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Section A: Chemical Sciences



Research Article

Ultrasonic velocity studies of solutions of some organic compounds at 298.15 K

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ABSTRACT

The density, viscosity and sound velocity of 1-H-benzimidazole and 2- methyl benzimidazole derivatives in methanol and chloroform solutions have been studied at 298.15 K over a wide range of concentration. From these experimental data, some acoustical parameters such as intermolecular free length (L_f), isentropic compressibility (κ_s), relaxation strength (r), internal pressure (π) and free volume (V_f) have been evaluated. A fairly good correlation between a given parameter and concentration is observed. The results are interpreted in terms of molecular interactions like solvent-solvent, solvent-solute and solute-solute interactions.

Keywords: Ultrasonic velocity (U), internal pressure (π), density (ρ), 2-methyl benzimidazole

INTRODUCTION

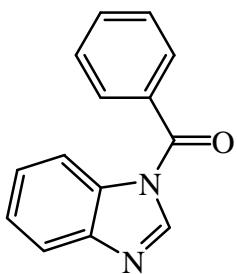
Ultrasonic studies are useful in extensive research in different field of science ¹⁻⁴. It is also found to be most suitable for investigating various liquid mixtures and solutions of organic and inorganic compounds, polymers, etc ⁵⁻¹⁰. The study of acoustical parameters gives a new sight of ion-solvent interactions ¹¹ occurring in the solutions. A considerable work on solutions of organic compounds has been reported¹²⁻¹⁵. The present work describes the effect of concentration and solvent on acoustical parameters of 1-H-benzimidazole and 2-methyl benzimidazole derivatives at 298.15 K.

EXPERIMENTAL

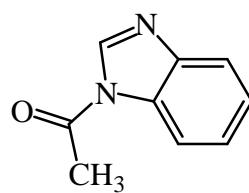
Both 1-H-benzimidazole (VJF) and 2- methyl benzimidazole (JMC) derivatives were purified. The structures of compounds are given in **Fig. 1**. The solvents, methanol and chloroform, used in the present work were of AR grade and were purified by fractional distillation according to the standard procedure¹⁶.

Solutions of different concentrations were prepared in both the solvents for all the compounds. The density (ρ), viscosity (η) and sound velocity (U) of pure solvents and solutions were measured at 298.15 K by using specific gravity bottle, Ubbelhobe suspended level viscometer and ultrasonic Interferometer (Mittal Enterprise, New Delhi, Model No. F-81 operated at 2 MHz) respectively. The accuracy of these measurements were ρ 0.0001 gcm⁻³, ρ 0.01 mPas and ρ 0.12% respectively.

Theory: From the experimental data of density, viscosity and ultrasound velocity of pure solvents and solutions, various acoustical parameters were calculated using standard equations:



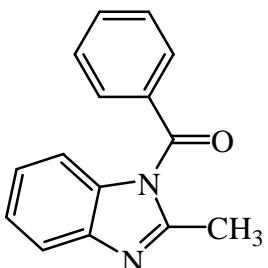
VJF-1

(1*H*-benzo[*d*]imidazol-1-yl)(phenyl)methanone

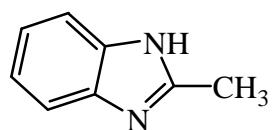
VJF-2

1-(1*H*-benzo[*d*]imidazol-1-yl)ethanone

(a)



JMC-I

(2-methyl-1*H*-benzo[*d*]imidazol-1-yl)(phenyl)methanone

JMC-II.

2-methyl-1*H*-benzo[*d*]imidazole

(b)

Fig 1: Structure of synthesized compounds,(a)1-H-bezimidazole derivatives (b) 2-methyl-bezimidazole derivatives**Intermolecular length (L_f):** $L_f = K_J \kappa_S^{1/2}$ where K_J is Jacobson constant (2.0965×10^{-6}).**Isentropic compressibility (κ_S):** $\kappa_S = 1/(U^2 \rho)$ **Relaxation Strength (r):** $r = 1 - [U/U_\infty]^2$ where $U_\infty = 1600$ m/s**Internal Pressure (π):** $\pi = bRT [K\eta/U]^{1/2} \rho^{2/3}/M^{7/6}$ where b is the packing factor and its value is 2. K is a constant (4.28×10^9).**Free volume (V_f):** $V_f = [MU/K\eta]^{3/2}$

RESULTS AND DISCUSSION

Table -1 show the experimental data of density (ρ), viscosity (η) and sound velocity (U) of pure solvents and solutions at 298.15 K. It is observed that in methanol solutions, ρ increases for all the four compounds whereas in chloroform, it decreases. However, η and U increases linearly with concentration for all the solutions. The ultrasonic velocity (U) depends on intermolecular free length (L_f). As intermolecular free length decreases, velocity increases or vice versa. **Tables 2 and 3** show some of the acoustical parameters for all the systems in methanol and chloroform respectively. It is observed that L_f decreases continuously for all the solutions. The increase in velocity and decrease in L_f suggest strong interaction between solvent and solute molecules in both solvents.

Table 1. The density (ρ), ultrasonic velocity (U) and viscosity (η) of synthesized compounds in methanol and chloroform at 298.15 K.

Conc. (Mol/lit.)	ρ Kg/m ³	U (m/sec)	η (Pas)	ρ Kg/m ³	U (m/sec)	η (Pas)
1-H-benzimidazole						
Methanol						
	VJF-I			VJF-II		
0.00	788.1	1099.2	0.5366	788.1	1099.2	0.5366
0.01	789.5	1111.6	0.5460	789.3	1106.4	0.5495
0.02	791.3	1113.2	0.5518	790.8	1108.0	0.5544
0.04	792.5	1116.0	0.5612	791.5	1109.2	0.5611
0.06	793.4	1116.8	0.5714	792.9	1114.8	0.5654
0.08	794.3	1122.4	0.5747	793.2	1116.8	0.5718
0.10	796.3	1124.8	0.5817	794.7	1121.2	0.5770
Chloroform						
0.00	1482.6	979.2	0.5676	1482.6	979.2	0.5676
0.01	1481.0	981.6	0.5764	1481.7	983.2	0.5768
0.02	1480.9	985.2	0.5849	1481.0	984.8	0.5826
0.04	1479.0	987.2	0.5887	1480.6	987.6	0.5894
0.06	1476.6	990.4	0.5929	1479.7	988.4	0.5938
0.08	1473.6	992.8	0.5956	1477.1	992.4	0.5996
0.10	1469.9	994.4	0.6078	1475.8	994.8	0.6184
2-methyl benzimidazole						
Methanol						
	JMC-I			JMC-II		
0.00	788.1	0.5366	1099.2	788.1	0.5366	1099.2
0.01	791.5	0.5546	1104.4	789.3	0.5485	1104.0
0.02	792.5	0.5621	1106.4	790.3	0.5546	1107.6
0.04	794.1	0.5753	1109.6	791.4	0.5566	1109.2
0.06	795.7	0.5846	1112.4	792.7	0.5672	1111.6
0.08	797.1	0.5899	1115.2	793.2	0.5714	1112.4
0.10	797.6	0.5916	1116.4	794.7	0.5815	1114.4
Chloroform						
	JMC-I			JMC-II		
0.00	1482.6	0.5676	979.2	1482.6	0.5676	979.2
0.01	1479.4	0.5733	979.6	1475.3	0.5749	982.0
0.02	1478.2	0.5835	981.2	1477.4	0.5779	985.6
0.04	1476.2	0.5893	982.0	1478.6	0.5878	987.2
0.06	1475.4	0.6017	984.4	1479.4	0.5953	992.4
0.08	1471.9	0.6039	986.8	1480.2	0.6045	993.6
0.10	1466.4	0.6049	988.0	1480.9	0.6105	997.2

Table 2.Variation of some acoustical parameters of synthesized compounds in methanol

Conc. (mol/lit)	$L_f \cdot 10^{10}$ (m)	$K_s \cdot 10^{-10}$ (Pas)	r ($m \cdot s^{-1}$)	V_f (m)	$L_f \cdot 10^{10}$ (m)	$K_s \cdot 10^{-10}$ (Pas)	r ($m \cdot s^{-1}$)	V_f (m)
1-H benzimidazole								
VJF-I					VJF-II			
0.00	0.678	10.501	0.528	0.000	0.678	10.501	0.528	0.000
0.01	0.670	10.250	0.517	0.599	0.673	10.349	0.522	0.584
0.02	0.668	10.197	0.516	0.585	0.672	10.300	0.520	0.577
0.04	0.666	10.131	0.513	0.573	0.670	10.269	0.519	0.568
0.06	0.665	10.105	0.513	0.558	0.667	10.148	0.515	0.566
0.08	0.661	09.993	0.508	0.558	0.665	10.108	0.513	0.558
0.10	0.659	09.925	0.506	0.549	0.662	10.009	0.509	0.553
2-methyl benzimidazole								
JMC-I					JMC-II			
0.01	0.674	10.358	0.524	0.574	0.675	10.395	0.524	0.583
0.02	0.673	10.308	0.522	0.564	0.673	10.314	0.521	0.577
0.04	0.670	10.228	0.519	0.547	0.671	10.270	0.519	0.575
0.06	0.666	10.156	0.517	0.536	0.669	10.209	0.517	0.560
0.08	0.665	10.087	0.514	0.531	0.669	10.188	0.517	0.553
0.10	0.664	10.059	0.513	0.530	0.667	10.132	0.515	0.542

Table 3.Variation of some acoustical parameters of synthesized compounds in chloroform

Conc. mol/lit	$L_f \cdot 10^{10}$ (m)	$K_s \cdot 10^{-10}$ (Pas)	r ($m \cdot s^{-1}$)	V_f (m)	$L_f \cdot 10^{10}$ (m)	$K_s \cdot 10^{-10}$ (Pas)	r ($m \cdot s^{-1}$)	V_f (m)
1-H benzimidazole								
VJF-I					VJF-II			
0.00	0.555	7.034	0.625	0.000	0.555	7.034	0.625	0.000
0.01	0.554	7.007	0.624	0.327	0.553	7.934	0.622	3.242
0.02	0.552	6.957	0.621	0.322	0.552	7.938	0.621	3.283
0.04	0.551	6.937	0.619	0.320	0.551	7.940	0.619	3.200
0.06	0.550	6.904	0.617	0.318	0.550	7.945	0.618	3.168
0.08	0.549	6.884	0.615	0.317	0.549	7.959	0.615	3.141
0.10	0.549	6.880	0.614	0.308	0.547	7.967	0.613	3.010
2-methyl benzimidazole								
JMC-I					JMC-II			
0.01	0.556	7.044	0.625	0.329	5.918	7.029	0.623	3.294
0.02	0.557	7.027	0.624	0.321	5.914	6.968	0.621	3.286
0.04	0.555	7.025	0.623	0.317	5.911	6.940	0.619	3.211
0.06	0.554	6.994	0.621	0.308	5.910	6.863	0.615	3.176
0.08	0.553	6.977	0.620	0.308	5.908	6.843	0.614	3.109
0.10	0.554	6.986	0.619	0.308	5.907	6.791	0.612	3.080

This is further supported by isentropic compressibility (κ_s) and relaxation strength (r). Both isentropic compressibility and relaxation strength (as shown in **Tables 2 and 3**) decrease with concentration for all the compounds, in both the solvents. The decrease of κ_s with increasing concentration might be due to aggregation of solvent molecules around solute molecules indicating thereby the presence of solute-solvent interactions in the studied systems.

The internal pressure (π) is the result of forces of attraction and repulsion between the molecules in solutions. **Fig. 2 and 3** show that π increases with concentration of solutions, indicating thereby increase in cohesive forces. This further confirms the predominance of solute-solvent interactions in these systems. The free volume (V_f) is an inverse function of internal pressure. **Tables- 2 and 3** show that V_f decreases with concentration for all the solutions. The decrease in volume again proves close association between solvent and solute molecules i.e., strong solute-solvent interactions. Thus, it is concluded that in both solvents, solute-solvent interactions exist for the studied compounds.

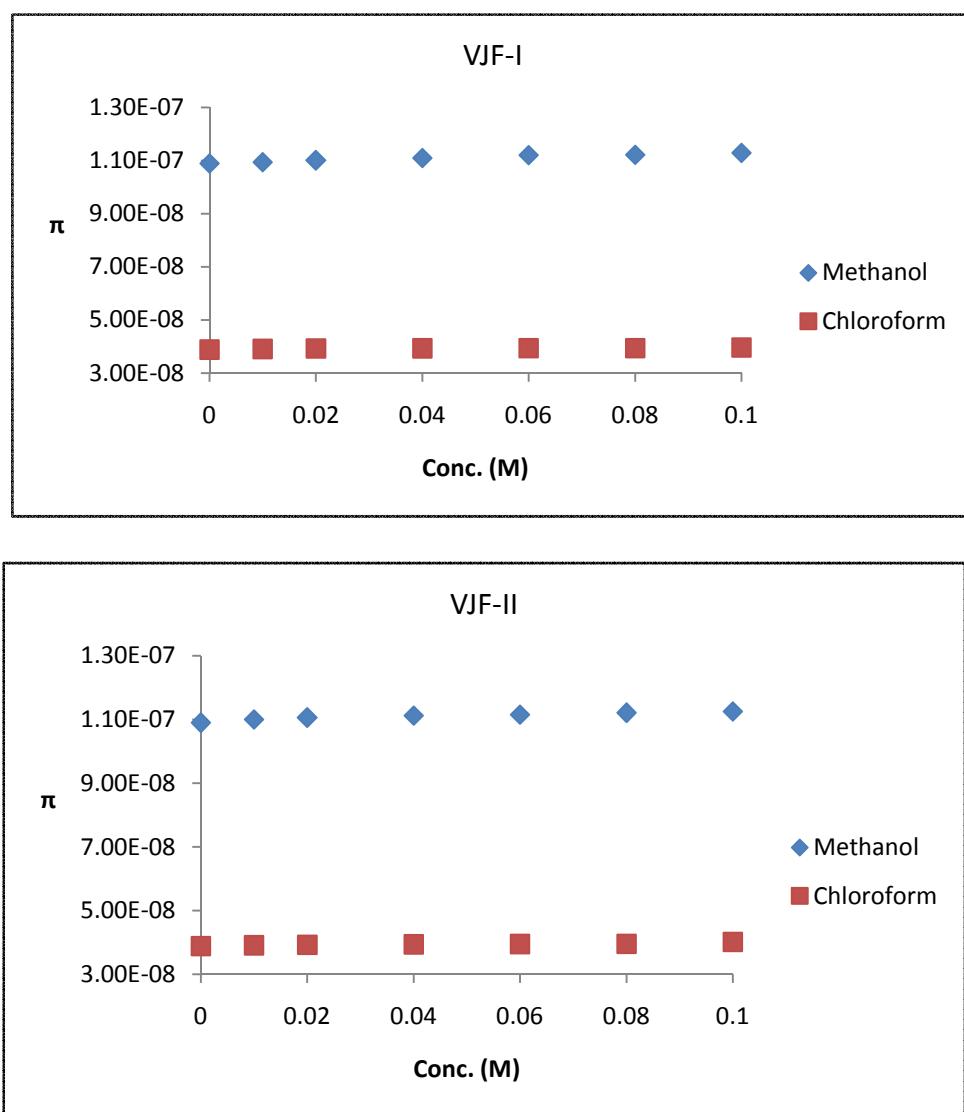


Fig 2: Variation of Internal Pressure (π) against Concentration for VJF-I and VJF-II at 298.15K.

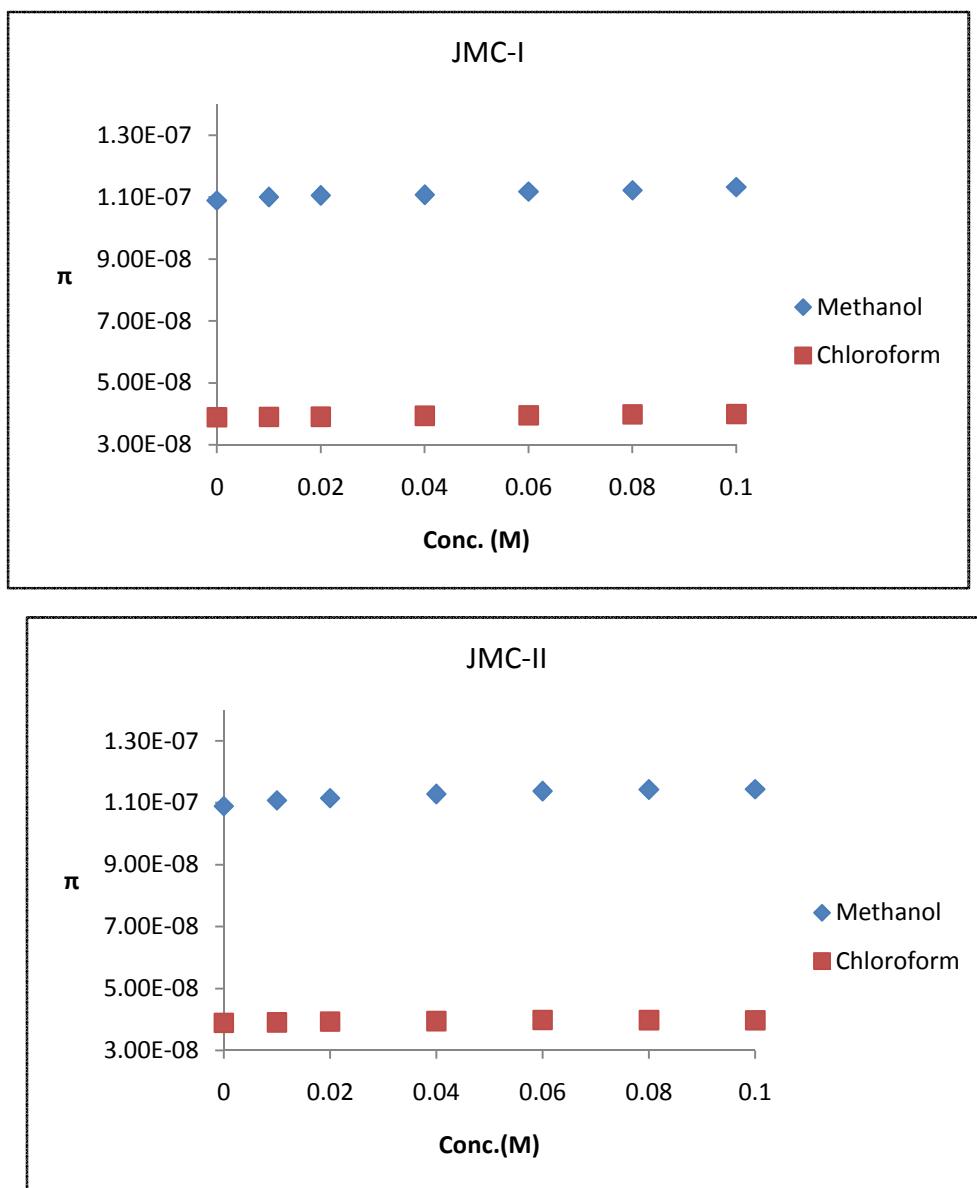


Fig 3: Variation of Internal Pressure (π) against Concentration for JMC-I and JMC-II at 298.15K.

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