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A study of suggested Formula (ADJ) of Specific Refraction

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Abstract

The measurement of refractive index and optical activity of organic liquids is of great importance in chemistry. These measurements provide invaluable information regarding the molecular structure, purity of organic compounds and the composition of binary mixtures. Early years there are so many formulae found out by the various scientists. Amongst Lorentz and Lorenz formula is very familiar for the calculation of specific refraction of the organic compounds. It is worthwhile to suggest one more empirical formula for the calculation of specific refraction of organic compounds. This formula is known as Andher Desai Joshi (ADJ)'s formula. The suggested formula compared with that of Lorentz and Lorenz formula. From the comparison it is remarkable fact that the suggested formula holds good to the extent of ±0.02 marginal differences.

Keywords: Density, refractive index, specific refraction, Andher, Desai, Joshi (ADJ), Lorentz and Lorenz.

Introduction

The measurement of refractive index and optical activity of organic liquids is of great importance in chemistry. These measurements provide invaluable information regarding the molecular structure, purity of organic compounds and the composition of binary mixtures[1-2]. Often, it is used to determine the concentration of solutions.

The velocity of light depends upon the medium through which it travels. The ratio of velocities of light in vacuum and medium in any substance is called the absolute refractive index of that substance. For all solids and liquids this definition is replaced by the more practical (and nearly equivalent) one.

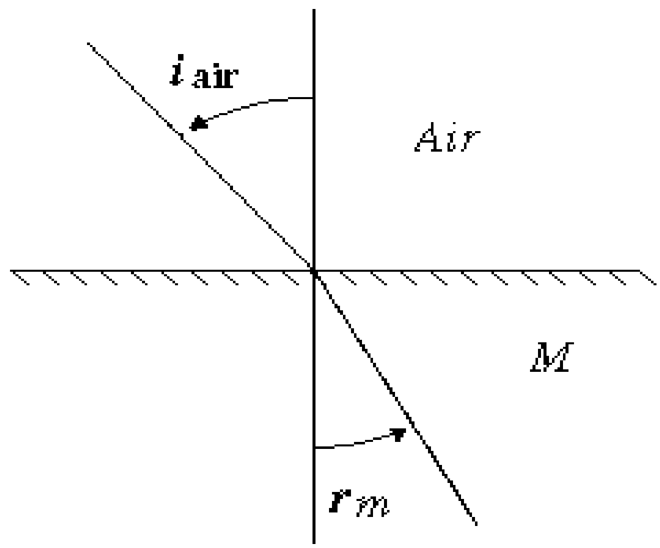
$$n_\lambda^t = \frac{\gamma_{air}}{\gamma_m} \qquad (1)$$

Where, n_λ^t is the refractive index of the medium through which light travels with velocity γ_m, the superscript indicates the temperature and the subscript the wave-length of the light. γ_{air} is the velocity of the light in the air.

It is possible to show the refractive index as also given by

$$n = \frac{\sin i_{air}}{\sin r_m} \qquad (2)$$

Where i_{air} is the angle of incidence of the light which can be measured by drawn the boundary perpendicular between air and medium *'M'* and r_m is the angle of refraction in medium *M*, also measured from the normal. These relationships are shown in the following figure. Equation (ii) is Snell's law of refraction.



(Refraction of a ray of light on passing from air into medium M)
In short, the bending of a ray of light on passing from one medium to another is called refraction.

The refractive index of organic liquids is quite sensitive to temperature, an increase of temperature at 1°C results in a decrease in n of 0.0004 - 0.0005.

Since, even the most routine measurements of refractive index provide a reproducibility of about 0.0002. Evidently temperature control is essential for accurate measurements. Also the wave-length of the light used in measuring the refractive index is another important factor. Nearly all tabulated refractive indices for liquids refer to wave-length of 589.3 nm.

In recent years the molar refraction has acquired an important significance, which will be considered more fully later. In the mean time reference may be made to the additive and constitutive nature of this property. In 1858, J. H. Gladstone and T. P. Dale[3] found empirically that the quantity $\frac{n-1}{d}$, where n is the refractive index and d is the density of the liquid was almost independent of temperature for light of a definite wave-length. Galdstone and Dale considered that the refractivity $\frac{n-1}{d}$ of a mixture is additively composed from those of its components according to the volumes of these in the mixture. The product of this quantity and the molecular weight is called the molar refraction and this proved to be a property which was partly additive and constitutive. The deduction of a theoretical relationship between refractive index n and density d should be constant at all temperatures. Viz,

$$\frac{n^2-1}{n^2+2} \cdot \frac{1}{d} = constant(R) \quad (3)$$

Where 'R' is the specific refraction was made independently by Lorentz and Lorenz, from the electromagnetic and wave theories of light, respectively. This has rendered obsolete the empirical equation of Gladstone and Dale. The molar refraction of a compound is now defined by the expression,

$$R_M = \frac{n^2-1}{n^2+2} \cdot \frac{M}{d} \quad (4)$$

The molar refraction is equal to the specific refraction. An extensive discussion will be found in N. Bauer and K. Fajans and Lewin in physical methods of organic chemistry.[4]
Later on, the empirical Eykman equation

$$\frac{n^2-1}{n+0.4} \cdot \frac{1}{d} = C \quad (5)$$

offers an accurate means not only for checking the accuracy of experimental densities and refractive indices but also for calculating one from the other. In the above equation *n* is the refractive index and d is the density. Eykman stated that the constant *'c'* is independent of temperature[5].

In spite of its empirical nature Eykman's equation is to be preferred to the more familiar Lorentz and Lorenz[6] expression

$$\frac{n^2-1}{n^2+2} \cdot \frac{1}{d} = R \quad (6)$$

even though the latter has a theoretical basis.

$$R = \frac{1}{0.09}\left[\frac{3n-2.85}{n2+73} \cdot \frac{1}{d} + 0.004\right] \quad (7)$$ [7]

$$\frac{Sin(0.5n-0.4567)}{d} = R \quad (8)$$ [8]

As seen above the various formulae were used for the calculation of specific refraction. It is worthwhile to suggest one more empirical formula to determine the specific refraction. This formula may be known as Andher Desai and Joshi's formula.

Methodology

Derivation of suggested formula (ADJ) It is seen form all the formulae of calculating specific refraction from refractive index 'n' and density 'd', it is found that refractive index 'n' is always found in numerator and 'd' in denominator. So the most simple formula should very likely be n/d, but it is not so simple and therefore, some factors be incorporated in the above simple formula and therefore the universal formula should be,

$$R = \frac{1}{b}\left[\frac{xn-y}{d} + c\right] \quad (9)$$

In the above formula the numerical values of b, c, x and y should be evaluated and they are as follows,
From the above equation we consider

$$\frac{xn-y}{d} = p \quad (10)$$

So equation no.9 is written as under

$$R = \frac{1}{b}[p+c] \quad (11)$$

$$\therefore Rb = p + c \quad (12)$$

To find out the value of specific refraction of organic compounds, CRC Handbook[9] is used. According to Lorenz and Lorentz equation, it is observed that the mean values of specific refraction R, Refractive index n density d in CRC Handbook should be as follows,
R=0.27212, n= 1.4699, d=1.0251

Substituting the above values in equation no. 10 should be

$$\frac{x(1.4699)-y}{1.0251} = p \quad (13)$$

Consider different values of x and y and determine the values of P, after all the values of R (0.2721028) and different values of P are added in equation no. 11
Moreover we have considered the different values of constant b and also concluded different values of c.

From the above modification at the time fixed the values of x=3, y=2.47, b=9 then the values of p= 1.8922 was proved according to our evaluation. x, y and b constant's total value of amount we have obtained the constants C i.e. 0.557.

By comparing our formula with Lorenz and Lorentz formula we have found out that the proposed formula holds good to the extent of 96.00%.

It is observed that the suggested formula is in good agreement within the limit of ±0.0199 marginal differences with Lorenz and Lorentz formula, so the formula can be written as under.

$$R = \frac{1}{9}\left[\frac{3n - 2.47}{d} + 0.557\right] \quad (14)$$

This is known as "ADJ" formula of specific refraction is nearly equal to the Lorenz and Lorentz formula.

The suggested formula applied for the all organic data which are selected from the CRC Handbook[9], are calculated by using Lorentz and Lorenz and suggested formula (ADJ) of specific refraction. The data obtained by a little difference confirming that the applicability of the suggested formula (ADJ) is comparable to those of Lorentz and Lorenz formula.

Table-1
Indicated the difference between the Lorentz and Lorenz (R1) and Suggested formula (ADJ) (R2) as under by the different ranges as follows

Table and their range		
Tables	**Range**	**Values**
Table-1	±0.0000	8
Table-2	±0.0001 to ±0.0004	85
Table-3	±0.0005 to ±0.0010	137
Table-4	±0.0011 to ±0.0050	931
Table-5	±0.0051 to ±0.0100	1239
Table-6	±0.0101 to ±0.0200	1636
Table-7	> ±0.0201	183
Total		**4219**

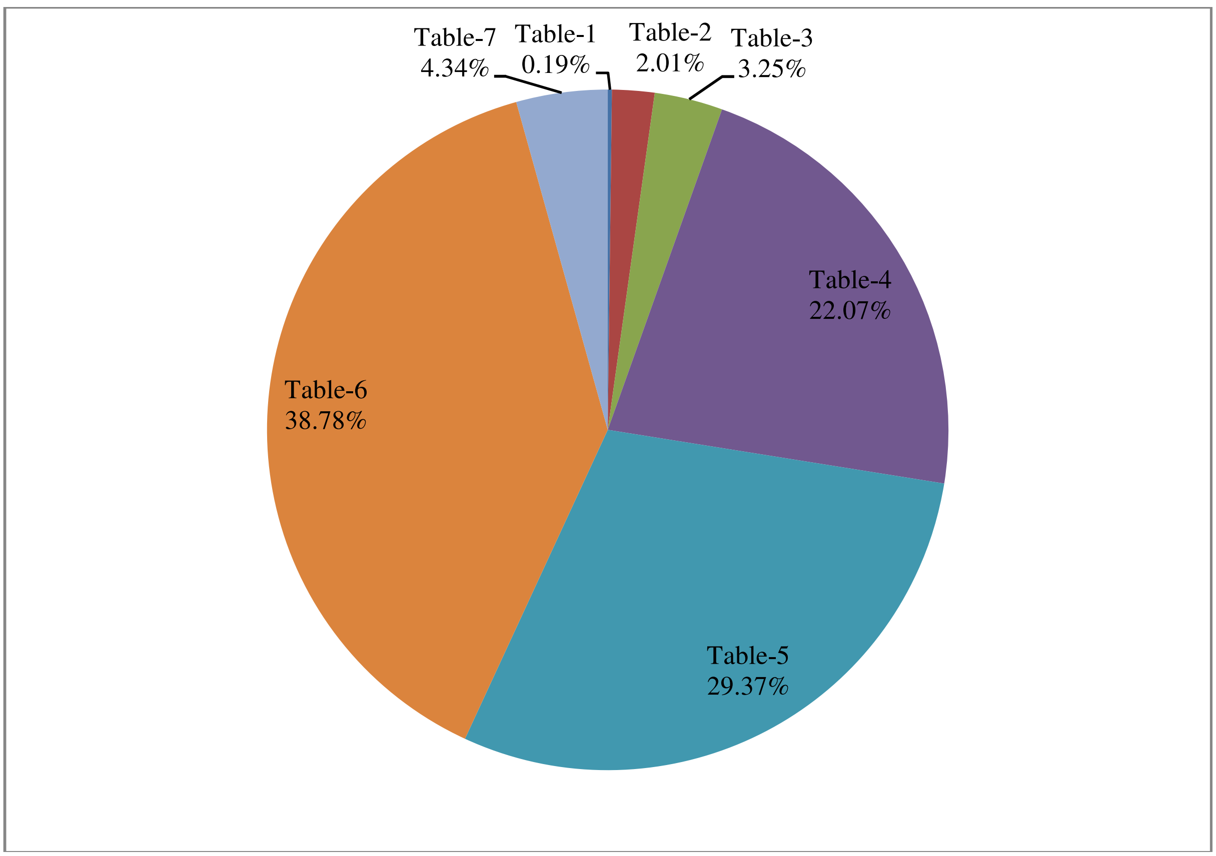


Figure-2
Showing values of all seven tables

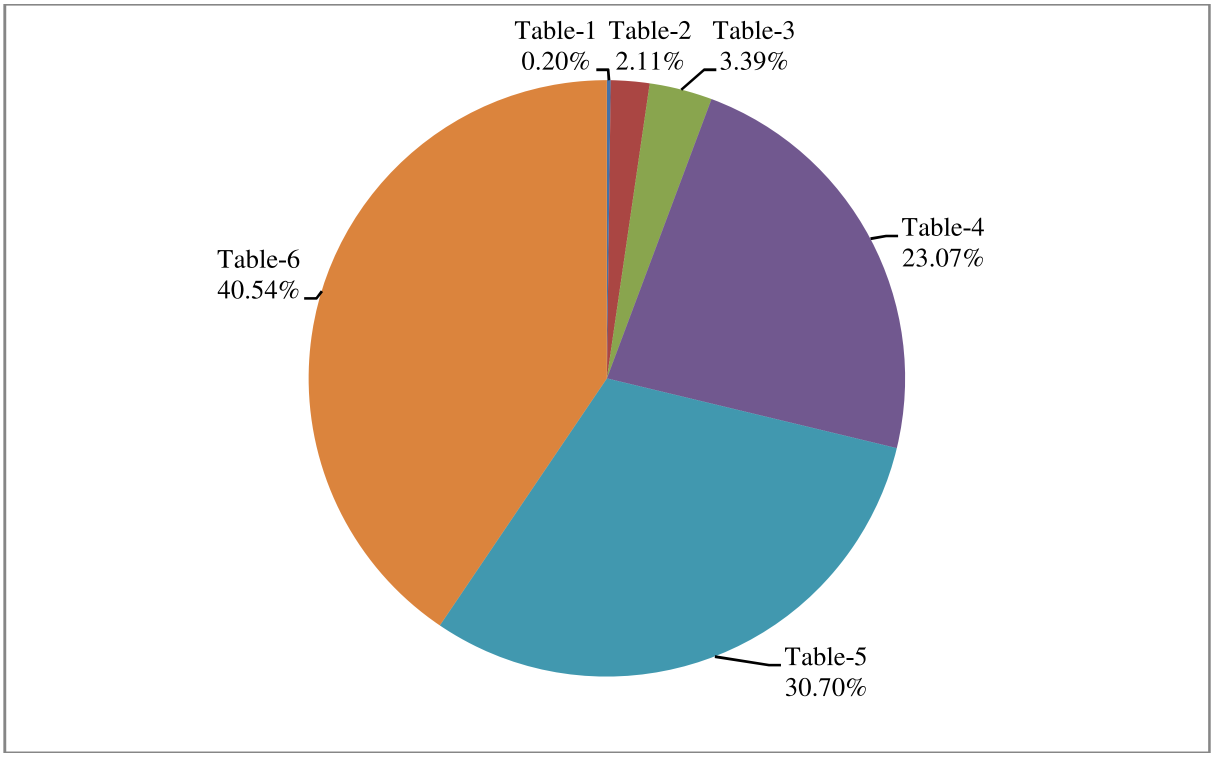


Figure-3
Showing successful values

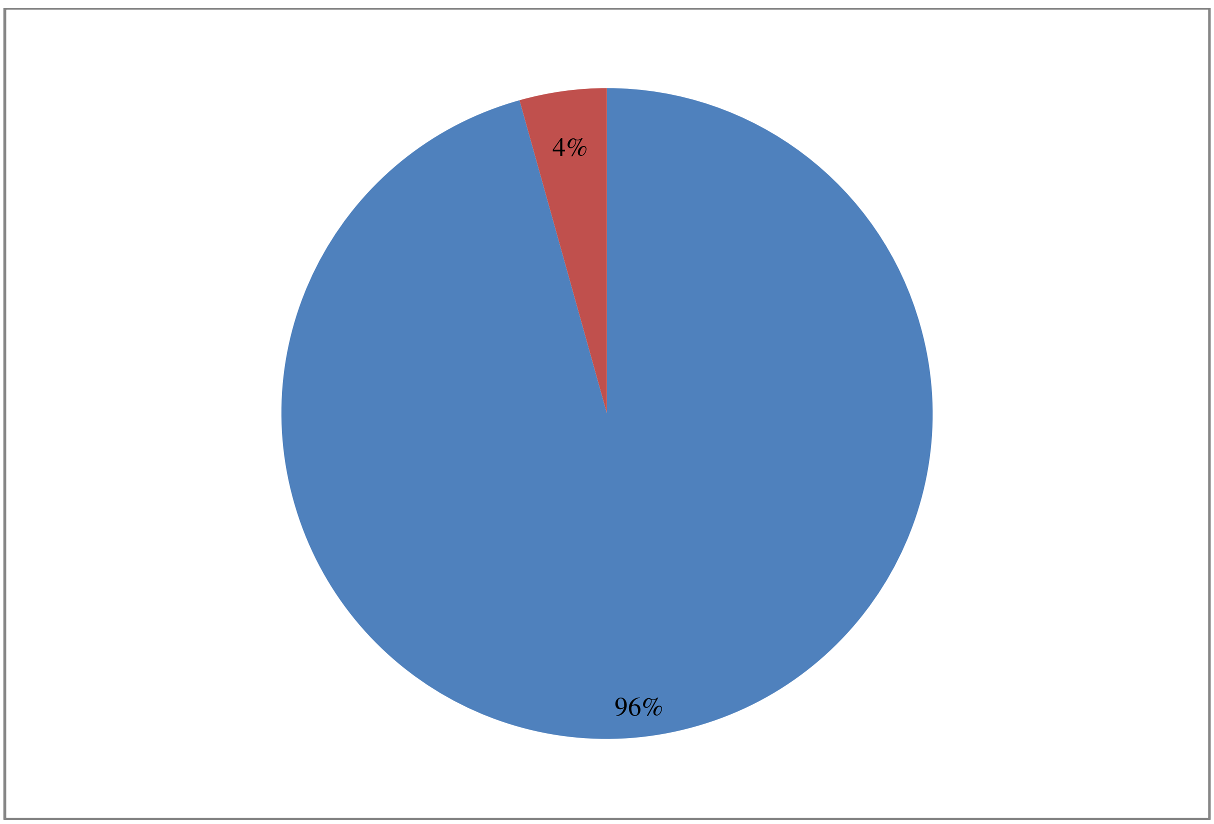


Figure-4
Showing comparision of obeying and not obeying values

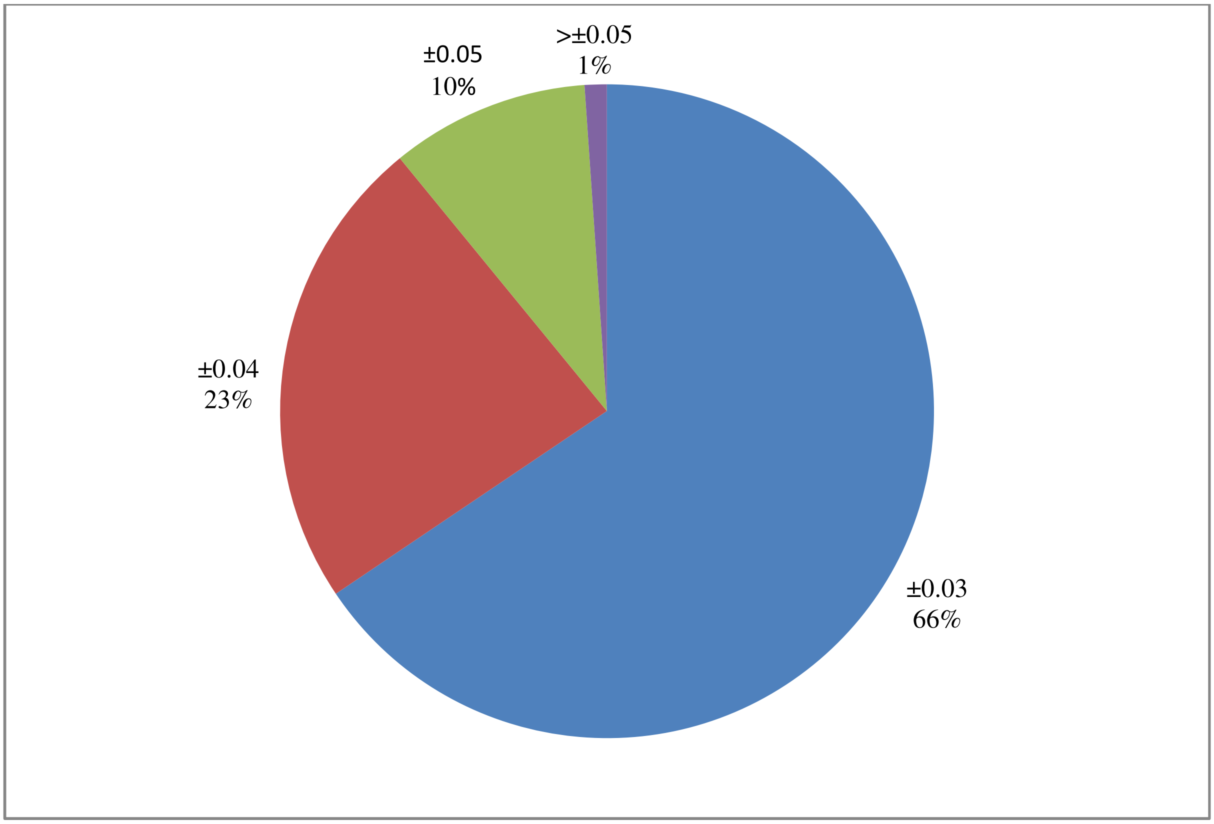


Figure-5
Showing comparision of not obeying values

Table-2
Comparison of theoretical and practical specific refraction for Lorentz and Lorenz and Suggested formula (ADJ)

Name of liquid	Theoretical				Practical			
	Density d	R.I. n	Specific Refraction(R) LandL	ADJ	Density d	R.I.	Specific Refraction(R) LandL	ADJ
Acetone	0.7920	1.3588	0.2788	0.2870	0.7910	1.369	0.2870	0.2918
Toluene	0.8660	1.4978	0.3384	0.3214	0.8511	1.497	0.3438	0.3257
Xylene	0.8745	1.5077	0.3407	0.3227	0.8598	1.506	0.3473	0.3265
Methanol	0.7960	1.3311	0.2571	0.2745	0.7780	1.335	0.2652	0.2811
Ethanol	0.7891	1.3624	0.2813	0.2896	0.8066	1.360	0.2770	0.2836
Propanol	0.8024	1.3854	0.2916	0.2953	0.7950	1.380	0.2946	0.2952
Chloroform	1.4984	1.4464	0.1781	0.2004	1.4992	1.448	0.1786	0.2007
Carbon tetrachloride	1.5950	1.4640	0.1730	0.1957	1.5978	1.442	0.1734	0.1909
Cyclohexane	0.7784	1.4266	0.3295	0.3202	0.7768	1.430	0.3369	0.3222
Cyclohexanone	0.9478	1.4508	0.2840	0.2825	0.9427	1.455	0.2889	0.2852
Cyclohexanol	0.9624	1.4641	0.2868	0.2838	0.9590	1.471	0.2915	0.2870

Table-3
Comparison of specific refraction by theoretical and practical difference between Lorentz and Lorenz and Suggested Formula (ADJ)

Name of liquids	Difference between Theoretical values of R (Theo. Land L-ADJ)	Difference between Practical values of R (Prac.Land L-ADJ)	Difference between Theoretical values and practical values of R	
			Theo.L and L-Prac.L andL	Theo.ADJ-Prac.ADJ
Acetone	0.0090	0.0048	0.0082	0.0048
Toluene	0.0171	0.0181	0.0054	0.0043
Xylene	0.0182	0.0208	0.0066	0.0038
Methanol	0.0171	0.0159	0.0081	0.0066
Ethanol	0.0080	0.0066	0.0043	0.0006
Propanol	0.0037	0.0006	0.0030	0.0001
Chloroform	0.0223	0.0221	0.0005	0.0003
Carbon tetrachloride	0.0221	0.0175	0.0004	0.0048
Cyclohexane	0.0093	0.0147	0.0074	0.0020
Cyclohexanone	0.0015	0.0037	0.0049	0.0027
Cyclohexanol	0.0030	0.0045	0.0047	0.0002

Results and Discussion

Organic substances having refractive index n and density d have been selected from the CRC Handbook, are calculated by using Lorentz and Lorenz and suggested formula(ADJ) of specific refraction. It can be observed that the results obtained by a minor diffrence shows the wide applicability of the suggested formula(ADJ) is comparable with Lorentz and Lorenz formula.The obtained values are in the various range shown in Scheme-1.whereas the same values observed in the percentage wise in figure 2.The marginal diffrences ±0.02 of the organic substances indicated in figure 3.Comparison of the percentage values shown in figure 4.Moreover the variation of > ±0.0201 indicated the chloro, iodo and flouro (halogenated group) and mercury group contains organic compounds[9] not obeying due to having higher density 'd' and refractive index 'n' reported in figure 5 Table-2 shows the comparison values from the CRC Handbook by theoretically and practically basis of the specific refraction and the Table-3 indicated the difference of the specific refraction between the Lorentz and Lorenz Formula and suggested Formula (ADJ).

Conclusion

From the above experimental basis the suggested formula (ADJ) holds good to the extent of little marginal differences.

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