

CHAPTER 3
RESULTS AND DISCUSSION

SECTION 3.1

EXPERIMENTAL PROCEDURE

Viscosities of pure liquids and their solutions were determined using a Modified Ostwald Glass Capillary Viscometer mentioned in section 2.1. The accuracy of obtaining the results are $\pm 5 \times 10^{-6} \text{ Nsm}^{-2}$. Densities of pure liquids and their solutions were measured using a Single Stem Pycnometer described in section 2.2 with an accuracy of $\pm 0.002\%$. The details of the experimental procedure is given in chapter 2. While doing the experiment the following precautions must be taken

(1) Solutions of desired concentrations were prepared by weighing the sample in a bottle. Before doing the experiment the bottles are cleaned thoroughly with Chromic Acid, dried with Acetone and Air.

(2) For each solution seven to ten readings are taken and the average flowtimes are calculated to minimize the errors obtained in measuring flow times.

(3) After filling the liquid into the viscometer, the viscometer is kept in a temperature controlled bath for more than half an hour to achieve equilibrium temperature.

(4) Temperature of the experimental liquid was measured using a Thermistor as a temperature sensor, which is placed in

one arm of a Wheatstone bridge. Thermistor is highly sensitive, therefore very small changes occurring in temperature controlled bath can be detected.

(5) While doing the experiment fixed volume of the liquid is taken every time.

(6) Viscometer is completely immersed in the temperature bath upto the marks 'P' and 'Q' shown in fig. 2.1.3

The symbols used in the tables that follow in this chapter, are explained in Table 3.1.1.

TABLE 3.1.1

Symbol	Parameter	Units
η	Viscosity	10^{-3} Nsm^{-2}
ρ	Density	10^3 kg m^{-3}
t	Flow time	seconds
B	Viscometer Constant	-----
η^E	Excess Viscosity	10^{-3} Nsm^{-2}
X_1	Mole fraction of solvent	mole
X_2	Mole fraction of solute	mole

SECTION 3.2

RESULTS - DENSITY, VISCOSITY AND EXCESS VISCOSITY

Densities and viscosities are experimentally determined and excess viscosities are calculated for two systems at temperature 30°C. The experimental procedure for the determination of Density and Viscosity are given in section 2.2 and 2.1 respectively. Densities are determined using single stem pycnometer. By using the density data viscosity are determined by measuring flow times with the Microprocessor Based Viscometer using the relation.¹

$$\eta = \rho B t \text{ -----} > (1)$$

Where ρ is the density of the mixture

B is the viscometric constant and

t is the flow time

The calculated value of the viscometric constant is 0.0128789 at a temperature 30°C. From the measured viscosity data the excess viscosity is determined using the expression.²

$$\eta^E = \eta - \eta_1 X_1 - \eta_2 X_2 \text{ -----} > (2)$$

Where η is the viscosity of the mixture

η_1 is the viscosity of the solvent

X_1 is the mole fraction of the solvent

η_2 is the viscosity of the solute and

X_2 is the mole fraction of the solute

In the present study viscosities and densities of the systems Benzene + Nitrobenzene, Toluene + Chlorobenzene are experimentally measured and excess viscosities are calculated. All these values are tabulated in Table 3.2.1 and Table 3.2.2 for the systems Benzene + Nitrobenzene and Toluene + Chlorobenzene respectively. Mole fraction verses viscosity graphs are shown in fig. 3.2.1 and fig. 3.2.2 and mole fraction verses excess viscosity graphs are shown in fig. 3.2.3. and fig. 3.2.4. for the systems studied in the present work.

TABLE 3.2.1

SYSTEM : BENZENE + NITROBENZENE

S.No	Concentration of Solute (mole)	Density (10^3 kg m^{-3})	Viscosity (10^{-3} Nsm^{-2})	Excess Viscosity (10^{-3} Nsm^{-2})
Benzene	0.0000	0.86895	0.5647	0.000
1	0.0731	0.89560	0.6097	-0.033±0.005
2	0.1982	0.94533	0.6992	-0.077±0.005
3	0.2981	0.98260	0.7876	-0.096±0.005
4	0.3993	1.01499	0.8688	-0.123±0.005
5	0.4995	1.04851	0.9431	-0.155±0.005
6	0.5996	1.07989	1.0467	-0.159±0.005
7	0.6954	1.10393	1.1860	-0.122±0.005
8	0.8017	1.14117	1.3271	-0.095±0.005
9	0.8952	1.16700	1.4690	-0.052±0.005
Nitro-benzene	1.0000	1.19459	1.8334	0.000

TABLE 3.2.2

SYSTEM : TOLUENE + CHLOROBENZENE

S.No	Concentration of Solute (mole)	Density (10^3 kg m^{-3})	Viscosity (10^{-3} Nsm^{-2})	Excess Viscosity (10^{-3} Nsm^{-2})
Toluene	0.0000	0.85790	0.5357	0.000
1	0.1129	0.88450	0.5743	0.018±0.005
2	0.2051	0.90640	0.5914	0.018±0.005
3	0.3080	0.93010	0.6149	0.220±0.005
4	0.4697	0.97710	0.6369	0.017±0.005
5	0.6098	1.00190	0.6632	0.016±0.005
6	0.7059	1.02430	0.6772	0.012±0.005
7	0.8373	1.05640	0.6961	0.007±0.005
8	0.9030	1.07250	0.7045	0.004±0.005
chloro-benzene	1.0000	1.09510	0.7188	0.000

SECTION 3.3

DISCUSSION

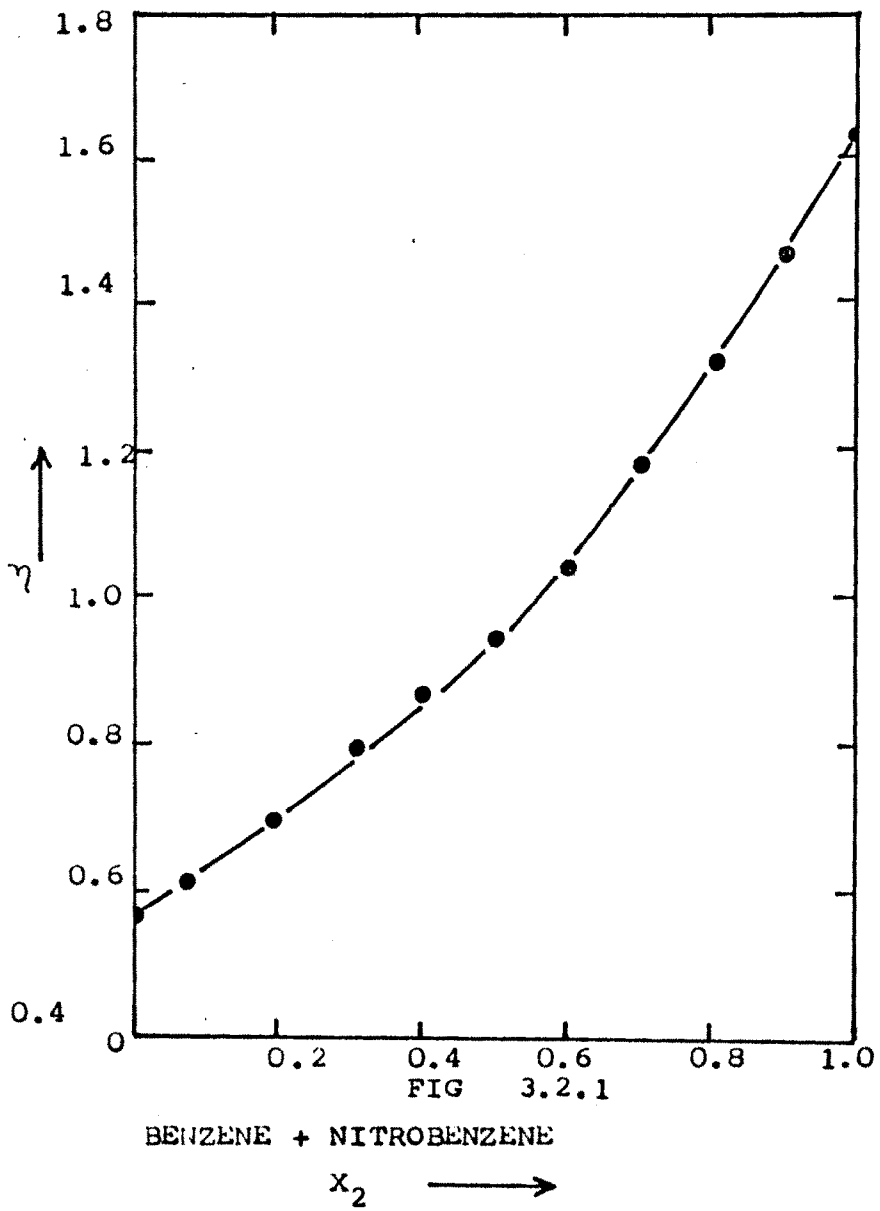
3.3.1 MOLE FRACTION - VISCOSITY GRAPHS

Mole fraction verses viscosity graphs are shown in fig. 3.2.2 and fig. 3.2.1, for the systems Toluene + Chlorobenzene and Benzene + Nitrobenzene respectively. The graphs obtained are slightly non-linear. The trend of variation of η indicates that there is some amount of interaction between molecules. Otherwise it would have been a straight line. The results of Nigam and Singh³ are also shown in the graph for comparison. Our results almost agree with in experimental error with their results. This further confirms that the newly designed instrument can be used satisfactorily for the viscosity measurement of solutions and mixtures.

3.3.2 MOLE FRACTION - EXCESS VISCOSITY GRAPH

The graphs drawn between mole fraction and excess viscosity of the systems Benzene + Nitrobenzene and Toluene + Chlorobenzene are shown in fig. 3.2.3 & fig. 3.2.4 respectively. For Benzene + Nitrobenzene mixture excess viscosities obtained are in negative directions, where as positive deviations occur for the mixture Toluene + Chlorobenzene.

Fig. 3.2.3 shows η^E to be negative and larger in



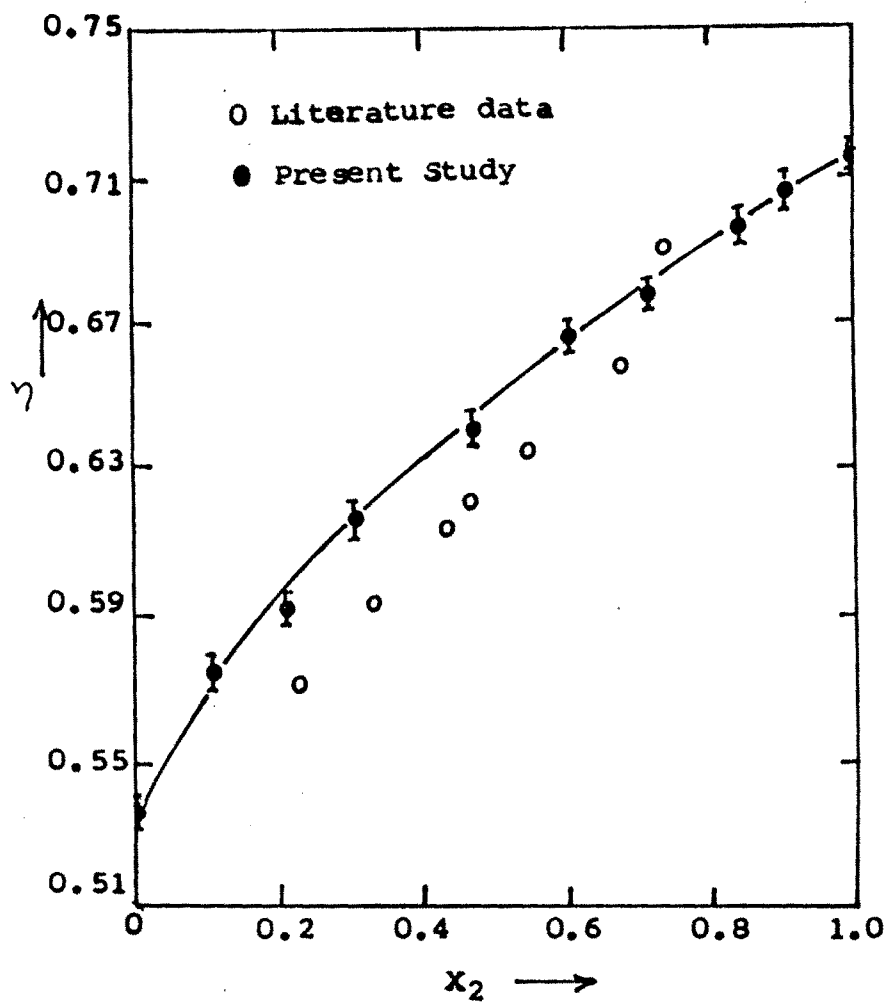


FIG3.2.2.

TOLUENE+CHLOROBENZENE

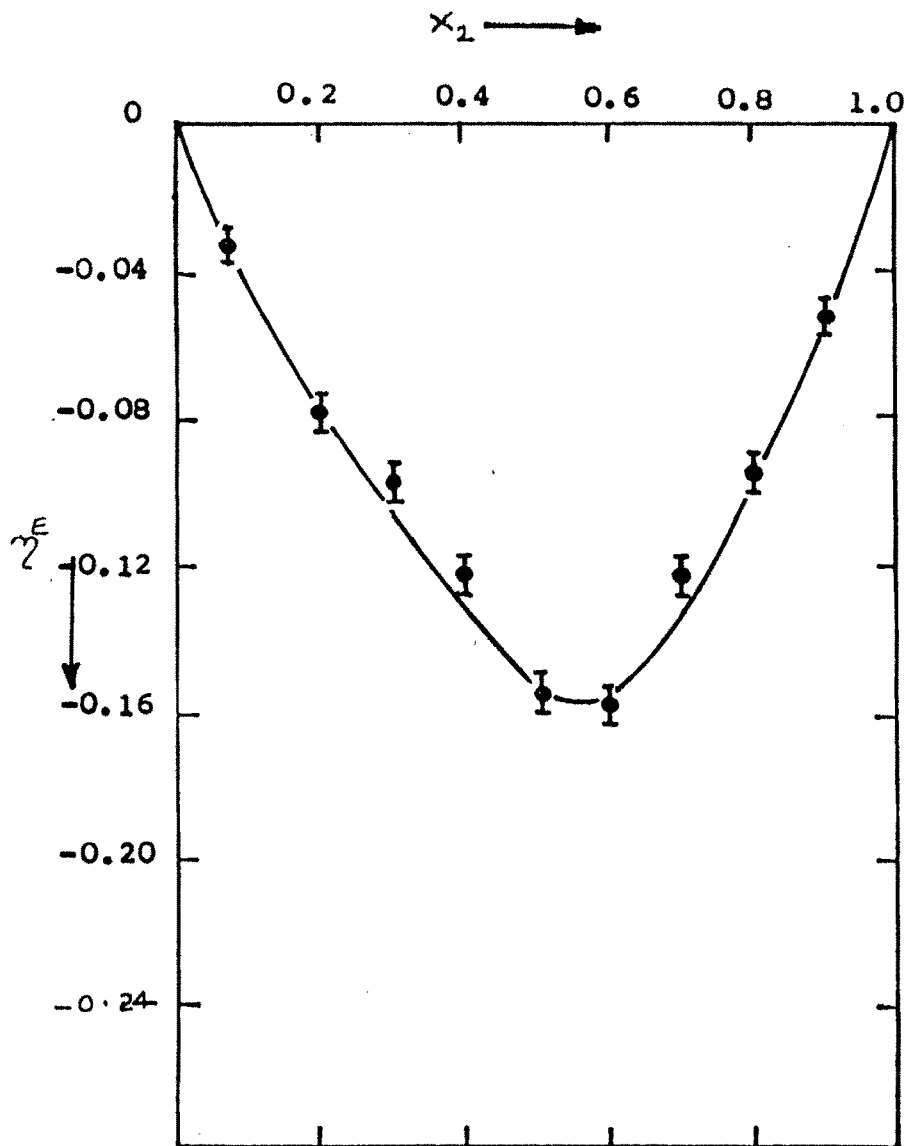


Fig. 3.2.3

BENZENE + NITROBENZENE

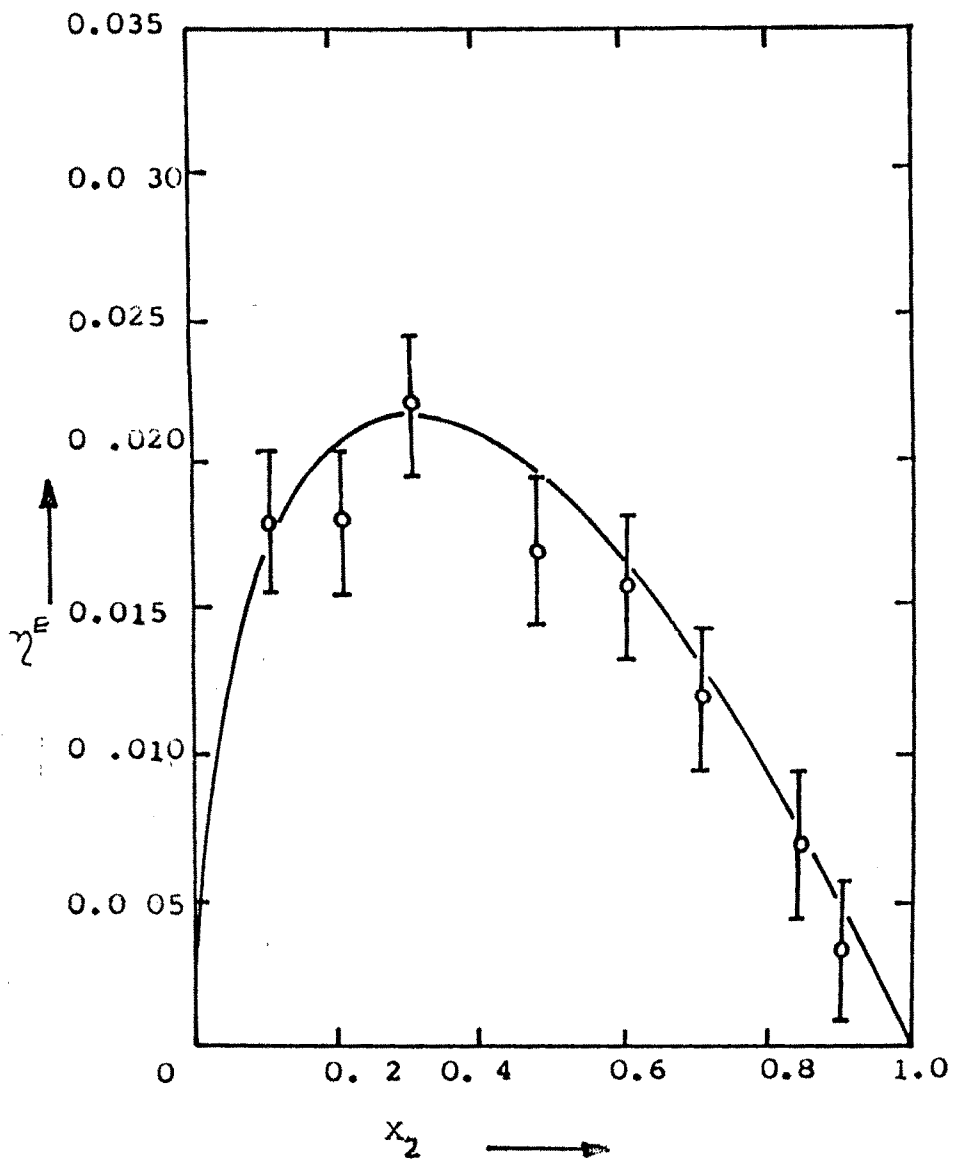


FIG3.2.4

TOLUENE + CHLOROBENZENE

magnitude for the system Benzene + Nitrobenzene. The negative deviations indicate that dispersion forces are primarily responsible for interaction^{2,4,5} but they may also occur when the components are known to interact more strongly.⁴ Benzene is a non-polar liquid and Nitrobenzene is a strong polar liquid. The negative and larger values of η^E may be due to strong solute - solute dipolar interactions in addition to the other solute - solvent and solvent - solvent interactions.

Positive deviations from rectilinear dependence on mole fraction and maxima in excess viscosity^{2,4,5} may occur if strong specific interaction causes complex formation. In the case of Toluene + Chlorobenzene system the excess viscosities are positive and very small in magnitude. This indicates that some specific interaction resulting in some type of complex formation is present in this system. The studies of Fort and Moore also confirm this.