# STUDIES IN THE DIELECTRIC CONSTANTS OF FATTY ACIDS*

## Part III. The Applicability of Jatkar's Equation to Concentrated Solutions of Esters of Fatty Acids

By R. S. Phadke

*(Department of General Chemistry, Indian Institute of Science, Bangalore)*

It is now generally accepted that the Debye-Clausius-Mosotti[1] equation for determining the dipole moment of polar substances is satisfactory, only when applied to vapours at low pressures and to dilute solutions of polar substances in non-polar solvents. The equation is not applicable to pure polar liquids or their concentrated solutions. Jatkar[2] in 1943 introduced the following equation and claimed that it was applicable to solids, liquids, gases and to concentrated solutions. The equation is

$$\frac{(\epsilon - n^2)\,M}{d} = \frac{4\pi N\mu^2}{3kT}\left(\frac{j+1}{j}\right),$$

where $j = \infty$ for gases and $\frac{1}{2}$ for solids and liquids.

The experimental errors in the determination of dipole moments, from a study of concentrated solutions and of pure polar liquids, are very much less than those which occur in the case of vapours at low pressures and of dilute solutions. The present author has, therefore, attempted to study the applicability of Jatkar's equation to concentrated solutions of polar liquids. Investigations relating to the dipole moments of ethyl ricinoleate and ethyl ricinelaidiate in solutions of various concentrations in the following solvents: benzene, petrol, carbon tetrachloride and dioxane are presented in this paper.

### Experimental

The experimental technique was the same as described in earlier investigations.[3, 4]

The benzene, dioxane and carbon tetrachloride employed as solvents, were purified by standard methods as described by Weissberger and Prosskauer.[5] Aviation petrol was fractionated and the fraction distilling over the range 70–80° C. was collected and further purified by the technique employed for benzene. The purity of the solvents was checked by determining density, boiling point and dielectric constant. The physical constants agreed closely with the standard values.

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To measure densities, a specific gravity bottle fitted with a thermometer was employed.

Refractive indices were determined with an Abbe refractometer, provided with an efficient thermostatic control.

*Calculation of Dipole Moment*.—The dipole moment was calculated on the basis of Jatkar's[2] equation†

$$P_0 = \frac{(\epsilon - n^2) \times M}{d} = \frac{4\pi N\mu^2}{kT} = P_2 - P_E$$

$P_2$, the molecular polarisation of the solute was calculated by the weight fraction method.

$P_E$, the electronic polarisation of the solute was calculated by Jatkar's[2] formula:

$$P_E = (n^2 - 1) \times \frac{M}{d}.$$

Values at 25° C. of refractive index and of density of the pure substance were employed. It was assumed that $P_E$ remained constant over the temperature range 25°–40° C.

## RESULTS

The results obtained are presented in Tables I to IX.

TABLE I. *Dipole Moment of Ethyl Ricinoleate in Benzene*

$P_E = 407 \cdot 9$ c.c.

| $W_2$ (Ethyl ricinoleate) | $\epsilon_{1\cdot 2}$ | $d_{1\cdot 2}$ | $P_2$ | $\mu \times 10^{-18}$ (Jatkar) | |
|---|---|---|---|---|---|
| *Solvent: Benzene at 25° C.* | | | | | |
| 0·00000 | 2·273 | 0·8740 | .. | .. | |
| 0·09807 | 2·430 | 0·8750 | 1066·1 | 1·88 | $\mu_{av.} = 1 \cdot 91$ |
| 0·1379 | 2·500 | 0·8770 | 1075·1 | 1·89 | |
| 0·4076 | 2·958 | 0·8870 | 1075·4 | 1·89 | |
| 0·6374 | 3·492 | 0·8982 | 1148·8 | 1·99 | |
| 1·0000 | 4·075 | 0·9090 | 1102·8 | 1·93 | |
| *Solvent: Benzene at 40° C.* | | | | | |
| 0·00000 | 2·243 | 0·8590 | .. | .. | |
| 0·90807 | 2·400 | 0·8615 | 1043·5 | 1·89 | $\mu_{av.} = 1 \cdot 93$ |
| 0·1379 | 2·472 | 0·8642 | 1077·4 | 1·94 | |
| 0·4076 | 2·882 | 0·8750 | 1034·7 | 1·87 | |
| 0·6374 | 3·420 | 0·8835 | 1132·5 | 2·02 | |
| 1·0000 | 3·950 | 0·8990 | 1069·7 | 1·93 | |

† The symbols used have the usual meaning.[3]

TABLE II. *Dipole Moment of Ethyl Ricinoleate in Petrol*

| $W_2$ (Ethyl ricinoleate) | $\epsilon_{1\cdot 2}$ | $d_{1\cdot 2}$ | $P_2$ | $\mu \times 10^{-18}$ (Jatkar) | |
|---|---|---|---|---|---|
| | | *Solvent: Petrol at 25° C.* | | | |
| 0·0000 | 1·915 | 0·7006 | .. | .. | |
| 0·1001 | 2·210 | 0·7206 | 1215·4 | 2·08 | |
| 0·2100 | 2·320 | 0·7395 | 1169·4 | 2·02 | |
| 0·3000 | 2·450 | 0·7532 | 1099·4 | 1·93 | $\mu_{av.}$ = 2·03 |
| 0·3811 | 2·705 | 0·7760 | 1187·9 | 2·05 | |
| 0·5217 | 3·030 | 0·7984 | 1198·6 | 2·06 | |
| 1·0000 | 4·075 | 0·9090 | 1102·8 | 1·93 | |
| | | *Solvent: Petrol at 40° C.* | | | |
| 0·0000 | 1·885 | 0·6850 | .. | .. | |
| 0·1001 | 2·180 | 0·7060 | 1235·9 | 2·16 | |
| 0·2100 | 2·260 | 0·7260 | 1109·7 | 1·99 | |
| 0·3000 | 2·436 | 0·7404 | 1124·7 | 2·01 | $\mu_{av.}$ = 2·09 |
| 0·3811 | 2·685 | 0·7640 | 1202·6 | 2·12 | |
| 0·5217 | 2·981 | 0·7876 | 1259·0 | 2·20 | |
| 1·0000 | 3·950 | 0·8990 | 1069·7 | 1·93 | |

TABLE III. *Dipole Moment of Ethyl Ricinoleate in Carbon Tetrachloride*

| $W_2$ (Ethyl ricinoleate) | $\epsilon_{1\cdot 2}$ | $d_{1\cdot 2}$ | $P_2$ | $\mu \times 10^{-18}$ (Jatkar) | |
|---|---|---|---|---|---|
| | | *Solvent: Carbon tetrachloride at 25° C.* | | | |
| 0·0000 | 2·228 | 1·5850 | .. | .. | |
| 0·0995 | 2·555 | 1·4800 | 1156·6 | 2·00 | |
| 0·1595 | 2·695 | 1·4160 | 1151·6 | 1·95 | |
| 0·2833 | 3·040 | 1·3080 | 1155·7 | 2·00 | $\mu_{av.}$ = 2·01 |
| 0·3493 | 3·252 | 1·2560 | 1202·8 | 2·06 | |
| 0·5605 | 3·700 | 1·1180 | 1206·5 | 2·07 | |
| 1·0000 | 4·075 | 0·9090 | 1102·8 | 1·93 | |
| | | *Solvent: Carbon tetrachloride at 40° C.* | | | |
| 0·0000 | 2·198 | 1·5565 | .. | .. | |
| 0·0995 | 2·520 | 1·4600 | 1140·2 | 2·03 | |
| 0·1595 | 2·665 | 1·3980 | 1112·1 | 1·99 | |
| 0·2833 | 2·980 | 1·2920 | 1128·7 | 2·02 | $\mu_{av.}$ = 2·05 |
| 0·3493 | 3·222 | 1·2380 | 1207·7 | 2·12 | |
| 0·5605 | 3·617 | 1·1060 | 1179·5 | 2·08 | |
| 1·0000 | 3·950 | 0·8990 | 1069·7 | 1·93 | |

TABLE IV. *Dipole Moment of Ethyl Ricinoleate in Dioxane*

| $W_2$ (Ethyl ricinoleate) | $\epsilon_{1\cdot 2}$ | $d_{1\cdot 2}$ | $P_2$ | $\mu \times 10^{-18}$ (Jatkar) | |
|---|---|---|---|---|---|
| | | *Solvent: Dioxane at 25° C.* | | | |
| 0·0000 | 2·236 | 1·0277 | .. | .. | |
| 0·1115 | 2·475 | 1·0145 | 1123·0 | 1·96 | $\mu_{av.}$ = 1·97 |
| 0·2069 | 2·655 | 1·0040 | 1094·3 | 1·92 | |
| 0·3432 | 2·902 | 0·9854 | 1083·1 | 1·90 | |
| 0·5827 | 3·486 | 0·9581 | 1170·8 | 2·02 | |
| 0·7347 | 3·814 | 0·9408 | 1185·6 | 2·04 | |
| 1·0000 | 4·075 | 0·9090 | 1102·8 | 1·93 | |
| | | *Solvent: Dioxane at 40° C.* | | | |
| 0·0000 | 2·206 | 1·0127 | .. | .. | |
| 0·1115 | 2·460 | 1·0017 | 1167·7 | 2·07 | $\mu_{av.}$ = 1·99 |
| 0·2069 | 2·600 | 0·9925 | 1051·9 | 1·91 | |
| 0·3432 | 2·830 | 0·9744 | 1040·9 | 1·90 | |
| 0·5827 | 3·414 | 0·9476 | 1147·0 | 2·04 | |
| 0·7347 | 3·702 | 0·9405 | 1135·5 | 2·02 | |
| 1·0000 | 3·950 | 0·8990 | 1069·7 | 1·93 | |

TABLE V. *Dipole Moment of Ethyl Ricinelaidiate in Benzene*

$P_E$ = 406·1 c.c.

| $W_2$ (Ethyl ricinelaidiate) | $\epsilon_{1\cdot 2}$ | $d_{1\cdot 2}$ | $P_2$ | $\mu \times 10^{-18}$ (Jatkar) | |
|---|---|---|---|---|---|
| | | *Solvent: Benzene at 25° C.* | | | |
| 0·0000 | 2·273 | 0·8740 | .. | .. | |
| 0·1512 | 2·542 | 0·8800 | 1112·6 | 1·95 | $\mu_{av.}$ = 2·03 |
| 0·3007 | 2·820 | 0·8824 | 1131·9 | 1·97 | |
| 0·4707 | 3·195 | 0·8890 | 1176·2 | 2·03 | |
| 0·5841 | 3·500 | 0·8936 | 1223·5 | 2·09 | |
| 0·7203 | 3·845 | 0·8988 | 1248·2 | 2·12 | |
| 1·0000 | 4·560 | 0·9110 | 1273·9 | 2·15 | |
| | | *Solvent: Benzene at 40° C.* | | | |
| 0·0000 | 2·243 | 0·8590 | .. | .. | |
| 0·1512 | 2·496 | 0·8650 | 1080·7 | 1·95 | $\mu_{av.}$ = 2·03 |
| 0·3007 | 2·770 | 0·8704 | 1107·4 | 1·99 | |
| 0·4707 | 3·150 | 0·8760 | 1169·4 | 2·07 | |
| 0·5841 | 3·380 | 0·8812 | 1121·8 | 2·01 | |
| 0·7203 | 3·770 | 0·8848 | 1233·9 | 2·15 | |
| 1·0000 | 4·400 | 0·9020 | 1228·8 | 2·15 | |

TABLE VI. *Dipole Moment of Ethyl Ricinelaidiate in Petrol*

| $W_2$ (Ethyl ricine-laidiate) | $\epsilon_{1\cdot2}$ | $d_{1\cdot2}$ | $P_2$ | $\mu\times10^{-18}$ (Jatkar) | |
|---|---|---|---|---|---|
| | | *Solvent: Petrol at 25° C.* | | | |
| 0·0000 | 1·915 | 0·7006 | .. | .. | |
| 0·1602 | 2·190 | 0·7294 | 1088·2 | 1·91 | $\mu_{av.}$ = 1·96 |
| 0·3962 | 2·625 | 0·7720 | 1083·0 | 1·90 | |
| 0·5298 | 2·930 | 0·8000 | 1106·8 | 1·94 | |
| 0·5907 | 3·150 | 0·8140 | 1162·8 | 2·01 | |
| 0·7305 | 3·530 | 0·8460 | 1177·5 | 2·03 | |
| 1·0000 | 4·560 | 0·9110 | 1273·9 | 2·15 | |
| | | *Solvent: Petrol at 40° C.* | | | |
| 0·0000 | 1·885 | 0·6850 | .. | .. | |
| 0·1602 | 2·155 | 0·7144 | 1082·0 | 1·95 | $\mu_{av.}$ = 1·99 |
| 0·3962 | 2·595 | 0·7600 | 1107·6 | 1·99 | |
| 0·5298 | 2·880 | 0·7880 | 1094·4 | 1·97 | |
| 0·5907 | 3·080 | 0·8020 | 1139·4 | 2·03 | |
| 0·7305 | 3·460 | 0·8360 | 1158·0 | 2·00 | |
| 1·0000 | 4·400 | 0·9020 | 1228·8 | 2·15 | |

TABLE VII. *Dipole Moment of Ethyl Ricinelaidiate in Carbon Tetrachloride*

| $W_2$ (Ethyl ricine-laidiate) | $\epsilon_{1\cdot2}$ | $d_{1\cdot2}$ | $P_2$ | $\mu\times10^{-18}$ (Jatkar) | |
|---|---|---|---|---|---|
| | | *Solvent: Carbon Tetrachloride at 25° C.* | | | |
| 0·0000 | 2·228 | 1·5850 | .. | .. | |
| 0·1012 | 2·550 | 1·4849 | 1119·2 | 1·95 | $\mu_{av.}$ = 1·94 |
| 0·2200 | 2·800 | 1·3400 | 1095·0 | 1·92 | |
| 0·4297 | 3·295 | 1·2130 | 1100·3 | 1·93 | |
| 0·6384 | 3·695 | 1·0885 | 1121·1 | 1·96 | |
| 0·7833 | 3·925 | 1·0150 | 1129·6 | 1·97 | |
| 1·0000 | 4·560 | 0·9110 | 1273·9 | 2·15 | |
| | | *Solvent: Carbon Tetrachloride at 40° C.* | | | |
| 0·0000 | 2·198 | 1·5565 | .. | .. | |
| 0·1012 | 2·505 | 1·4700 | 1070·0 | 1·93 | $\mu_{av.}$ = 1·92 |
| 0·2200 | 2·710 | 1·3240 | 1024·0 | 1·87 | |
| 0·4297 | 3·210 | 1·1950 | 1070·0 | 1·93 | |
| 0·6384 | 3·585 | 1·0750 | 1086·0 | 1·91 | |
| 0·7833 | 3·800 | 1·0015 | 1094·1 | 1·97 | |
| 1·0000 | 4·400 | 0·9020 | 1228·8 | 2·15 | |

TABLE VIII. *Dipole Moment of Ethyl Ricinelaidiate in Dioxane*

| $W_2$ (Ethyl ricine-laidiate) | $\epsilon_{1\cdot 2}$ | $d_{1\cdot 2}$ | $P_2$ | $\mu \times 10^{-18}$ (Jatkar) | |
|---|---|---|---|---|---|
| *Solvent: Dioxane at 25° C.* | | | | | |
| 0·0000 | 2·236 | 1·0277 | .. | .. | |
| 0·1003 | 2·460 | 1·0105 | 1178·9 | 2·04 | |
| 0·2363 | 2·720 | 0·9979 | 1110·7 | 1·94 | |
| 0·3600 | 2·980 | 0·9817 | 1129·2 | 1·97 | $\mu_{av.}$ = 2·02 |
| 0·6246 | 3·640 | 0·9529 | 1210·4 | 2·08 | |
| 0·7070 | 3·820 | 0·9439 | 1215·0 | 2·09 | |
| 1·0000 | 4·560 | 0·9110 | 1273·9 | 2·15 | |
| *Solvent: Dioxane at 40° C.* | | | | | |
| 0·0000 | 2·206 | 1·0127 | .. | .. | |
| 0·1003 | 2·420 | 0·9960 | 1151·1 | 2·05 | |
| 0·2363 | 2·674 | 0·9856 | 1088·5 | 1·96 | |
| 0·3600 | 2·920 | 0·9679 | 1106·1 | 1·99 | $\mu_{av.}$ = 2·04 |
| 0·6246 | 3·525 | 0·9409 | 1167·4 | 2·07 | |
| 0·7070 | 3·680 | 0·9322 | 1164·8 | 2·07 | |
| 1·0000 | 4·400 | 0·9020 | 1228·8 | 2·15 | |

TABLE IX. *Dipole Moments of Ethyl Ricinoleate and Ethyl Ricinelaidiate in Various Solvents*

| t° C. | Solvent | Ethyl Ricinoleate $\mu_{av.}$ | Ethyl Ricinelaidiate $\mu_{av.}$ |
|---|---|---|---|
| 25 | (Pure Liquid) .. .. | 1·93 | 2·15 |
| 40 | (Pure Liquid) .. .. | 1·93 | 2·15 |
| 25 | Benzene .. .. .. | 1·91 | 2·03 |
| 40 | Benzene .. .. .. | 1·93 | 2·03 |
| 25 | Petrol .. .. .. | 2·03 | 1·96 |
| 40 | Petrol .. .. .. | 2·09 | 1·99 |
| 25 | Carbon tetrachloride .. | 2·01 | 1·94 |
| 40 | Carbon tetrachloride .. | 2·05 | 1·92 |
| 25 | Dioxane .. .. .. | 1·97 | 2·02 |
| 40 | Dioxane .. .. .. | 1·99 | 2·04 |

## DISCUSSION

Tables I to VIII give the dipole moments of the two esters in different solvents. In Table IX, the values recorded for ($\mu_{av.}$) are averages of those obtained for various concentrations in the same solvent. It will be noticed that the moments are unaffected by temperature. With different concentrations, maximum deviation from the average value of the dipole moment is not more than 6 per cent. This shows that Jatkar's equation gives consistent values of dipole moments when applied to pure liquids and their concentrated solutions.

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