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VISCOSITY AND DENSITY OF AQUEOUS SOLUTIONS OF HYDRAZINE AND PHENYLHYDRAZINE AS FUNCTIONS OF TEMPERATURE AT ATMOSPHERIC PRESSURE

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Using the method of hydrostatic weighing and a capillary viscosimeter, we measured the density and viscosity of aqueous solutions of hydrazine and phenylhydrazine in the temperature range from 293 to 353 K and obtained an empirical equation.

Previously, the viscosity of liquid hydrazine was studied experimentally as a function of temperature [1]. Our data agree with the data of [1] with an error of 0.1%.

In the present work we conducted an experimental investigation of the viscosity of liquid binary hydrazine-water mixtures in the temperature range from 293 to 353 K and at a concentration of 10–90 mole % H_2O.

The purity of the initial substances for hydrazine and phenylhydrazine was 99.98%.

The values obtained for the viscosity and density of the investigated liquids and their mixtures are given in Tables 1 and 2. The overall relative error in the measurement of viscosity is 1.6%.

According to the data of Table 1, the temperature dependence of the viscosity for the investigated aqueous solutions of hydrazine varies exponentially. The viscosity of the mixtures increases with increase in the percent content of water in the hydrazine. The viscosity-composition isotherms of the solutions investigated (see Fig. 1) have maxima in all of the measured temperature ranges.

It follows from the data of Table 2 that the temperature dependence of the density for the aqueous solutions of phenylhydrazine decreases as the temperature increases. The density of the solutions decreases with an increase in the percent content of water in phenylhydrazine. The densities of the phenylhydrazine solutions over the temperature range 293-353 K at concentrations of 40–60 mole % differ little.

Previously, the density of liquid phenylhydrazine at room temperature was studied experimentally [2]. Our data agree with the data of [2] within a 0.1% error. The density of liquid phenylhydrazine as a function of the molar concentration of water (10–90 mole %) was studied in the temperature range 293–353 K at atmospheric pressure. The measurements were performed by the method of hydrostatic weighing. The mass and volume of the quartz float are equal to 8.832 g and 4.0271 cm^3, respectively. The overall relative measurement error for density is 0.1%.

The calculational equation for the viscosity of the aqueous solutions of hydrazine as a function of temperature at atmospheric pressure is obtained in the form of the following functional relation as a result of treatment of experimental data:

$$\frac{\eta}{\eta_1} = f\left(\frac{T}{T_1}\right), \tag{1}$$

where η is the viscosity of the aqueous solutions at the temperature T; η_1 is the viscosity of the investigated substances at the temperature T_1; $T_1 = 313$ K.

Relation (1) for the aqueous solutions of hydrazine is presented in Fig. 2, from which it is evident that the experimental data are fitted well by a curve. The equation for this curve can be written in the form

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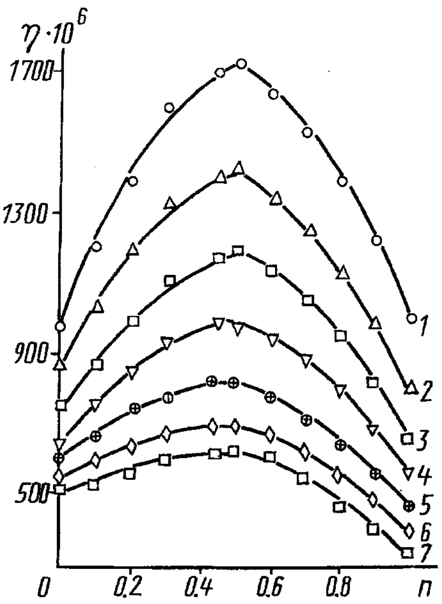
TABLE 1. Experimental Values of the Viscosity ($\eta \cdot 10^6$, Pa·sec) for Aqueous Solutions of Hydrazine as a Function of Temperature and Concentration

T, K	Hydrazine	10% N_2H_4+ 90% H_2O	20% N_2H_4+ 80% H_2O	30% N_2H_4+ 70% H_2O	40% N_2H_4+ 60% H_2O	55% N_2H_4+ 45% H_2O	60% N_2H_4+ 40% H_2O	70% N_2H_4+ 30% H_2O	80% N_2H_4 +20% H_2O	90% N_2H_4 +10% H_2O	Distilled water
293	970	1146	1403	1653	1673	1697	1670	1580	1450	1220	1020
303	850	1009	1181	1357	1364	1430	1410	1340	1210	1020	800
313	750	869	989	1138	1148	1190	1170	1100	980	830	650
333	650	659	732	808.9	814	840	830	770	685	570	470
353	510	522	570	600.4	608	625	620	590	550	480	350

TABLE 2. Experimental Values of the Density (ρ, kg/m^3) for Aqueous Solutions of Phenylhydrazine as a Function of Temperature and the Molar Concentration of Water

T, K	n, %									
	0	10	20	30	40	50	60	70	80	90
293	1091.2	1080	1069.4	1060.7	1057.3	1056.5	1046.2	1125.2	1009.3	999.6
303	1084.1	1074	1062.3	1054.9	1054.6	1062.3	1038.5	1018.3	1005.6	997.3
313	1078.8	1068	1056.2	1048.2	1045.9	1043.7	1031.8	1013.9	1001.2	994.7
323	1072.7	1061	1049.7	1040.5	1038.1	1035.2	1024.3	1010.5	998.3	992.1
333	1066.0	1054	1044.3	1034.6	1029.2	1026.4	1016.7	1006.7	993.4	988.7
343	1059.3	1048	1037.1	1027.9	1024.5	1019.3	1012.3	1001.4	988.9	984.3
353	1052.6	1041	1030.7	1020.3	1015.4	1010.3	1005.3	998.2	984.2	977.5



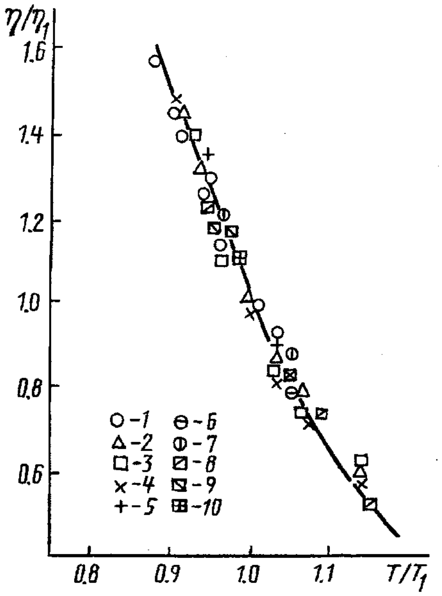


Fig. 1. Viscosity vs concentration for hydrazine-water systems: 1) 293; 2) 303; 3) 313; 4) 323; 5) 333; 6) 343; 7) 353 K. η, Pa·sec; n, %.

Fig. 2. Relative viscosity n/n_1 vs relative temperature T/T_1 for the solutions studied: 1) 100%N_2H_4; 2) 90%N_2H_4+10%H_2O; 3) 80%N_2H_4+20%H_2O; 4) 70%N_2H_4+30%H_2O; 5) 60%N_2H_4+40%H_2O; 6) 50 N_2H_4+ 50%H_2O; 7) 40%N_2H_4+60%H_2O; 8) 30%N_2H_4+70%H_2O; 9) 20%N_2H_4+ 80%H_2O; 10) 10%N_2H_4+90%H_2O.

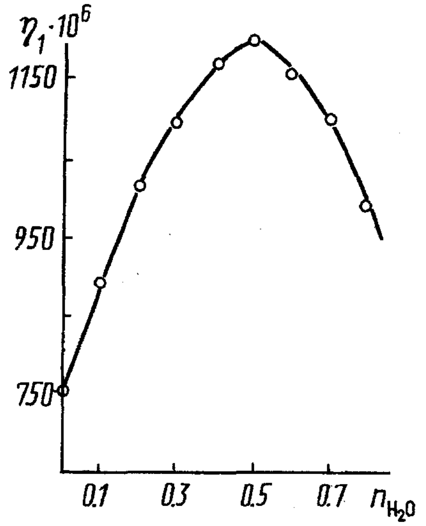


Fig. 3. Dependence of η_1 on the molar concentration of water n_{H_2O} (%).

$$\eta = \left[6.432 \left(\frac{T}{T_1} \right)^2 - 17.01 \left(\frac{T}{T_1} \right) + 11.59 \right] \eta_1 . \tag{2}$$

Using this equation, we can calculate the viscosity of the solutions of hydrazine if the values of η_1 are known.

An analysis of the value of η_1 for the solutions studied shows that the viscosity is a function of the molar concentration of water η_{H_2O} (Fig. 3). The curve in Fig. 3 is described by the equation

$$\eta_1 = 6.73 \cdot 10^{-4}\, n_{H_2O}^2 + 5.82 \cdot 10^{-4}\, n_{H_2O} + 8.39 \cdot 10^{-4}, \quad \mathrm{Pa \cdot sec} . \tag{3}$$

Equation (2), with account for Eq. (3), yields the following relation for calculating the viscosity of the aqueous solutions of hydrazine as a function of temperature at atmospheric pressure:

$$\eta = \left[6.423 \left(\frac{T}{T_1} \right)^2 - 17.01 \left(\frac{T}{T_1} \right) + 11.59 \right] \times$$
$$\times \left(6.73\, n_{H_2O}^2 + 5.82\, n_{H_2O} + 8.39\right) \cdot 10^{-4}, \quad \mathrm{Pa \cdot sec} . \tag{4}$$

Processing of experimental data on the density of the aqueous solutions of phenylhydrazine gave the following equation:

$$\rho = \left[1.209 - 0.211 \left(\frac{T}{T_1} \right) \right] \left(1085.6 - 3.095\, n_{H_2O} + 0.0715\, n_{H_2O}^2 - 6.111 \cdot 10^{-4}\, n_{H_2O}^3 \right) . \tag{5}$$

Knowing the values of the molar concentration of water, we can calculate from Eqs. (4) and (5) the temperature dependence of the viscosity and density for solutions of hydrazine and phenylhydrazine that were not studied experimentally. Verification of these equations showed that they describe the viscosity and density of the investigated aqueous solutions of hydrazine at atmospheric pressure in the temperature range from 293 to 353 K with an error of 2–3%.

REFERENCES

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