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ANALYSIS OF DIELECTRIC PROPERTIES OF SOME POLAR AND NON- POLAR LIQUIDS

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Abstract

The study of dielectric behavior of polar, non polar liquids and their binary mixtures at various temperatures is very interesting. In this article the values of dielectric constant of polar, non polar & their binary mixtures has been experimentally determined and study their properties at various temperatures 288k, 298k, 308k & 318 K. In this experiment the dielectric constant of the mixture of carbon tetra chloride - ethyl acetate and carbon tetra chloride – dimethyl ether was calculated at different temperatures in different concentrations. The results are discussed in the light of intermolecular interactions occurring in the binary mixture.

Key words

Dielectric constant; polar and non-polar substances; mole fraction; volume fraction

Introduction

The dielectric study of polar and nonpolar liquids gives important information about molecular structures, molecular interactions between components of solutions, dynamics and kinetics of the solution. The dielectric constant of a solvent is a relative measure of its polarity. Dielectric characterization has great potential in studying the H-bond interactions (Hill et al., 1969).

Dielectrics are the electrical insulating materials in which all the electrons are tightly bound to the atoms or molecules so that there are no free electrons to carry current. There are two types of dielectric substances such as polar and non-polar. The substances in which all the positive charges are assumed to be concentrated at a single point which is known as centre of gravity of the positive charges. Similarly, the points at which all negative charges are concentrated at a point is known as center of gravity of negative charges. Thus, if the center of gravity of positive and negative charges consider at a point i.e. ; the atoms or molecules do not have any permanent dipole moment but possess only electronic & ionic conduction. These substances are known as non-polar dielectric substances. H_2, O_2, N_2, CO_2, CH_4 etc. are non-polar dielectrics. The polarization depends upon the frequency of applied electric field. In absence of external electric field, the dipole moments of such molecules of substances are always zero. On the other hand, if the centre of gravity of positive and negative charges of a system does not consider at a point and these substances are known as polar dielectric. In the absence of external electric field, the certain molecules of these substances possess permanent dipolemoment. NH_3, Nacl, H_2O, NO_2, $Fecl_3$ etc. are polar dielectrics. However, such molecules, when placed in an external electric field, then dipoles experience torque due to the electric field and they try to align along the field direction. Due to this we get net dipole moment in any volume of the material i.e, polarization takes place due to change in orientations of permanent dipoles (Acharya, 1993 & Tarveer, 1975).

There has been several attempts to investigate the nature and behavior of dielectric molecules. The different between properties of polar and non-polar dielectrics can be illustrated by considering the temperature dependence of dielectric constant. Since the variation of dielectric constant with temperature is different for polar and non-polar dielectrics, the determination of dielectric constant could be used as a means of analyzing the presence of polar & non-polar in their mixtures (Kamble et al., 2012).

Very few attempts have been made to study carbon tetrachloride and ethyl acetate binary mixture. Ethyl acetate is used as a volatile law toxicity solvent in paints, nail polish remover etc and carbon tetrachloride is also used as cleaning solvent, refrigerant etc. because of such wide applications of the ethyl acetate and carbon tetrachloride, it will be intresting to study dielectric and other properties of their binary liquid mixtures (Kamble, et al., 2011).

Theory

The dielectric polarization can be calculated from the Clausius- Mossotti equation. However, this equation which is based on the Lorentz “local field" does not lead to correct dipole moment of polar molecules in non-polar solvent. The Clasius-Mossotti relation for non-polar dielectrics is given by

$$\frac{\epsilon-1}{\epsilon+2} \quad \frac{M}{\rho} \quad = \frac{4\pi}{3}\alpha \text{ N}$$

Where,

Є=dielectric constant

M = molar weight

N = Avogardro's number

α = polarizibility

ρ = density

However, for polar molecules the polarization as calculated from Clausius – Mossotti equation is disagreement with the polarization calculated according to Debye theory using the dipole moment of the molecules. Debye modified the Clausius – Mossotti relation for polar molecules by replacing induced polarizability (α) Which is equal to the sum of deformational polarizability (α_o) and polarizability due to dipole polarization (α_d). (Onsager, 1954)

i.e ; $\alpha = \alpha_O + \alpha_d$

Where, $\alpha_d = \frac{p2}{3KT}$

Here, P=dipole moment

K=Boltzmann constant

T=absolute temperature

Hence, Debye modified the Clausius-Mossotti equation as

$$\left(\frac{\epsilon-1}{\epsilon+2}\right)\frac{M}{\rho} = \frac{4\pi}{3}N\left(\alpha_o + \frac{p2}{3KT}\right)$$

From this equation it is clear that the polarization of dielectric $\left(\frac{\epsilon-1}{\epsilon+2}\right)\frac{M}{P}$, for polar dielectric depends inversely upon the temperature.

Again, Onsager pointed out that the essential difficulty of the Clausius – Mossotti equation is in the choice of the inner or local field due to Lorentz. The derivation of Lorentz local field is an artificial procedure and for polar liquids does not lead to agreement with experimental result. Onsager determined the local field on a molecule in liquid by regarding the molecule as a real cavity imbedded in a medium with a homogeneous dielectric constant right up to the surface of the molecule. Onsager relation to compute dielectric Constant for strongly polarized liquids (Jatkar & Iyengar, 1949) is given by

$$\frac{(\epsilon-n^2)(2\epsilon+n^2)}{\epsilon(n^2+2)^2}\frac{M}{\rho} = \frac{4\pi}{9}\frac{Np^2}{KT}$$

Where n^2 = high Frequency dielectric constant.

Theory of mixture

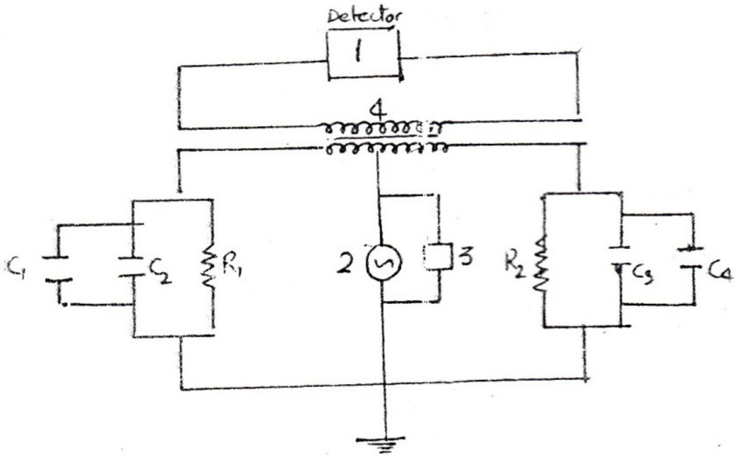
ϵ_1 and ϵ_2 be the dielectric constant of two non reacting dielectric forming a homogenous mixture, then dielectric constant of binary mixture (ϵ_m) with the volume fraction V_1 & V_2 (Gawali, 1993) is given by

(i) Beer model

$(\epsilon_m)^{½} = V_1 \epsilon_1^{½} + V_2 \epsilon_2^{½}$

(ii) Landau and Lifshitz model

$(\epsilon_m)^{1/3} = V_1 \epsilon_1^{1/3} + V_2 \epsilon_3^{1/3}$



In the above figure 1, represents oscilloscope, 2 frequency generator, 3 Frequency counter, 4 Transformer, C_1& C_2 are fixed condensers, R_1 & R_2 are fixed resistors, C_3 is variable cell capacitor and C_4 is variable balance capacitor. The technique involves the measurement of capacitance with and without liquid in the cell capacitor. The two arms of this bridge are balanced by changing the capacitance of variable Capacitor (Mahat & Mishra, 1994).

$$\text{Dielectric constant} = \frac{\text{Change in Capacitance in liquid}}{\text{Change in capacitance in air}}$$

The dielectric cell provides a considerable amount of space for including the liquids and temperature of liquid can also be altered.

Table 1: The estimated dielectric constant of the different substances is shown in the table

Liquid	Dielectric constant	Temperature
Benzene	2.23	297 k
Diethyl ether	4.72	296 k
Carbon tetrachloride	2.12	298 k
Methyl acetate	1.54	299 k
Ethyl acetate	6.02	293 k

For the dielectric constant of binary mixture, the solutions are prepared to different volume fraction. These volume fractions are converted in to mole fraction for further Calculations. There can take place two process, a disassociation of liquids and combination between two liquids of non- reacting missible organic liquids (Grazzotti, 1999).

Table 2:

The calculated dielectric constant of the mixture of carbon tetrachloride and dimethyl ether at 210 k is given in the table below.

Mole Fraction (X)	Dielectric constant of mixture
0.00	4.32
0.20	3.48
0.40	3.02
0.60	2.62
0.80	2.28
1.0	2.08

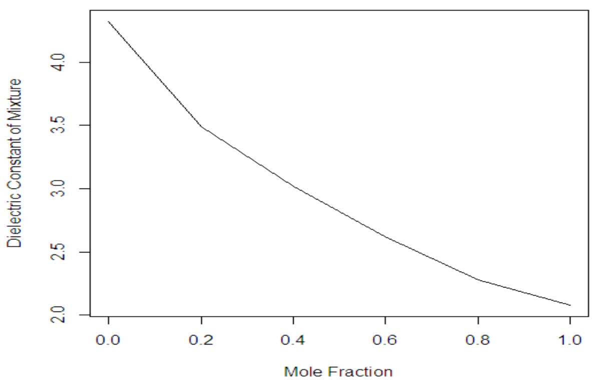


Figure 1

Table 3:

The calculated dielectric constant of carbon tetrachloride and ethyl acetate binary mixture at different temperatures are given below

Mole Fraction (X)	**Temperatures**			
	288k	298k	308k	318k
0.00	2.22	1.99	2.05	2.16
0.08	3.14	2.52	2.52	2.67
0.25	4.22	3.98	3.75	3.50
0.44	5.70	5.01	5.02	4.92
0.65	6.21	5.52	5.31	5.45
0.88	6.30	6.31	5.75	5.73
1.00	6.52	6.40	6.05	5.89

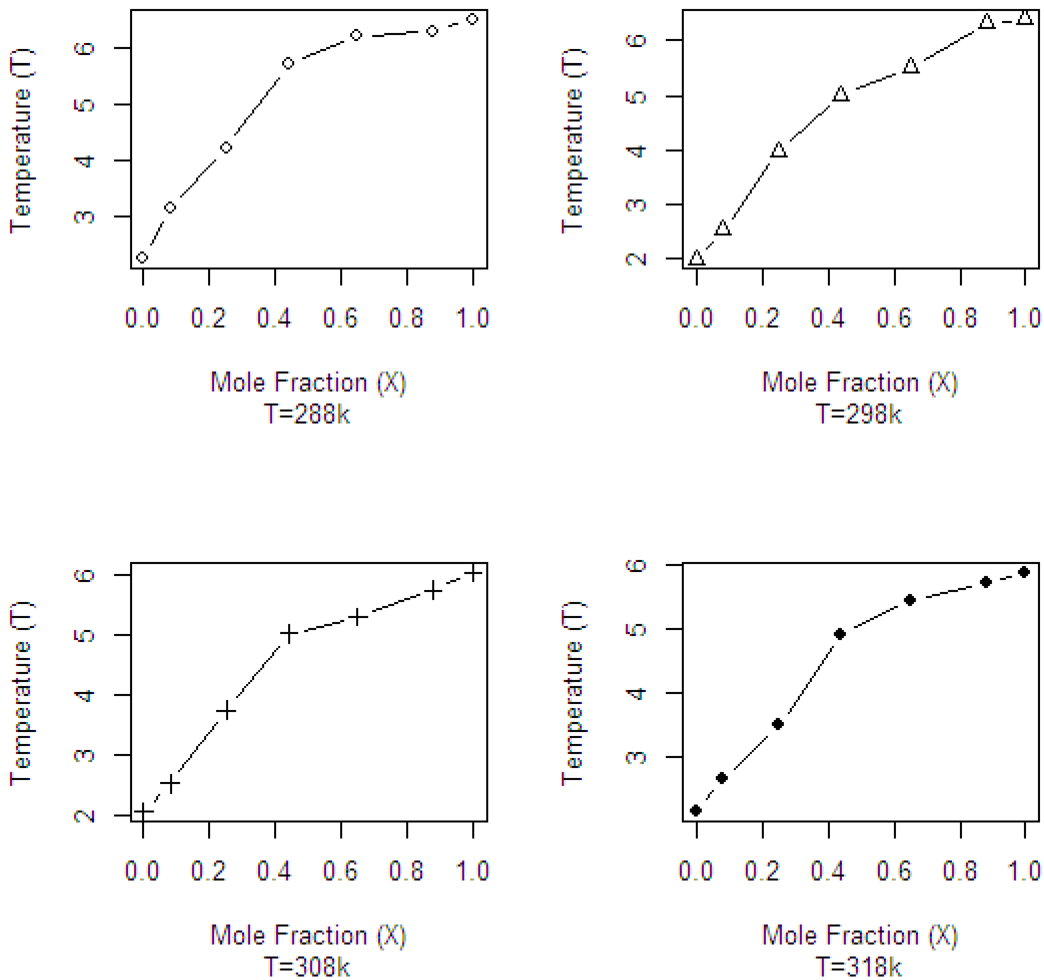


Fig. 2 Dielectric constant of carbon tetrachloride and ethyl acetate binary mixture at different temperature

Results & Discussion

The values of dielectric constant of some substance are tabulated in table -1. From this it is observed that the dielectric constant of methyl – acetate decreases slightly with increase in temperature due to the variation of density with temperature. But dielectric constant of other substances shows strong temperature dependence. Thus the temperature dependence of dielectric constant show that benzene, carbon tetrachloride, ethyl acetate & methyl acetate are non- polar liquid while diethyl ether and dimethyl ether is polar liquid.

Similarly, the values of dielectric constant of the mixture of carbon tetrachloride and dimethyl either at 210 k are shown in figure 1. Which shows that the dielectric constant decreases with increases in mole fraction when two non-reacting missible organic liquids are mixed together? Again, from figure 2, it is observed that the dielectric constant of the mixture of carbon tetrachloride and ethyl acetate increases with increases in mole fraction but decreases with increases in temperature. Thus in binary liquid mixtures there is a possibility of interactions between the constituents such as hydrogen bonding, molecular associations, dipole-dipole and dipole-induced dipole interactions (Fajans, 1941).

Conclusion

The dielectric constant of polar & non-polar liquids and their mixture shows that the dielectric constant depends upon the temperature due to variation of density with temperature. Thus, the temperature dependence of dielectric constant shows that carbon-tetrachloride and ethyl acetate are non polar liquids while dimethyl ether is polar liquid. Similarly, the dielectric parameter of binary mixture of carbon tetrachloride and ethyl acetate shows systematic change with concentration and temperature. From the dielectric study of carbon tetrachloride with ethyl acetate we get some structured informations which will be helpful in industrial and medical application. The values of excess dielectric constant can also be evaluated from mole fraction mixture which also explains intermolecular interactions.

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