

CHAPTER 9

DISCUSSION

9.1: Ultrasonic behaviour of dilute solutions of water in glycols

Diffraction corrected ultrasonic velocities in dilute solutions of water in diethylene glycol (DEG), poly ethylene glycol (PEG) – 200, PEG-300, PEG-400 and PEG-600 as a function of concentration of water are shown in Fig. 9.1.1. The excess ultrasonic velocity data for these solutions are shown in Fig. 9.1.2. Also included in these figures, the ultrasonic velocity and excess ultrasonic velocity data for the solutions of water in ethylene glycol (EG) taken from literature [36] for comparison.

An examination of the data presented in Fig. 9.1.1 indicates that the ultrasonic velocity varies nonlinearly with concentration of water in all the systems, except at very low concentrations. The optimum concentrations up to which a linearity is observed in u versus X_2 are presented in Table 9.1.1. Beyond these optimum concentrations, $(X_2)_{opt}$, u versus X_2 is nonlinear up to certain extent for all the systems. Normally, we would expect a linear variation if there were no water-water and water-glycol (EG and PEG) interactions. The observations therefore indicate some sort of association between the water molecules themselves and also with the glycol (EG and PEG) molecules.

The temperature of density maximum [32,120] and sound velocity maximum and adiabatic compressibility minimum [75,161,162] studies indicate destabilization of the hydrogen bonded structure of water by EG, DEG, PEG-200, PEG-300, PEG-400 and PEG-600. It is also inferred from these studies that as the chain length increases the structure disrupting efficiency increases. From studies on the volumetric properties of aqueous solutions of the oligomers of polyethylene glycol and propylene

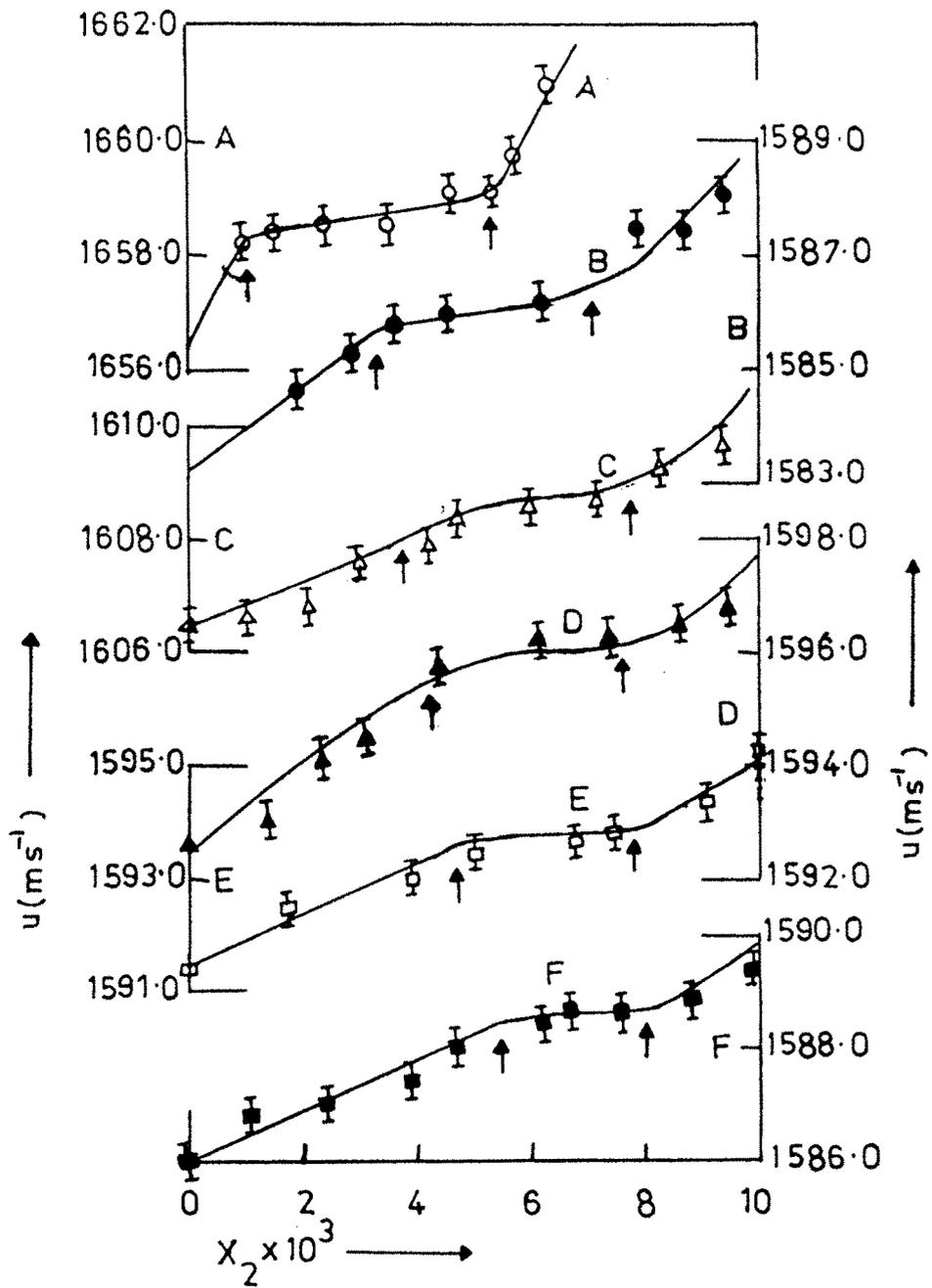


Fig. 9.1.1: Ultrasonic velocity (u) versus molefraction (X_2) of water in dilute solution of water in glycols

A \rightarrow ethylene glycol; B \rightarrow DEG; C \rightarrow PEG-200;
 D \rightarrow PEG-300; E \rightarrow PEG-400; F \rightarrow PEG-600.

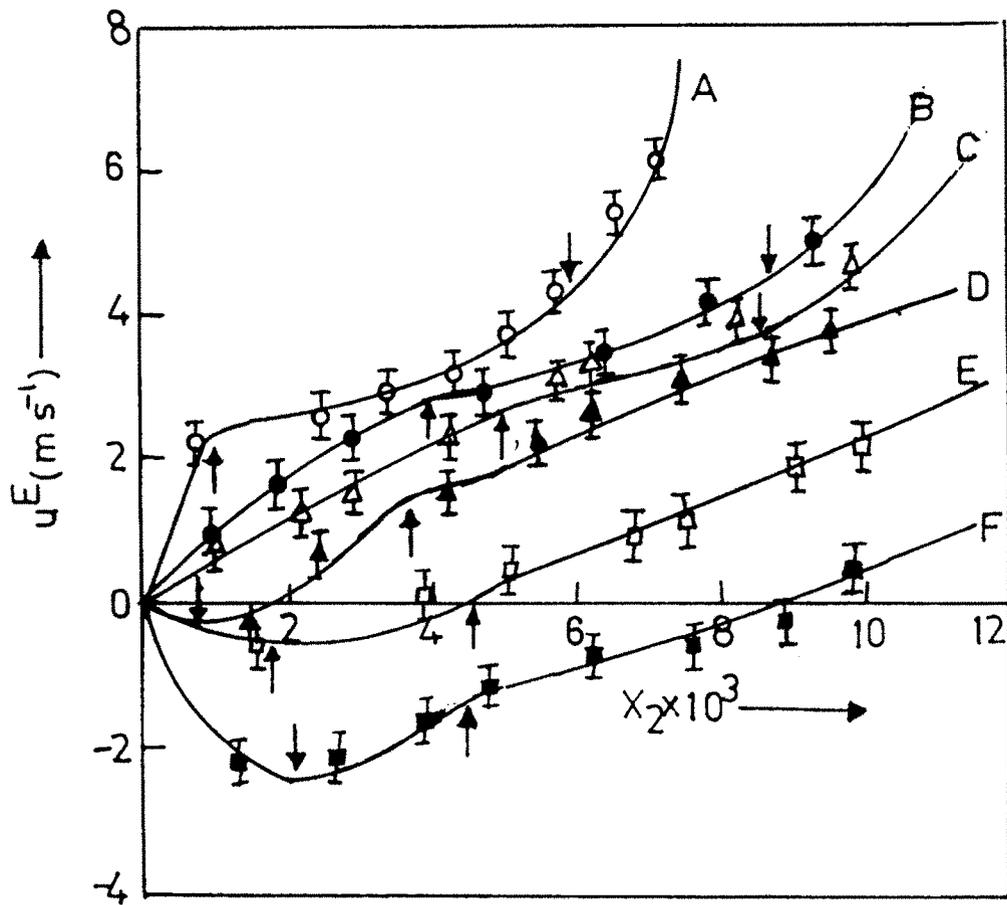


Fig. 9.1.2: Excess ultrasonic velocity (u^E) versus molefraction (X_2) of water in dilute solution of water in glycols

A → ethylene glycol; B → DEG; C → PEG-200;
 D → PEG-300; E → PEG-400; F → PEG-600.

Table 9.1.1. Optimum concentration of water (X_2) up to which u versus X_2 and u^E versus X_2 are linear

System	$(X_2)_{opt}$	
	u versus X_2	u^E versus X_2
Ethylene glycol + water	0.0010	0.0010
Diethylene glycol + water	0.0032	0.0035
PEG-200 + water	0.0038	0.0047
PEG-300 + water	0.0043	0.001 (Negative minimum)
PEG-400 + water	0.0048	0.0018 (Negative minimum)
PEG-600 + water	0.0055	0.0021 (Negative minimum)

glycol, Sandell and Goring [163] observed the apparent specific expansibility increasing with increase in chain length. This indicates that the extent of the hydrophobic hydration is reduced as the chain length increases.

In the very high dilution region of water in glycols, it is how the water molecules exist as clusters or monomers that decide the ultrasonic behaviour as is reflected from Figs. 9.1.1 and 9.1.2. According to Eucken [164] water may be considered to be composed of four distinct molecules monomers, (H_2O) , dimers $(\text{H}_2\text{O})_2$, quadrumers $(\text{H}_2\text{O})_4$ and octomers, $(\text{H}_2\text{O})_8$. If water exists as monomers then ultrasonic velocity must vary linearly with concentration in dilute solutions of water in nonelectrolytes. The linearity in u versus X_2 and u^E versus X_2 up to $(X_2)_{\text{opt}}$ may be explained as due to the water molecules existing as monomers, that is as isolated molecules dispersed uniformly in the nonelectrolytes.

Beyond $(X_2)_{\text{opt}}$, u versus X_2 is nonlinear and this nonlinear behaviour can be seen more markedly in u^E versus X_2 curves for all the systems. This nonlinear variation indicates that in dilute solutions of water in glycols water molecules exist as polymeric molecules. This behaviour favours the interpretation of water as distorted ice like structure with bonds constantly breaking and reforming and the associations extending throughout the whole liquid. As per this view, when water is present in very small amounts in a non-electrolyte liquids one may consider the existence of water molecules dispersed homogeneously throughout the bulk of the solution with the possibility of formation of water-water or water-nonelectrolyte associations.

The possible dissociation reaction schemes [165] that may exist when water is dissolved in the nonelectrolyte are illustrated in Fig. 9.1.3. The observed nonlinear and nonideal behaviour in u versus X_2 and u^E versus X_2 may be attributed to the existence of hypothetical particles in the solution with the possibility of bond formation with either water molecules or glycol molecules.

As can be seen from Fig. 9.1.1, the extent of flatness of the u versus X_2 curves decreases as we go from EG to PEG 600 and is in the order EG > DEG > PEG 200 > PEG 300 > PEG 400 > PEG 600. This signifies that as chain length increases the percentage of water existing as monomers increases in dilute solutions of water in glycols. This behaviour is also very well reflected in u^E versus X_2 curves as shown in Fig. 9.1.2.

The excess sound velocity is positive and increases nonlinearly with increase in the concentration of water for dilute solutions of water in ethylene glycol, diethylene glycol and PEG-200. For dilute solutions of water in PEG-300, PEG-400 and PEG-600, the excess sound velocity is negative becoming minimum at $X_2 \simeq 0.0010$, 00014 and 0.0021 respectively for water in PEG-300, PEG-400 and PEG-600. u^E becomes positive for these solutions around $X_2 \simeq 0.0017$, 0.0038 and 0.0084 respectively for PEG-300, PEG-400 and PEG-600.

In the region between the two arrow marks shown in Figs. 9.1.1 and 9.1.2 the ultrasonic behaviour of glycol-water solutions may be interpreted in terms of the formation of some kind of specifically extended structures. In the case of polyethylene glycols the basic unit is ethylene glycol which consists of two

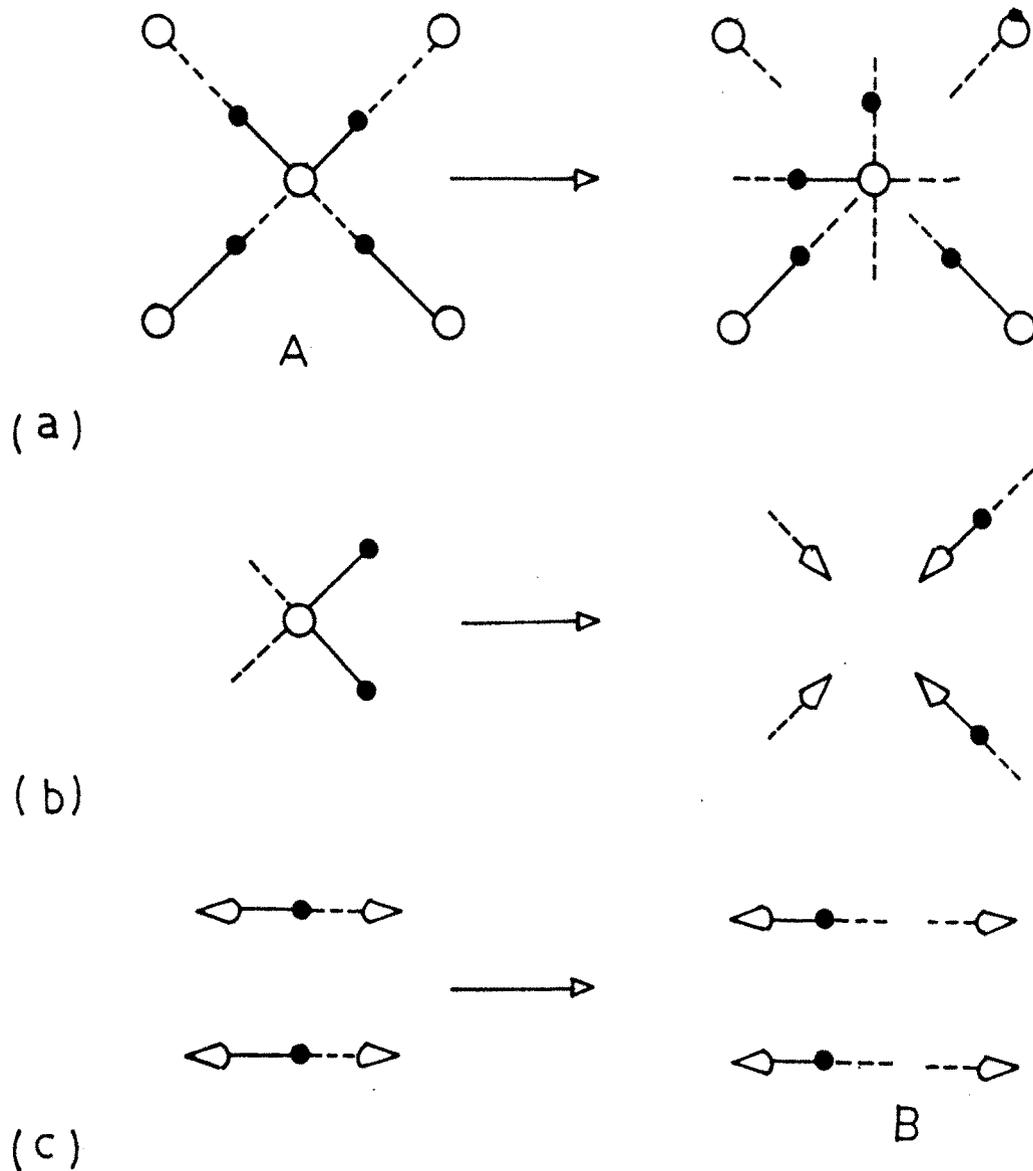


Fig. 9.1.3

Dissociation reaction schemes of water

a. Reaction scheme when all bonds are coupled.

b. Division into hypothetical 'subparticles'.

c. Reaction scheme for uncoupled bonds.

O → Oxygen; ● → Hydrogen

--- → hydrogen bond or possibility for bond formation

◁ → hypothetical 'subparticle' (has one bond possibility)

A → The four places available for bond formation in water molecule are coupled by neighbours (Hydrogen bonded cluster structure).

B → Normal close packed liquid (monomer water molecules).

hydrophilic hydroxyl groups and a hydrophobic hydrocarbon (-CH₂CH₂-) group. As one goes from EG to PEGs polymerization of EG groups takes place by elimination of H₂O molecules. Hence, in this series, the chain length of (-CH₂CH₂O-) groups increases gradually with the terminal group being the same having two hydrophilic hydroxyl groups. The (-CH₂CH₂O-) group contains a hydrophobic hydrocarbon part (-CH₂CH₂-) and hydrophilic oxygen with lone pair of electrons capable of forming hydrogen bonds with water molecules. The water molecules taking part may be monomers or dimers or quadrumers or octomers. The extent of change of ultrasonic velocity with concentration in the region between the arrow marks is either low or remains unchanged indicating that there is no much change in the intermolecular space as a result of addition of water to the glycols.

At higher concentrations beyond the second arrow shown in Figs. 9.1.1 and 9.1.2 u versus X_2 and u^E versus X_2 show a linear or gradual increase with X_2 . This behaviour might be due to collapse of the extended structures of water-glycol molecules and formation of free water molecules as monomers, dimers, quadrumers, or octomers distributed uniformly throughout the solution.

9.2 Ultrasonic behaviour of dilute solutions of water in n-alcohols

Diffraction corrected ultrasonic velocities in dilute solutions of water in methanol, ethanol and n-butanol as a function of concentration of water are shown in Fig. 9.2.1. The excess ultrasonic velocity data for these solutions are shown in Fig. 9.2.2. Also included in these figures, the ultrasonic velocity and excess ultrasonic velocity data for the solutions of water in n-propanol taken from literature [24] for comparison. An examination of the data presented in Fig. 9.2.1 indicates that the ultrasonic velocity varies nonlinearly with the concentration of water in all the systems, except at very low concentrations. The optimum concentrations upto which a linearity is observed in u versus X_2 are presented in Table 9.2.1. Beyond these optimum concentrations u versus X_2 is nonlinear upto certain extent for all the systems. Normally, we would expect a linear variation if there were no water-water and water - n-alcohol interactions. The observations therefore indicate some sort of association between the water molecules themselves and also with the n-alcohol molecules. This behaviour is well reflected in the excess of ultrasonic velocity behaviour as can be seen from Fig. 9.2.2. The $(X_2)_{opt}$ in u^E versus X_2 upto which the variation is linear for all the system are also given in Table 9.2.1.

In the water rich region, methanol, ethanol, n-propanol and n-butanol are known to enhance the hydrogen bonded structure of water [32,99,100,120,126, 166-168]. These molecules by interstitial substitution in the water structure stabilize

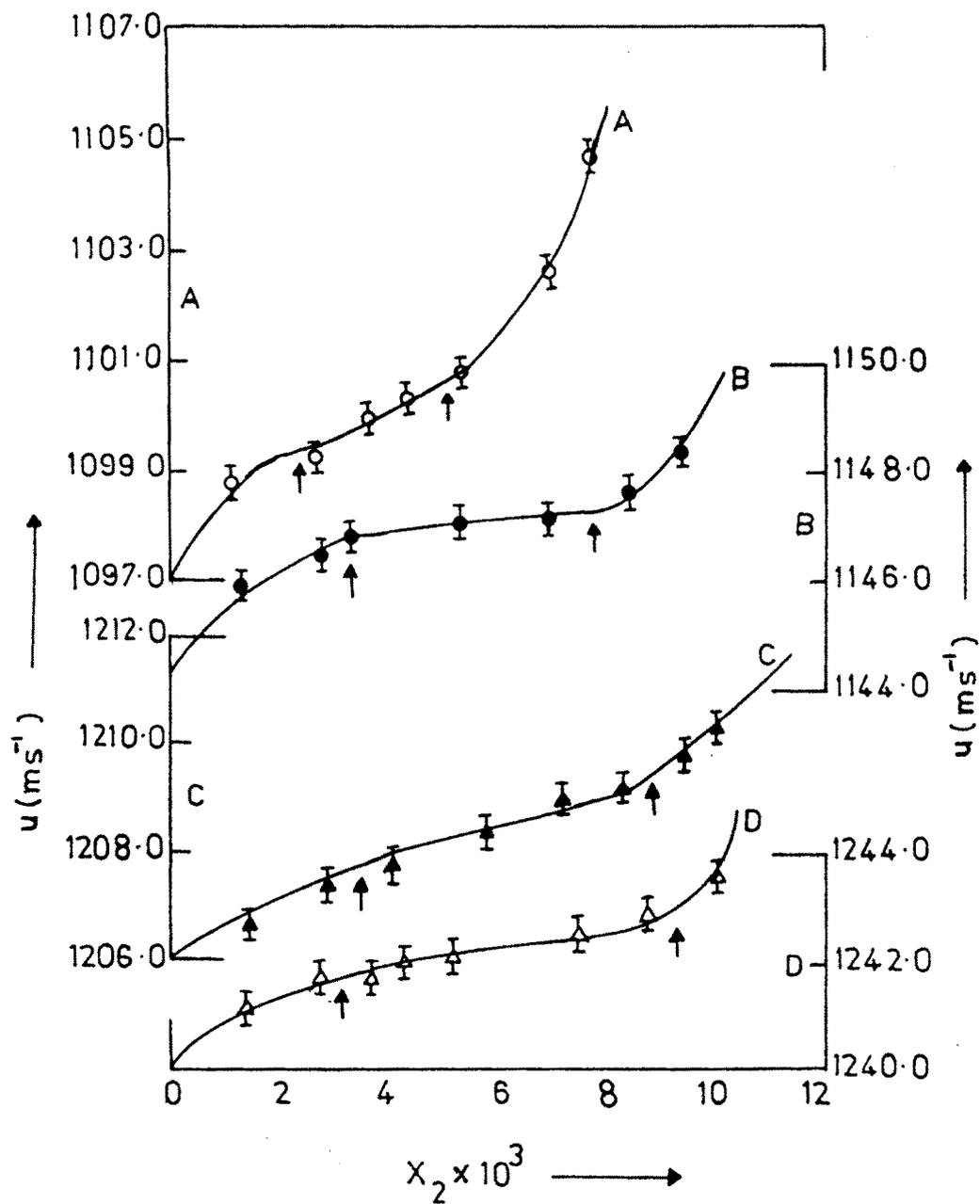


Fig. 9.2.1 Ultrasonic velocity (u) versus molefraction (X_2) of water in dilute solutions of water in n-alcohols.

A \rightarrow methanol; B \rightarrow ethanol; C \rightarrow n-propanol;
 D \rightarrow n-butanol.

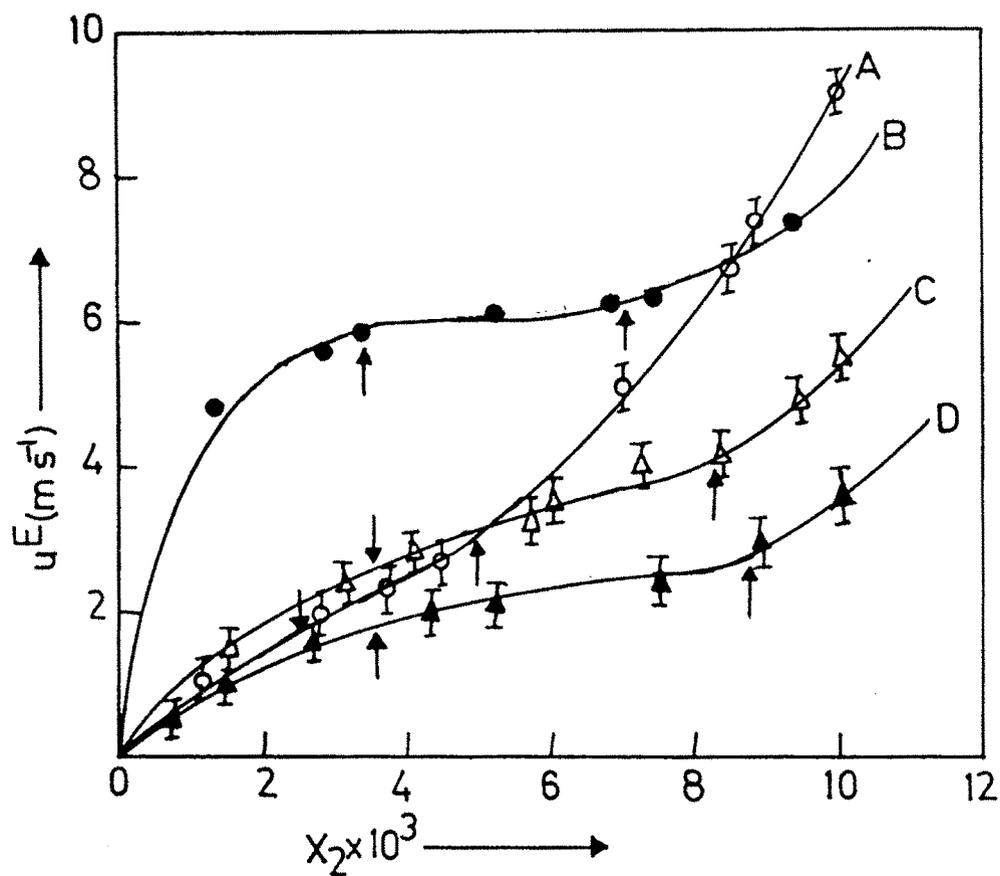


Fig. 9.2.2: Excess ultrasonic velocity (u^E) versus molefraction (X_2) of water in dilute solutions of water in n-alcohols.

A \rightarrow methanol; B \rightarrow ethanol; C \rightarrow n-propanol;
 D \rightarrow n-butanol.

the hydrogen bonded clusters against thermal collapse and as a result the solution structure is more structured than pure water.

In the very high dilution region of water in n-alcohols, it is how the water molecules exist as clusters or monomers that decide the ultrasonic behaviour as is reflected for Figs. 9.2.1 and 9.2.2. If water exists as monomers then ultrasonic velocity must vary linearly with concentration in dilute solutions of water in non-electrolytes. The linearity in u versus X_2 and u^E versus X_2 upto $(X_2)_{opt}$ may be explained as due to the existence of water molecules as monomers, dispersed uniformly in n-alcohols.

Beyond $(X_2)_{opt}$, u versus X_2 is nonlinear and this nonlinear behaviour can be seen more markedly in u^E versus X_2 curves for all the systems. This nonlinear variation indicates that in dilute solutions of water in n-alcohols, water molecules exist as polymeric molecules. This behaviour favours the interpretation of water as distorted ice like structure with bonds constantly breaking and reforming and the associations extending throughout the whole liquid. As per this view, when water is present in very small amounts in n-alcohol liquids, one may consider the existence of water molecules dispersed homogeneously throughout the bulk of the solution with the possibility of formation of water-water (or) water - n-alcohol associations. It may be mentioned here that the limiting partial molar volume of water v_w^∞ for solutions of lower alcohols are smaller than that of pure water and this behaviour has been attributed to the strong hydrogen bond formation between water and alcohol molecules [112,169].

As can be seen from Fig. 9.2.1. the extent of flatness of the u versus X_2 curves decreases as we go from n-butanol to methanol and is in the order n-butanol > n-propanol > ethanol > methanol. A similar behaviour is also observed in u^E versus X_2 curves as shown in fig. 9.2.2. The excess sound velocity is positive and increases nonlinearly with increase in the concentration of water for dilute solutions of water in methanol, ethanol and n-butanol.

In the concentration region between the two arrows marked in the Figs. 9.2.1 and 9.2.2, there appears to be formation of islands of clusters of water molecules dispersed uniformly throughout the solution. The extent of change of ultrasonic velocity with concentration in the region between the arrow marks is either low or remains unchanged indicating that there is no much change in the intermolecular space as a result of addition of water to the n-alcohols.

At higher concentrations beyond the second arrow shown in Figs. 9.2.1 and 9.2.2 u versus X_2 and u^E versus X_2 show a linear or gradual increase with X_2 . This behaviour might be due to collapse of the water - n-alcohol associations and formation of free water molecules as monomers, dimers, quadrumers and octomers distributed uniformly throughout the solution.

TABLE 9.2.1
Optimum concentration of water $(X_2)_{opt}$ up to which u versus X_2 and u^E versus X_2 are linear

System	$(X_2)_{opt}$	
	u versus X_2	u^E versus X_2
Methanol	0.0024	0.0025
Ethanol	0.0033	0.0036
n-Propanol	0.0035	0.0035
n-Butanol	0.0031	0.0036

9.3 Ultrasonic behaviour of dilute solutions of water in 2-alkoxy ethanols

Diffraction corrected ultrasonic velocities in dilute solutions of water in 2-methoxyethanol, 2-ethoxyethanol and 2-butoxyethanol as a function of concentration of water are shown in Fig. 9.3.1. The excess ultrasonic velocity data for these solutions are shown in Fig. 9.3.2. An examination of the data presented in Fig. 9.3.1 indicates that the ultrasonic velocity varies nonlinearly with concentration of water in all the systems, except at very low concentrations. The optimum concentrations up to which a linearity is observed in u versus X_2 are presented in Table 9.3.1. Beyond these optimum concentrations u versus X_2 is nonlinear up to certain extent for all the systems. Normally, we would expect a linear variation if there were no water-water and water-2-alkoxyethanol associations. The observations therefore indicate some sort of association between the water molecules themselves and also with the 2-alkoxy-ethanol molecules. This behaviour is well reflected in the excess ultrasonic velocity behaviour as can be seen from Fig. 9.3.2. The $(X_2)_{\text{opt}}$ in u^E versus X_2 up to which the variation is linear for all the systems are presented in Table 9.4.1. The inflection region narrows down as one goes from ME to EE to BE.

A sharp maximum in ultrasonic velocity and a sharp minimum in adiabatic compressibility have been observed at low BE concentrations in mixtures of (water + BE) at all temperatures [135]. These extrema have been attributed to the formation of "clathrate-like" structures of water and BE. The specific heat [159] studies also indicate the occurrence of clathrate structures at $\simeq 0.02 X_{\text{BE}}$. Beyond this

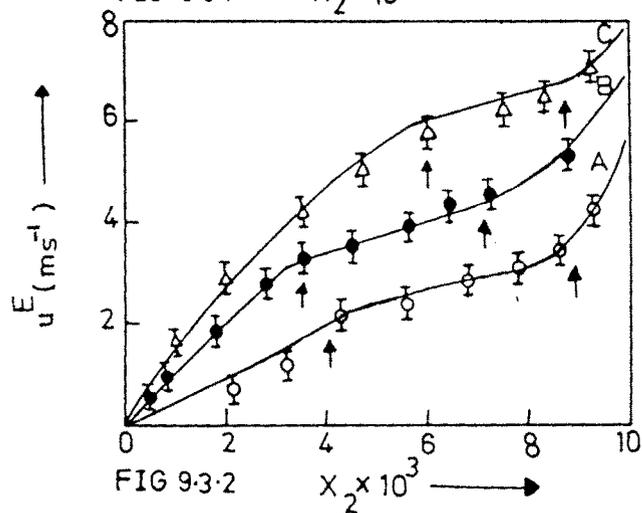
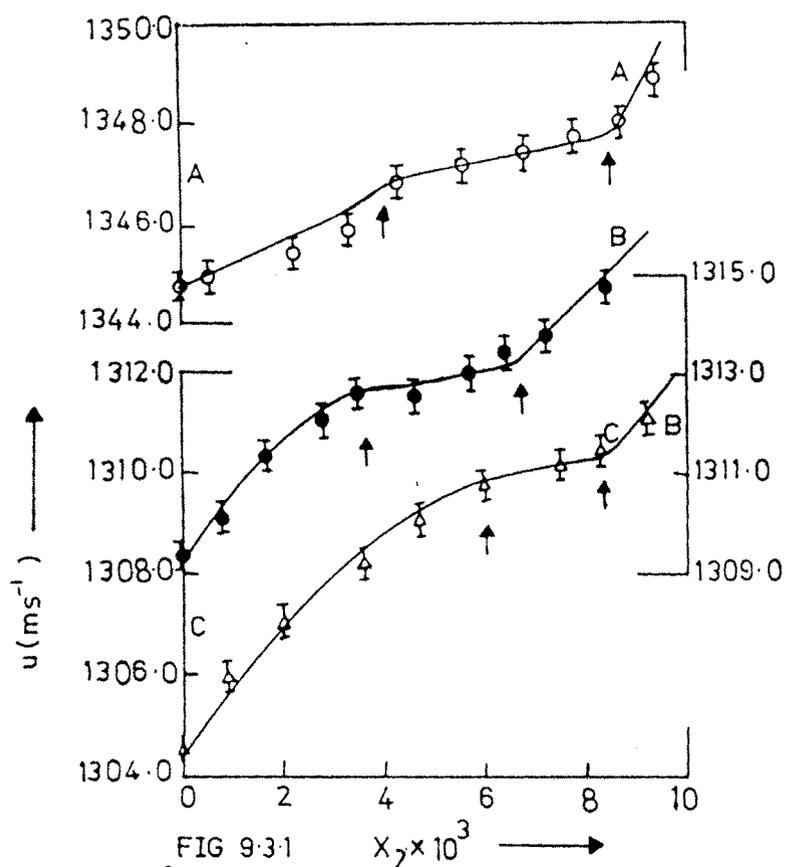


Fig. 9.3.1 Ultrasonic velocity (u) versus molefraction (X_2) of water in dilute solutions of water in 2-alkoxy ethanols.

A \rightarrow 2-methoxy ethanol; B \rightarrow 2-ethoxy ethanol;
C \rightarrow 2-butoxy ethanol.

Fig. 9.3.2: Excess ultrasonic velocity (u^E) versus molefraction (X_2) of water in dilute solutions of water in 2-alkoxy ethanols.

A \rightarrow 2-methoxy ethanol; B \rightarrow 2-ethoxy ethanol;
C \rightarrow 2-butoxy ethanol.

concentration microphase aggregates are predicted to occur and at very high concentrations of BE that clathrate and microphase structures cease to exist.

Douheret *et al* [148] studied ultrasonic speeds and isentropic functions of 2-methoxyethanol + water, 2-ethoxyethanol + water and 2-butoxyethanol + water across their entire composition range. These studies reveal significant variations in the patterns of molecular aggregation. While BE may not satisfy all the requirements for a truly micellar system, it is obvious that there exist some very dramatic structural changes around $x \simeq 0.02$. The composition dependence of (EE + water) and (ME + water) properties show no dramatic changes but appear as smoothed analogues of those of (BE + water) suggesting that there is a modest degree of hydrophobic aggregation by the smaller amphiphiles resulting in labile clusters. The partial molar heat capacities $C_{p,2}$ for alkoxyethanols have been observed to be large (170) and this behaviour has been attributed to the interaction between the hydrophobic alkyl groups and water resulting into a solution structure which is more structured than pure water.

A plot of $C_{p,2}^{\circ} = a + bn$ where n represents the number of carbon atoms and a and b are constants, it has been observed (170) that a values for simple alcohols and alkoxyethanols come out to be $(64 \pm 8) \text{ J K}^{-1}$ and $(32 \pm 12) \text{ J K}^{-1}$. This suggests that the ether groups tend to counteract the formation of structured water around the neighbouring alkyl groups.

The structure promoting nature of alkoxyethanols is sensitive to temperature. The temperature of sound velocity maximum and adiabatic compressibility minimum

studies [171,172,173] indicate destabilization of the hydrogen bonded structure of water by the alkoxyethanols.

In the very high dilution region of water in 2-alkoxyethanols, it is how the water molecules exist as clusters or monomers that decide the ultrasonic behaviour as is reflected from Figs. 9.4.1 and 9.4.2. According to Eucken [164] water may be considered to be composed of four distinct molecules namely monomers, (H_2O) , dimers $(\text{H}_2\text{O})_2$, quadrumers, $(\text{H}_2\text{O})_4$ and octomers $(\text{H}_2\text{O})_8$. If water exists as monomers then ultrasonic velocity must vary linearly with concentration in dilute solutions of water in nonelectrolytes. The linearity in u versus X_2 and u^E versus X_2 up to $(X_2)_{\text{opt}}$ may be explained as due to the water molecules existing as monomers, that is as isolated molecules dispersed uniformly in the nonelectrolytes.

Beyond $(X_2)_{\text{opt}}$, u versus X_2 is nonlinear and this nonlinear behaviour is also seen in u^E versus X_2 curves for all the systems. This nonlinear variation indicates that in dilute solutions of water in 2-alkoxyethanols, water molecules exist as polymeric molecules. This behaviour favours the interpretation of water as distorted ice like structure with bonds constantly breaking and reforming and the associations extending throughout whole liquid. As per this view, when water is present in very small amounts in a nonelectrolyte liquid, one may consider the existence of water molecules dispersed homogeneously throughout bulk of the solution with the possibility of formation of water – water or water – nonelectrolyte associations.

The possible dissociation reaction schemes [165] that may exist when water is dissolved in the nonelectrolyte are illustrated in Fig. 9.1.3. The observed nonlinear

and non-ideal behaviour in u versus X_2 and u^E versus X_2 may be attributed to the existence of hypothetical particles in the solution with the possibility of bond formation with either water molecules or 2-alkoxyethanols.

As can be seen from Fig. 9.3.1 the extent of the inflection region in u versus X_2 curves decreases as we go from 2-methoxyethanol to 2-butoxyethanol and is in the order 2-methoxyethanol > 2-ethoxyethanol > 2-butoxyethanol. This signifies that as molecular weight increases the percentage of water existing as monomers increases in dilute solutions of 2-alkoxyethanol. This behaviour is also reflected in u^E versus X_2 curves as shown in Fig. 9.3.2. The excess sound velocity is positive and increases nonlinearly with increase in the concentration of water for dilute solutions of water in 2-methoxyethanol, 2-ethoxyethanol and 2-butoxyethanol.

In the concentration region between the two arrows marked in the Figs. 9.3.1 and 9.3.2, there appears to be formation of islands of clusters of water molecules dispersed uniformly throughout the solution. The extent of change of ultrasonic velocity with concentration in the region between the arrow marks is low indicating that the change in the intermolecular space as a result of addition of water to the 2-alkoxyethanols is small.

There may exist an interaction between the hydrophobic alkyl groups and water molecules leading to isolated extended structures in dilute solutions of water in alkoxyethanols, resulting in the non-linear variation of u versus X_2 and u^E versus X_2 in the region between the two arrows as shown in Fig. 9.3.1 and 9.3.2.

At higher concentrations beyond the second arrow shown in Figs. 9.3.1 and 9.3.2, u versus X_2 and u^E versus X_2 show a linear or gradual increase with X_2 . This behaviour might be due to collapse of the extended structures of water – 2-alkoxyethanol molecules and formation of free water molecules as monomers, dimers, quadrumers and octomers distributed uniformly throughout the solution.

TABLE 9.3.1

Optimum concentration of water $(X_2)_{opt}$ up to which u versus X_2 and u^E versus X_2 are linear

System	$(X_2)_{opt}$	
	u versus X_2	u^E versus X_2
2-Methoxyethanol	0.0040	0.0041
2-Ethoxyethanol	0.0036	0.0035
2-Butoxyethanol	0.0060	0.0060

9.4 Ultrasonic behaviour of dilute solutions of water in amines

Diffraction corrected ultrasonic velocities in dilute solutions of water in diethylamine, triethylamine, dibutylamine and di-sec-butyl amine as a function of concentration of water are shown in Fig.9.4.1. The excess ultrasonic velocity data for these solutions are shown in Fig. 9.4.2. An examination of the data presented in Fig. 9.4.1 indicates that the ultrasonic velocity varies nonlinearly with concentration of water in all the systems, except at very low concentrations. The optimum concentrations upto which a linearity is observed in u versus X_2 are presented in Table 9.4.1. Beyond these optimum concentrations u versus X_2 is non linear upto certain extent for all the systems. Normally, we would expect a linear variation if there were no water-water and water-amine (DEA, TEA, DBA and DSBA) interactions. These observations therefore indicate association of water molecules among themselves and also with the amine molecules.

In the water rich region, diethyl amine, triethyl amine, dibutyl amine and di-sec-butyl amine are known to enhance the hydrogen bonded structure of water as revealed for temperature of sound velocity maximum [71,75], temperature adiabatic compressibility minimum [75,76] and temperature of density maximum [120] studies.

In the very high dilution region of water in amines, it is how the water molecules exist as cluster or monomers that decide the ultrasonic behaviour as is reflected from Figs. 9.4.1 and 9.4.2. The linearity in u versus X_2 and u^E versus X_2 upto $(X_2)_{opt}$ may be explained as due to the water molecules existing as monomers, that is as isolated molecules dispersed uniformly in the nonelectrolytes.

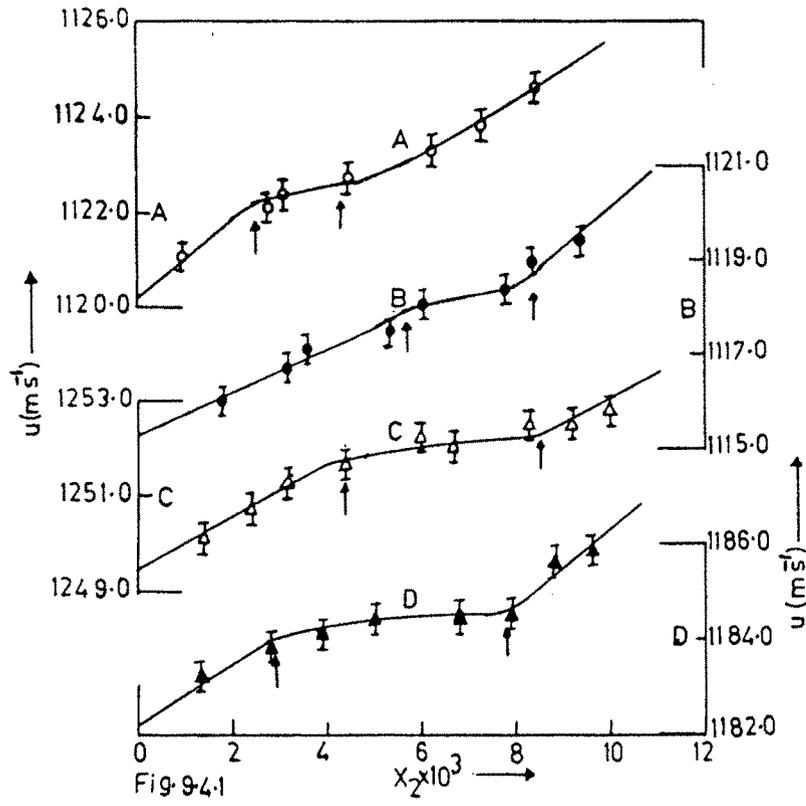


Fig. 9.4.1

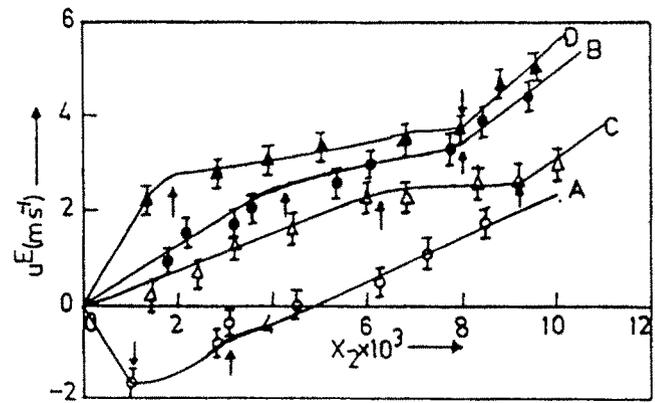


Fig. 9.4.2

Fig. 9.4.1 Ultrasonic velocity (u) versus molefraction (X_2) of water in dilute solutions of water in amines

A → diethylamine; B → triethylamine;
 C → dibutylamine; B → di-sec-butylamine

Fig. 9.4.2 Excess ultrasonic velocity (u^E) versus molefraction (X_2) of water in dilute solutions of water in amines

A → diethylamine; B → triethylamine;
 C → dibutylamine; B → di-sec-butylamine.

Beyond $(X_2)_{opt}$, u versus X_2 is nonlinear, and this nonlinear behaviour can be seen more markedly in u^E versus X_2 curves for all the systems. This nonlinear behaviour can be seen more markedly in u^E versus X_2 curves for all the systems. This nonlinear variation indicates that in dilute solutions of water in amines water molecules exist as polymeric molecules of the type proposed by Eucken [164]. The observed behaviour favours the interpretation of water as distorted ice like structure with bonds constantly breaking and reforming and the associations extending throughout the whole liquid. As per this view, when water is present in very small amount in a nonelectrolyte liquid, one may consider the existence of water molecules dispersed homogeneously throughout of the bulk of the solution with the possibility of formation of water-water or water-non-electrolyte associations.

The observed nonlinear and nonideal behaviour in u versus X_2 and u^E versus X_2 may be attributed to the existence of hypothetical particles in the solution with the possibility of bond formation with either water molecules or amines molecules.

As can be seen from Fig. 9.4.1, the extent of flatness of the u versus X_2 curves (concentration range between the arrow marks) increases as we go from DEA to DSBA and is in the order DSBA > DBA > TEA > DEA. This signifies that as molecular weight increase the association between water molecules and amine molecules increases in dilute solutions of amines. This behaviour is also very well reflected in u^E versus X_2 curves as shown in Fig. 9.4.2. The excess sound velocity is positive and increases nonlinearly with increase in concentration of water for dilute solutions of water in triethylamine, dibutyl amine and di-sec-butylamine. For dilute

solutions of water in diethylene amine, the excess sound velocity is negative becoming minimum at $X_2 \simeq 0.0013$ for water in diethylene amine. u^E becomes positive for DEA solution around $X_2 \simeq 0.0048$.

In the region between the two arrow marks shown in Figs. 9.4.1 and 9.4.2, the ultrasonic behaviour of amine-water solutions may be interpreted in terms of the formation of water amine cluster differing in size. The water molecules taking part may be monomers or dimers or quadrumers or octomers. The extent of change of ultrasonic velocity with concentration in the region between the arrow marks is either low or remains unchanged indicating that there is no much change in the intermolecular space due to the presence of islands of clusters of water-amine molecules as a result of addition of water to the amines.

At higher concentrations beyond the second arrow shown in Figs. 9.4.1. and 9.4.2 u versus X_2 and u^E versus X_2 show a linear or gradual increase with X_2 . This behaviour may be considered to be due to collapse of the water-amine clusters and formation of free water molecules as monomers, dimers, quadrumers or octomers distributed uniformly throughout the solution.

TABLE 9.4.1

Optimum concentration of water $(X_2)_{opt}$ up to which u versus X_2 and u^E versus X_2 are linear

System	$(X_2)_{opt}$	
	u versus X_2	u^E versus X_2
Diethyl amine	0.0025	0.0013 (-ve minimum)
Triethyl amine	0.0056	0.0045
Dibutyl amine	0.0044	0.0060
Di-sec-butylamine	0.0030	0.0020