and varnishes to obtain phthalic and toluene acids and is used as a high-octane additive to aviation gasoline. Bromoform is well known as a solvent for waxes, fats, and is widely used in medicine. During storage, transportation, and operation. These active organic liquids can come into contact with polymeric materials, particularly polystyrene [2-3-8-10].

Benzene belongs to the series of unsaturated hydrocarbons, but it differs from the hydrocarbons of the ethylene series in that it undergoes addition reactions only under harsh conditions. Benzene is more prone to substitution reactions. This is because the atoms in the benzene molecule are arranged in a single plane and have a conjugated 6п electron cloud [10]. The main objective of this work is to study the patterns of influence of the existing macromolecules of the studied sample on the change in thermal conductivity of polymer solutions of the specified category in a wide range of changes in the state parameters. Since the behavior of the thermal conductivity of the pure organic liquids under study is known, the changes in the thermal conductivity behavior of the solution will indicate the degree of influence of the polystyrene macromolecules on the change in the thermal conductivity of the solution.

The solutions were prepared as follows: 0.2, 0.4, 0.6, 0.8, and 1.0 g of polystyrene were added to 1 liter of benzene and allowed to dissolve for 2 weeks.

The role of precise studies of a number of specific parameters in clarifying the caloric properties of liquid substances and solutions is also important. In cases where it is necessary to study the caloric properties of substances, experiments are conducted to determine their dynamic viscosity coefficient and light refraction coefficient. These values are then used in graph-analytical processing, using the law of corresponding ratios and thermodynamic similarity, to find the desired caloric properties.

To measure the density of polystyrene solutions of the system (benzene + PS) at atmospheric pressure and room temperature, we used a float chamber of an

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experimental installation with the liquid under study and a glass viscometer. The results of the study are presented in Figures 1-2-3 and Tables 1-4. These figures and tables show the density values of the solutions for three measurements [4, 5, 6, 7, 8, 9].

Table 3. Physical and chemical properties of benzene

Solvent	Chemical formula	Molecular weight 10^{-3} kg/mol	Melting point TPL, K,	Boiling point T_{cip}, K	Critical temperature T_{cr}, K	Critical pressure P_{cr}, 10^5Pa	Dielectric constant
Benzene (99.97%) h.p.	C_6H_6	**78,11**	**278,68**	**353,22**	**553, 0**	**48,6**	**2,275**

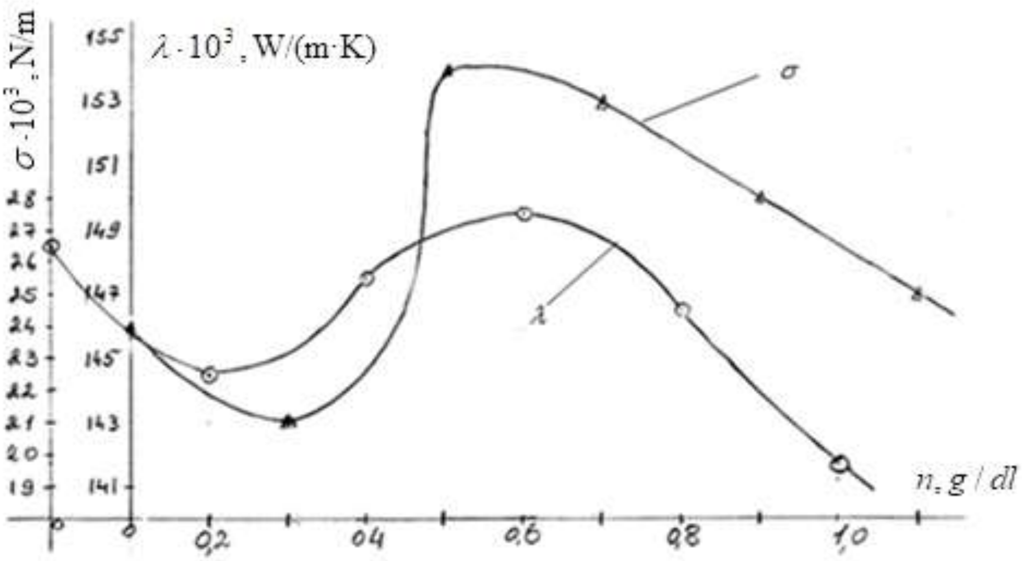

Figure 1. Graph of the dependence of the thermal conductivity of polystyrene solutions with benzene on the coefficient and concentration of polystyrene in these solutions: λ − thermal conductivity, σ −coefficient of surface tension.

Table 4. Thermal conductivity and surface tension coefficients of polymer solutions of polystyrene $M_n \sim 120 \cdot 10^3$ under normal conditions (experimental data).

N, g/dL	0	0,2	0,4	0,6	0,8	1,0
$\lambda \cdot 10^3$, W/(m·K)	146	143	154	153	150	147

$\delta \cdot 10^3, N/m$	28,8	22,5	26,5	27,5	24,5	19,6

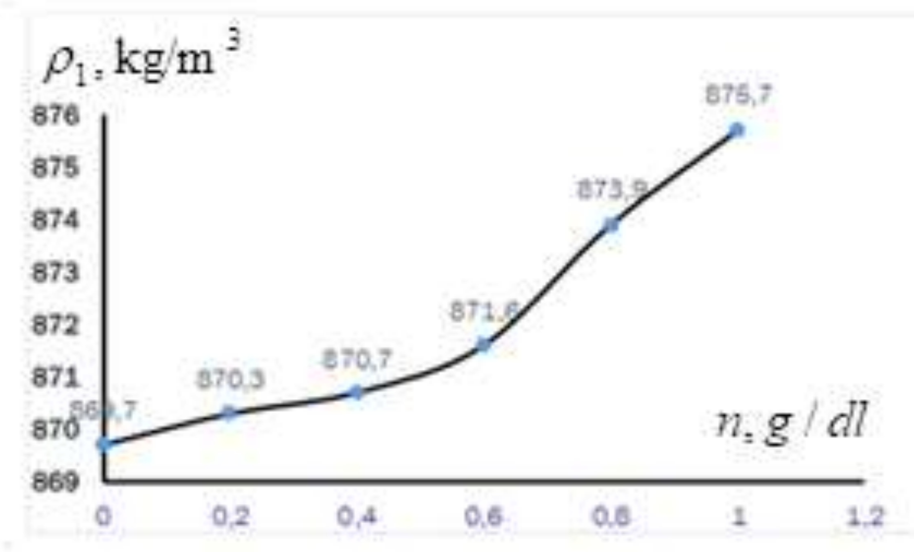

Figure 2. Change in density of benzene with respect to the concentration of polystyrene at atmospheric pressure and room temperature.

Table 5. Experimental values of density (ρ, kg/m3) of polystyrene solutions (benzene solvent).

N, g/dL	0	0,2	0,4	0,6	0,8	1,0
ρ_1, kg/m³	869,7	870,3	870,7	871,6	873,9	875,7
ρ_2, kg/m³	869,7	882,0	883,4	884,2	886,2	887,2
ρ_3, kg/m³	869,7	882,3	887,0	889,8	892,0	895,2

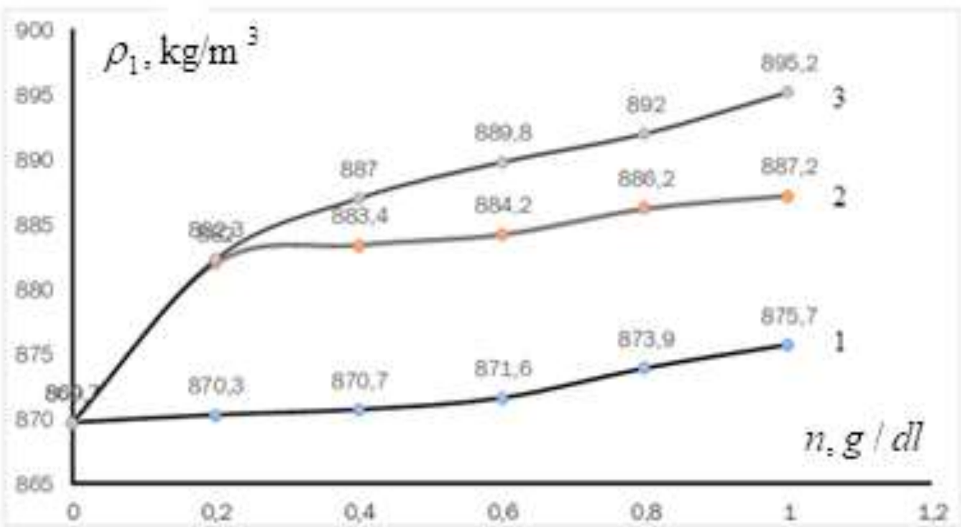

Figure 3. Change in the density of benzene as a function of polystyrene concentration at atmospheric pressure and room temperature.

Table 6. Dependence of the dynamic viscosity coefficient ($\eta \cdot 10^{-3}$ Pa·s) on temperature and polystyrene concentration

Concentration,T,K	301	308	313	318	323	328	333
C_6H_6+0,2 g/dlPs	1,46	1,35	1,08	1,02	0,97	0,86	0,85
C_6H_6+0,4 g/dlPs	8,44	8,05	7,75	7,33	6,95	6,41	5,99
C_6H_6+0,6 g/dlPs	15,57	14,98	14,53	13,66	12,63	12,01	11,15
C_6H_6+0,8 g/dlPs	17,63	16,72	15,64	14,63	13,65	12,67	11,85
C_6H_6+1,0 g/dL PS	19,77	18,50	16,77	15,62	14,60	13,36	12,58

As can be seen from Figures 2, 3, and Table 5, the density of the system (benzene and polystyrene) increases almost linearly with increasing polystyrene concentration for the first measurements, and almost parabolically for the second and third measurements.

For example, when 0.2 g/dL of polystyrene is added, the density of the solution increases by ~1.23%, and when 0.6 g/dL is added, the density increases by ~1.99%. When 1.0 g/dL of polystyrene is added to benzene, the density of the solutions increases by ~2.23%. This behavior of the density of the solutions depends on the solubility of polystyrene. Therefore, when 1.0 g/dL of polystyrene is added to benzene, the volume of the benzene-polystyrene system decreases, resulting in an increase in the density of the samples [4, 5, 6, 7, 8, 9].

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