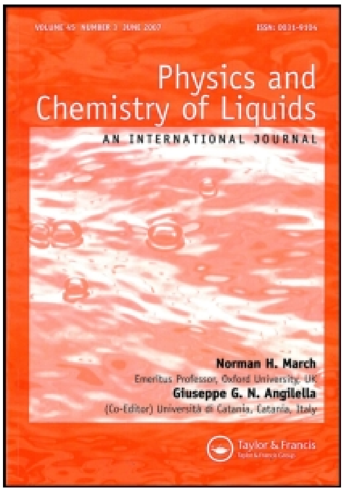

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DENSITIES AND VISCOSITIES OF $NiSO_4$-H_2SO_4-H_2O SYSTEM

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Densities and kinematic viscosity data for the ternary system $NiSO_4$-H_2SO_4-H_2O were determined over a wide range of concentrations (0.93 – 1.36 mols. dm^{-3}) and temperatures (20°C to 60°C). The results were fitted to polynomials.

KEY WORDS: Kinematic viscosity, density.

1. INTRODUCTION

For nickel extraction from a solution of nickel sulphate and sulphuric acid by electrolysis and in electroplating operations, it is important to know the density and viscosity of the solutions at different concentrations and temperatures. While measurements pertaining to other ternary systems $CuSO_4$-H_2SO_4-H_2O [1] and $ZnSO_4$-H_2SO_4-H_2O [2] have been recently reported, results for $NiSO_4$-H_2SO_4-H_2O system are not found in the literature. Therefore, the present study attempts to generate and correlate data for the present system simulating bath conditions for finding the transport and equilibrium properties which will help in designing electrolytic reactors.

2. EXPERIMENTAL

Densities and kinematic viscosities were measured for eleven solutions containing $NiSO_4$ and H_2SO_4 at three different temperatures, viz. 20, 40 and 60°C. The concentration of $NiSO_4$ was varied from 0.825 to 1.16 $mol \cdot kg^{-1}$ and H_2SO_4 from 0.0375 to 0.75 $mol \cdot kg^{-1}$ of nickel. Nickel sulphate and sulphuric acid (both analar-grade, purity ~99.5%) and double distilled water were used.

The densities of the solutions were measured using a 25 cm^3 specific gravity bottles calibrated with distilled water. The accuaracy of density measurements were within $\pm 0.1\%$. A throughly cleaned, dried and calibrated Ostwald viscometer (viscosity range 1 to 5 m^2s^{-1}) was used for viscosity measurements. The viscometer was kept in a glass container having arrangements for the circulatin of water from a thermostatic water bath. The temperature variation in the thermostatic bath was maintained within $(t \pm 0.01)$ K.

For measuring the density at different temperatures, the specific gravity bottle was kept for half an hour in the required temperature bath till the inner temperature was equilibriated with the bath temperature. An electronic balance was used for measuring mass to 10^{-3}g. For viscosity measurements the time of flow was measured after equilibriating the viscometer for about 30 min. in the constant temperature glass container. Care was taken to keep the viscometer limb vertical within 0.5° and limit the standard deviation for the time of flow within $\pm 0.1\%$. In the case of both density and viscosity, three independent sets of experiments were made and the average value was reported.

3. RESULTS AND DISCUSSION

Table 1 shows the experimental results for densities, and kinematic viscosities of the ternary $NiSO_4$-H_2SO_4-H_2O system.

3.1. Density

The results show that the variation of density depends on the concentration of $NiSO_4$ and H_2SO_4 at a particular temperature. The temperature dependence from 20 to 60°C is negligible. Similar observations are also previously reported for $ZnSO_4$-H_2SO_4-H_2O [2] and $CuSO_4$-H_2SO_4-H_2O [3] systems.

The density variation for $NiSO_4$-H_2SO_4-H_2O with concentration and temperature can be described by the following fitted polynomials, the coefficients K, L and M of which are shown in Table 2.

$$\rho(X, Y, t) = K + LX + MY - Nt. \tag{1}$$

Table 1 Densities (ρ) and Kinematic Viscosities (ν) of solutions in the system $NiSO_4$-H_2SO_4-H_2O.

X ($NiSO_4$) ($mol \cdot kg^{-1}$)	*Y* (H_2SO_4) ($mol \cdot kg^{-1}$)	Densities ($kg \cdot m^{-3}$) and viscosities ($m^2 \cdot S^{-1}$) 20°C		40°C		60°C	
		ρ	$\nu \times 10^6$	ρ	$\nu \times 10^6$	ρ	$\nu \times 10^6$
0.825	0.0375	1135	1.342	1133	0.803	1131	0.566
0.934	0.9750	1152	1.569	1151	0.947	1150	0.671
0.956	0.1510	1165	1.666	1163	0.989	1161	0.704
0.984	0.2252	1175	1.684	1172	1.010	1170	0.712
1.005	0.2627	1180	1.728	1178	1.032	1177	0.731
1.011	0.3002	1185	1.789	1183	1.060	1181	0.756
1.038	0.4128	1196	1.794	1193	1.072	1191	0.758
1.100	0.5630	1219	1.875	1215	1.119	1213	0.792
1.140	0.6005	1223	1.940	1218	1.159	1215	0.810
1.151	0.6756	1229	1.951	1225	1.165	1223	0.820
1.161	0.7507	1239	2.006	1236	1.204	1234	0.843

Table 2 Calculated polynomial coefficients.

Density	$K = 1000$	$M = 72$
	$L = 162$	$N = 0.1$
Viscosity	$A_0 = 75$	$A_3 = 139$
	$A_1 = 85$	$A_4 = -123$
	$A_2 = 137$	$A_5 = -32$
	$E_a = 17.53$ kj·mol $^{-1}$	

Table 3 Root mean square (RMS)* deviations at different temperatures.

	20°C	40°C	60°C
Density (ρ)	0.002	0.002	0.002
Kinematic viscosity (ν)	0.021	0.084	0.063

*rms deviation $= [d_i^2/n]^{1/2}$ where n is the number of observations and d = (experimental values-calculated values)/experimental values.

where,

ρ = density of mixture (kg·m^{-3})
X = Conc. of $NiSO_4$ (mol·kg^{-1} of water)
Y = Conc. of H_2SO_4 (mol·kg^{-1} of water)
t = temperature in °C

3.2. *Viscosity*

Table 1 shows that the variation in the concentration of components causes considerable change in the kinematic viscosity of the solution. Also with increase of temperature there is reduction of viscosity which is quite natural. An Arrhenius type of plot has been found to describe the viscosity dependence on temperature since $\ln \nu$ vrs $1/T$ is seen to be linear. Similar observations have been found to hold for $ZnSO_4$-H_2SO_4-H_2O system.

The experimental data on viscosity variation with concentration and temperature can be fitted to the following polynomials

$$\nu(X, Y, T) = 10^{-11}\,(A_0 + A_1X + A_2X + A_3X^2 + A_4XY + A_5Y^2)\,\mathrm{Exp}(E_a/RT) \quad (2)$$

where X and Y are molality (mol·kg^{-1} of H_2O) for $NiSO_4$ and H_2SO_4 respectively.

ν = Kinematic viscosity (m^2·S^{-1})
T = absolute temperature (degree Kelvin)
$A_0 - A_5$ = fitted coefficients
E_a = activation Energy (kj·mol^{-1})

The parameters included in Table 2 were used in Eqns. (1–2) to calculate the root mean square deviation as listed in Table 3.

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