

CHAPTER - V

AQUEOUS SOLUTIONS OF SUGARS
WITH
ALKALI HALIDES

INTRODUCTION:

Carbohydrates play an important role in animal and plant life. Understanding the behaviour of these in dilute solutions is of utmost importance in medicine and biology. This behaviour can be understood, among others, by measuring thermodynamic properties in dilute solutions, like limiting apparent molal volume, adiabatic compressibilities, specific heat etc. The extent of hydration of carbohydrates molecules depends on their conformation and configuration of their hydroxyl group. Franks and co workers (1) have demonstrated that equatorial hydroxyl groups are more readily hydrated than axial hydroxyl group and differently hydrated solute molecules will differ in compatibility with water structure. However, differences in hydration between different solutes depend on conformation in solution (2) and molecular dynamics simulations (3) have shown that hydration lifetimes are an important consideration. Several NMR studies in aqueous solutions of sugars and pure alkali halides have been reported (4-6). On the otherhand the influence of alkali halides on the physical properties of aqueous non electrolyte solutions have not been extensively studied in spite of their biological importance.

In addition to this, a variety of organic molecules are known to affect the electrical conductivity of ions in the solutions (7,8). The change in conductance was attributed

to the obstruction by the environmental non-electrolyte entities to the electrical migration of ions. However the functional resistance to the flow of ions may be due to change in the structure of the solvent or due to an increase in the ionic hydration. This problem has more interesting application in Human biology. The measurement of intracellular conductivity in Aplysia neurons shows variation of conductivity in presence of sugars (9)

There are several intravenous transfusion fluids. Usually 5% dextrose solution is used in the conditions of hypoglycaemia and normal saline (0.9%) is used in the case of dehydration. Dextrose saline (Dextrose 4.3% with saline 0.18%) is used as transfusion fluids in certain other conditions. In case where there is a need for 5% dextrose solution only, alkali halide presence is undesirable. In preparation of intravenous transfusion fluids, distilled, deionised water is to be used and any alkali halide impurities in water may overload the circulation with salt accompanying water. Even a sub clinical degree of alkali halide excess is harmful in post operative condition. In parenteral fluid therapy to overload the circulation is a grievous fault and grievously does the patient pay for it (10). In extracellular fluid potassium in mean concentrations of only 4.5 mmol/litre (11). In certain cases of psychiatry lithocarb (LiCo_3) is used as an antidepressant

Accumulation of potassium in the blood and extra

cellular fluids leads to oliguria or anuria (11). Hence it appears to be very useful to study the effect of electrolytes on the physical properties of non electrolyte solutions. Recent ultrasonic velocity and absorption studies (12-15) in aqueous solutions of non electrolyte like glucose, sucrose, fructose, maltose, galactose with the presence of alkali halides like NaF, LiCl, NaCl revealed very interesting features on the nature of molecular interactions in these solutions. The studies of sugars with the addition of low concentrations of alkali halides have been reported in this laboratory (16) but there is not much variation in the relaxation times in these low concentration. In order to understand more about the nature of molecular interactions in these solutions, the present PMR relaxation study have been undertaken and to elucidate the effect of alkali halides like NaCl and KCl on aqueous solutions of sugars such as D-glucose, fructose, sucrose, maltose and galactose since PMR relaxation studies are very sensitive to molecular environment (17).

EXPERIMENTAL:

The solutions were prepared by taking known amounts of sugar and dissolving it in double distilled water so as to obtain solutions in the concentration range 2% and 5% by w/w ratio. The experiment is repeated by adding NaCl and KCl in the concentration range 1 to 6 molar. The proton magnetic

spin-lattice relaxation times (T_1) and spin-spin relaxation times (T_2) were measured using Bruker PC 120 NMR process analyser at a RF frequency of 20 MHz and at a temperature of 40° C by circulating water from a thermostatically controlled water bath to an accuracy of $\pm 0.1^\circ$ C. 180- τ -90 pulse sequence was used for the measurement of T_1 and CPMG pulse sequences was used for the measurement of T_2 . Five fold accumulation was used for the reduction of error, which is usually less than 2%. The error in the 3-parameter fitting of relaxation curve for T_1 was less than 0.5%. The viscosity measurements were carried out with Ostwald's viscometer and density measurements were done using Pycnometer and a digital electronic balance as described previously in chapter.2. The accuracy in the measurement of viscosity is of the order of 1% and the accuracy in the measurement of density is of the order of 1%.

The observed data of spin-lattice and spin-spin relaxation times (T_1 & T_2), viscosity, density in aqueous solutions of D-glucose, sucrose, fructose, maltose and galactose without and with addition of NaCl and KCl are tabulated in tables 5.1 to 5.10. The variation of T_1 and T_2 as a function of sodium and potassium chloride concentration for 2% and 5% D-glucose, sucrose, fructose, maltose and galactose are shown in figures 5.1' to 5.10.

RESULTS:

AQUEOUS SUCROSE SOLUTIONS WITH SODIUM AND POTASSIUM CHLORIDE

Tables 5.1 and 5.2 shows the values of relaxation times T_1 and T_2 for aqueous solutions of sucrose with alkali halide concentration. The viscosity and density are also shown in tables 5.1 and 5.2. The variations of T_1 and T_2 as a function of sodium and potassium chloride concentration for 2% and 5% sucrose solution are shown in figures 5.1 and 5.2. From the figure 5.1(a,b), it can be seen that the addition of sodium chloride (NaCl) increases the relaxation time T_1 upto 1 molar concentration and then decreases slightly with further addition of NaCl. The addition of potassium chloride (KCl) in 2% aqueous sucrose solution increases the relaxation time initially upto 3 molar concentration and then decreases with further increase of KCl. The variation of relaxation times with increase of alkali halide concentration in 5% aqueous sucrose solution is similar to that of 2% aqueous sucrose solution. The relaxation times T_1 and T_2 for 2% aqueous sucrose solution (pure) are longer as compared to 5% aqueous sucrose solution. The values of viscosity generally increase with increase of alkali halide concentration in 2% and 5% aqueous solutions of sucrose. The viscosity values are higher in aqueous solutions of sucrose containing NaCl as compared to solutions containing KCl for both 2% and 5% aqueous

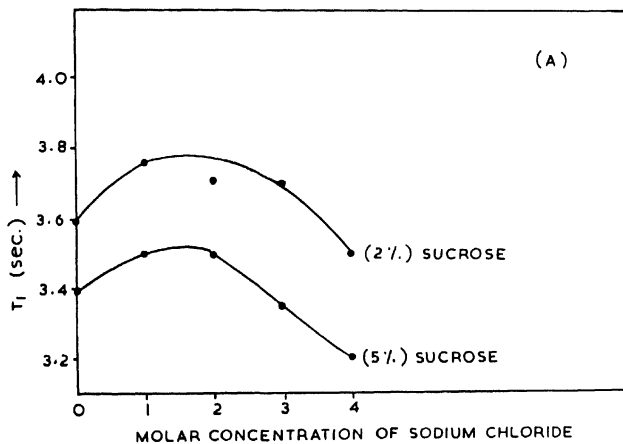
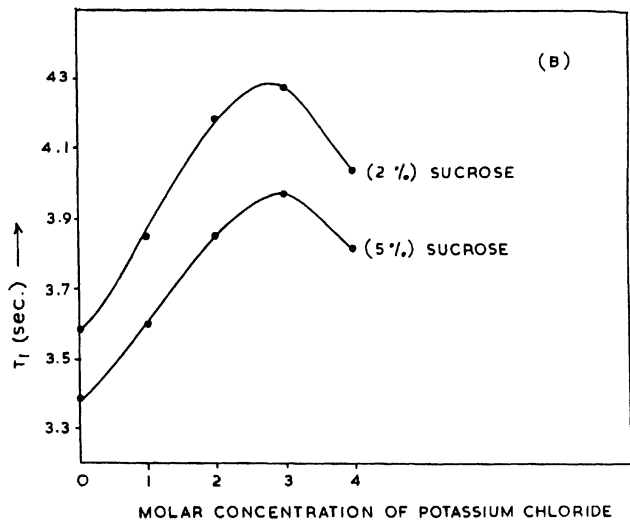


FIG. 5.1

VARIATION OF (T_1) WITH ALKALI HALIDE CONCENTRATION

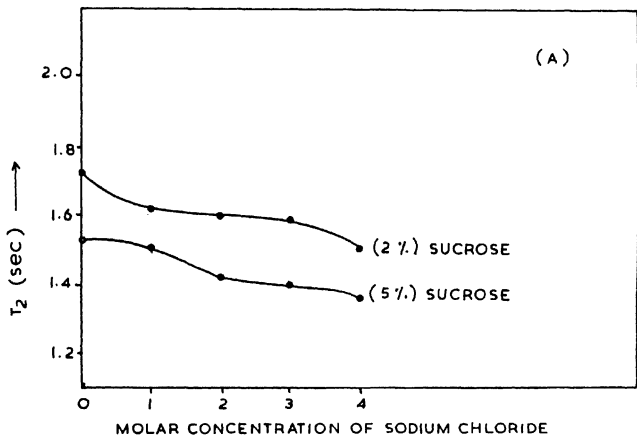
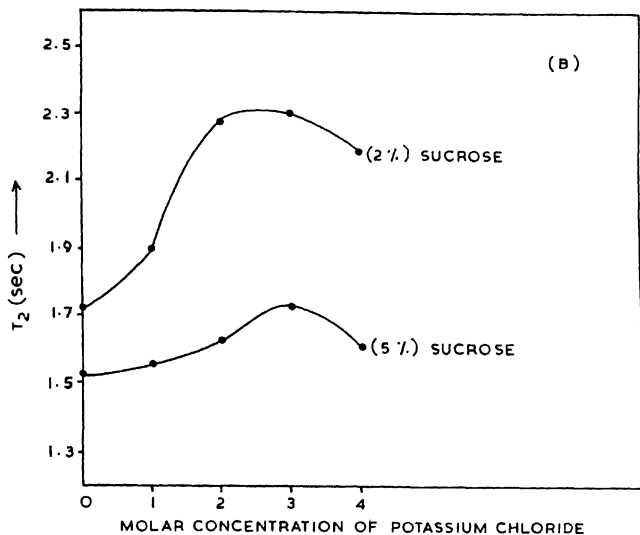


FIG. 5.2

VARIATION OF (T_2) WITH ALKALI HALIDE CONCENTRATION

sucrose solutions. The variation of spin-spin relaxation time T_2 as a function of NaCl and KCl concentrations are shown in figures 5.2(a,b). From the figures it can be seen that NaCl generally decreases the relaxation time whereas the addition of KCl increases the relaxation time T_2 upto 3 molar concentration in these aqueous sucrose solutions.

AQUEOUS GLUCOSE SOLUTIONS CONTAINING SODIUM AND POTASSIUM CHLORIDES

It can be seen from figure 5.3(a,b) that for glucose containing NaCl generally decreases the relaxation times. For solutions containing KCl in aqueous 2% and 5% glucose solution, the relaxation time T_1 increases initially upto 3 molar concentration and then decreases with further increase of KCl concentration. The variation of T_2 as a function of NaCl and KCl concentration in 2% and 5% aqueous glucose solutions are shown in figure 5.4(a,b). The relaxation time decreases with increase of NaCl concentration whereas the addition of KCl increases the relaxation time gradually in the case of 2% glucose. In 5% glucose solution, addition of KCl results in an increase of T_2 upto 3 molar concentration and then decreases with further increase of KCl concentration. The viscosity values are higher in 2% and 5% solution containing NaCl than KCl.

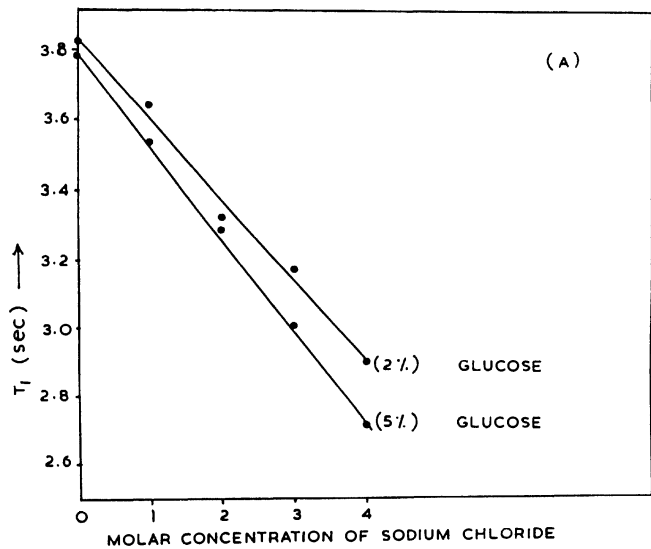
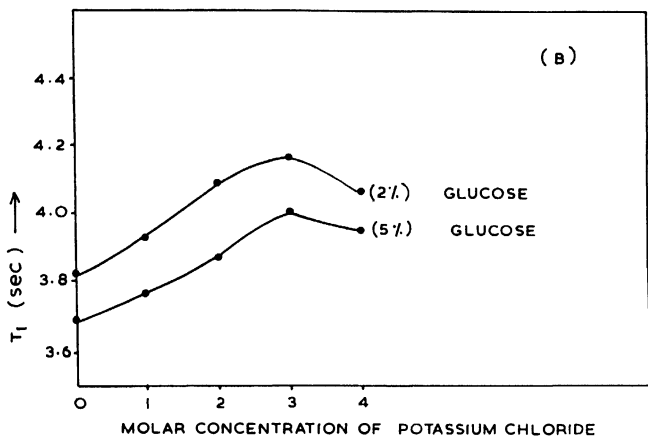


FIG. 5.3
 VARIATION OF (T_1) WITH ALKALI HALIDE CONCENTRATION

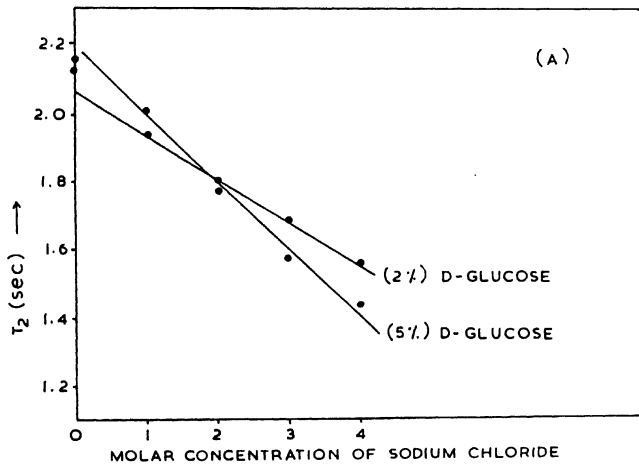
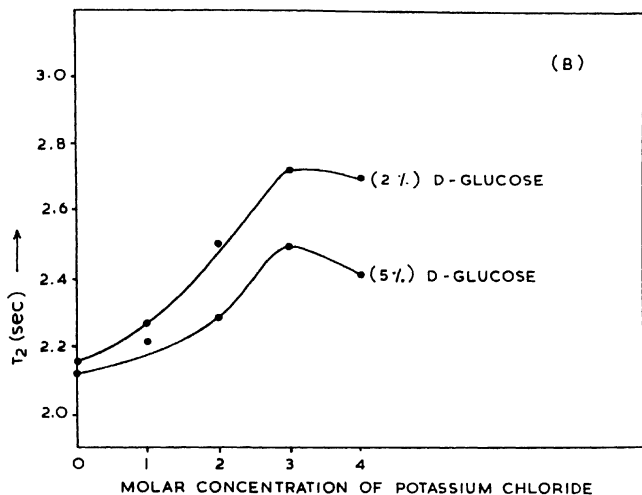


FIG. 5.4
VARIATION OF (T_2) WITH ALKALI HALIDE CONCENTRATION

AQUEOUS FRUCTOSE SOLUTIONS WITH NaCl and KCl

The variations of T_1 and T_2 as a function of NaCl and KCl concentrations for 2% and 5% aqueous fructose solutions are shown in figure 5.5(a,b). It can be seen from the figure that in 2% aqueous fructose solution, addition of NaCl results in a slight increase the relaxation time T_1 upto 2 molar concentration and then T_1 decreases with further addition of NaCl. In 5% fructose solution T_1 initially increases with increase of NaCl concentration upto 1 molar concentration and then decreases with further addition of NaCl. In 2% fructose solution, addition of KCl results in a sharp increase of T_1 upto 2 molar concentration and T_1 generally remains constant with further increase of KCl concentration. In 5% aqueous fructose solution, it can be seen from figure that T_1 increases gradually with increase of KCl concentration. From the figure 5.6(a,b) it can be seen that the variation of spin-spin relaxation time T_2 with increase of alkali halide concentration in 2% and 5% aqueous fructose solution is similar to the variation of T_1 discussed above.

AQUEOUS MALTOSE SOLUTIONS WITH NaCl AND KCl

Figure 5.7(a,b) shows the variation of T_1 for aqueous solutions of maltose with alkali halide concentration. It can be seen from the figure that in 2% and 5% aqueous maltose solution, the addition of NaCl results a sharp increase

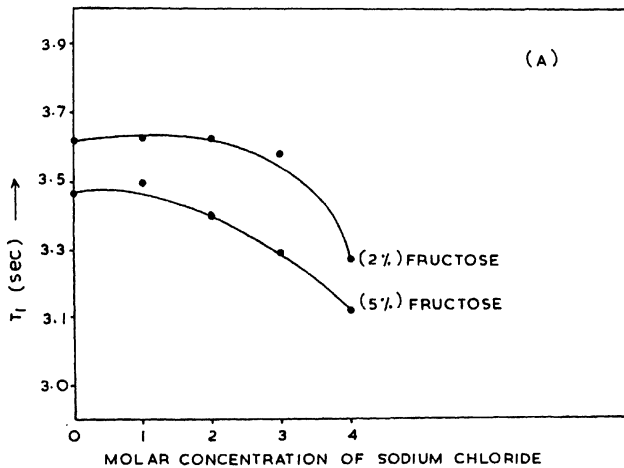
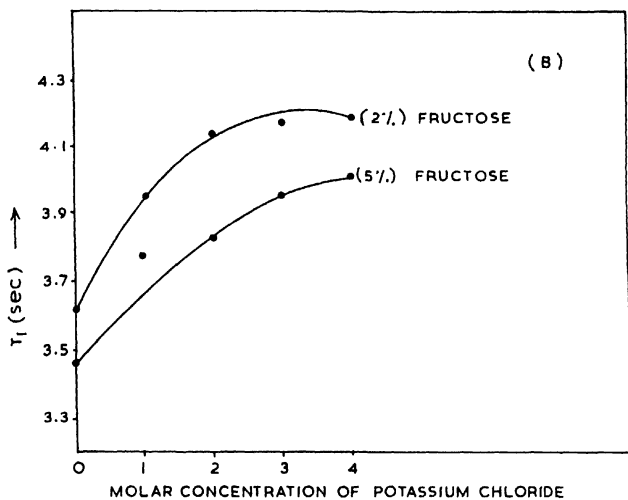


FIG. 5.5 VARIATION OF (T_1) WITH ALKALI HALIDE CONCENTRATION

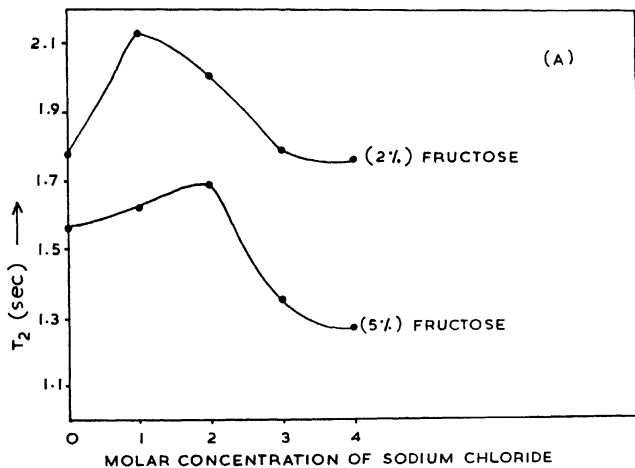
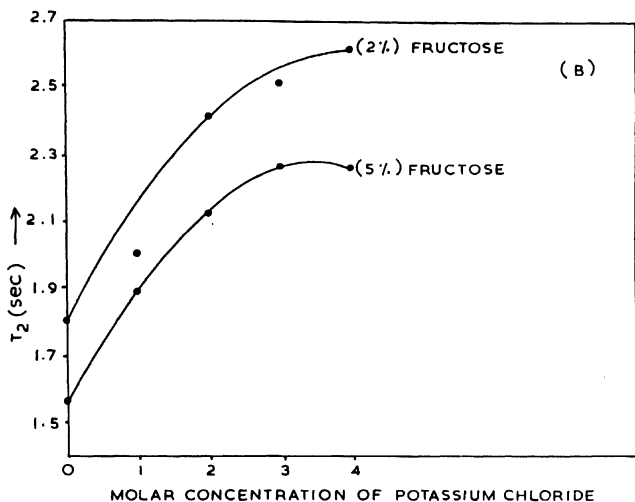


FIG. 5.6 VARIATION OF (T_2) WITH ALKALI HALIDE CONCENTRATION

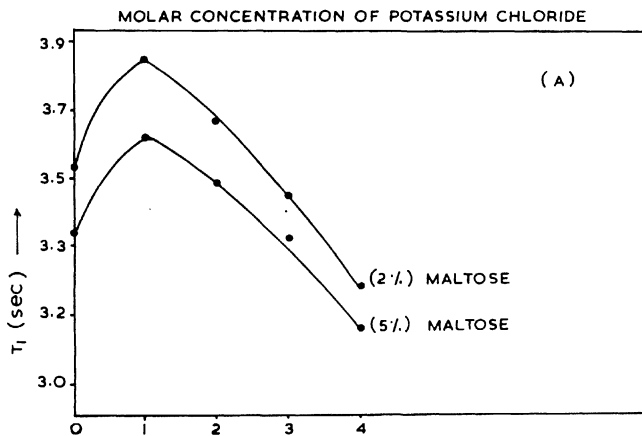
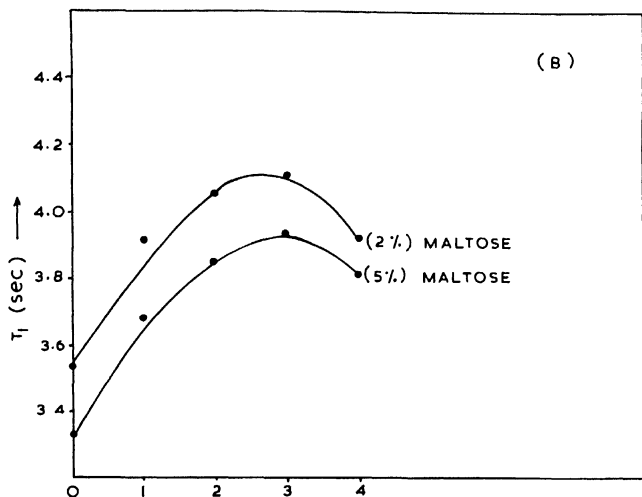


FIG. 5.7
 VARIATION OF (T_1) WITH ALKALI HALIDE CONCENTRATION

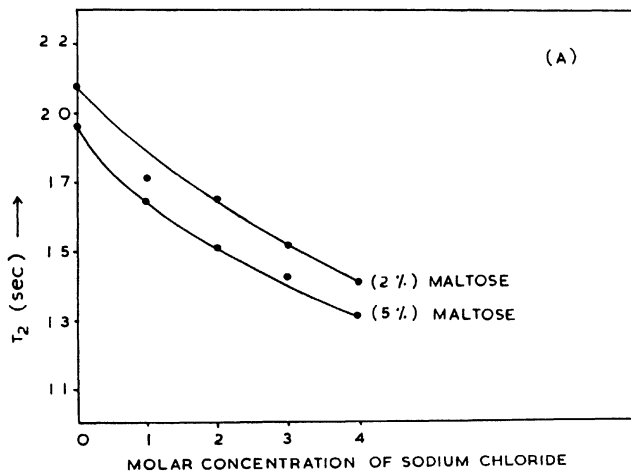
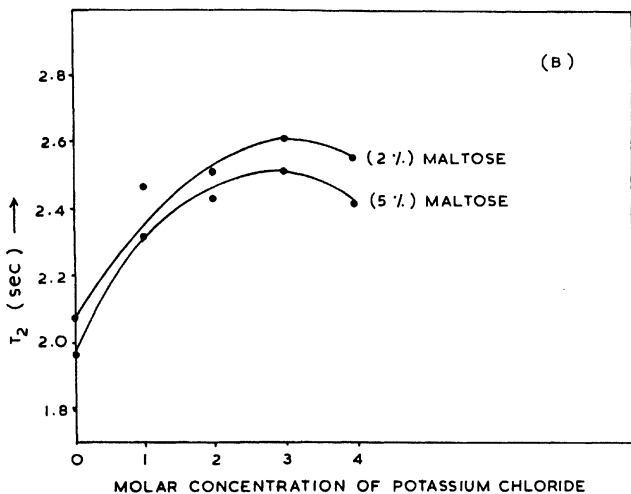


FIG. 5.8
VARIATION OF (T_2) WITH ALKALI HALIDE CONCENTRATION

upto 1 molar concentration and then T_1 decreases with further addition of NaCl. The addition of KCl in 2% and 5% aqueous maltose solution increases the relaxation time initially upto 3 molar concentration and then decreases with further increase of KCl. The variation of T_2 as a function of NaCl and KCl concentration in 2% and 5% aqueous maltose solutions are shown in figure 5.8 (a,b). From the figure it can be seen that in aqueous maltose solutions addition of NaCl generally decreases the PMR relaxation time. For solution containing KCl in 2% and 5% aqueous maltose solution, the relaxation time T_2 increases gradually. The values of viscosity also shows the same trend as observed in other sugar solutions.

aqueous galactose solutions with NaCl and KCl

It can be seen from figure 5.9(a,b) that for aqueous solutions of galactose containing NaCl increases the relaxation time upto 1 molar concentration and then decreases slightly with further addition of NaCl for both 2% and 5% aqueous galactose solution. The addition of KCl increases the relaxation time upto 3 molar and then decreases with further addition of KCl for both 2% and 5 % aqueous galactose solutions. The variation of T_2 as a function of NaCl and KCl concentration in 2% and 5% aqueous galactose solutions are shown in figure 5.10 (a,b). The relaxation time T_2 generally decreases for both 2% and 5% aqueous

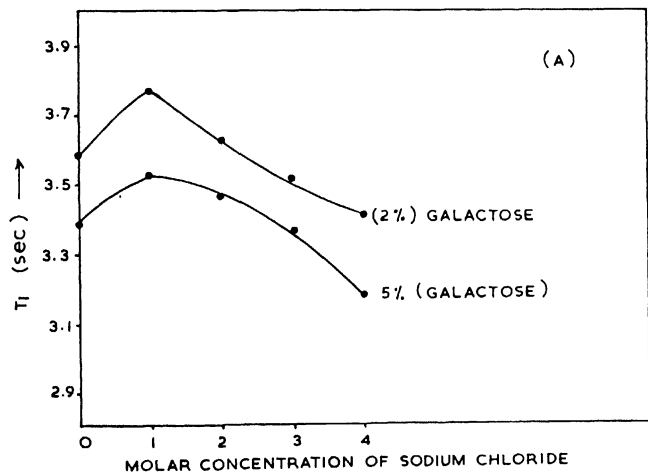
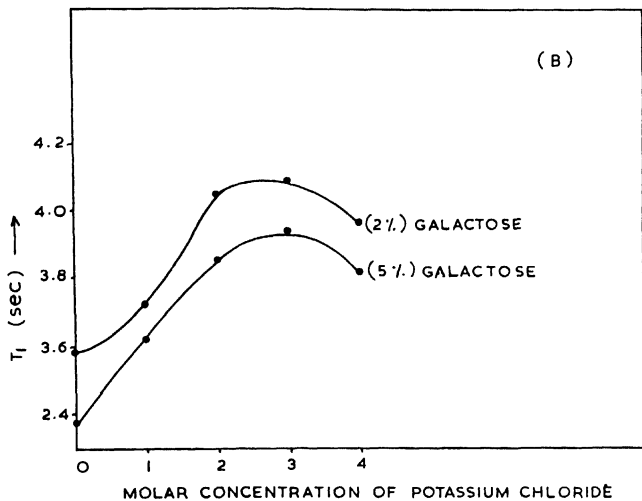


FIG. 5.9

VARIATION OF (T_1) WITH ALKALI HALIDE CONCENTRATION

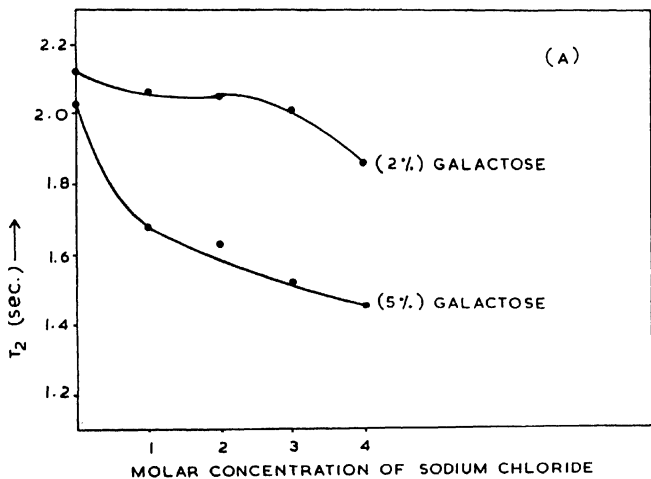
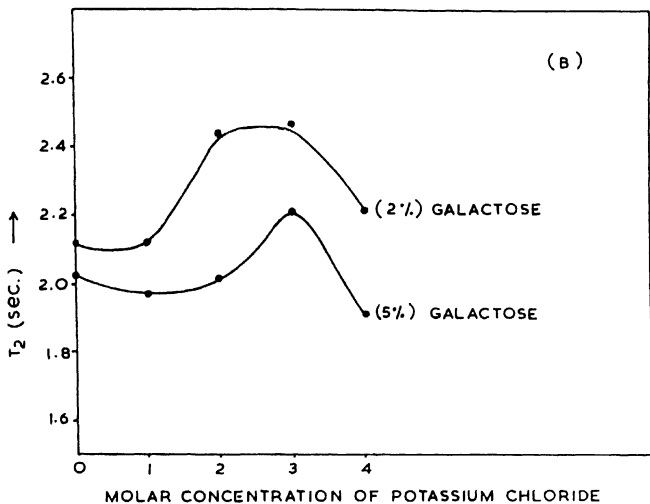


FIG. 5.10

VARIATION OF (T_2) WITH ALKALI HALIDE CONCENTRATION

galactose solutions containing NaCl. The addition of KCl to aqueous 2% and 5 % galactose solution results in an increase of T_2 upto 2 molar concentration followed by a slight decrease with further increase of KCl concentration.

To test whether the decay of magnetization in the solution is monoexponential or multiexponential, the variation of magnetisation (M) with the time interval for some aqueous solutions are shown in figures 5.11,5.12. From the figures it can be seen that the decay of magnetization is monoexponential in these solutions and the relaxing protons may be water protons.

SALIENT FEATURES:

- 1). The addition of sodium chloride to the sugar solutions generally reduces the relaxation time T_1 whereas the addition of potassium chloride results in an increase of T_1 for any particular sugar concentration.
- 2). The spin-spin relaxation time T_2 generally decrease with the addition of NaCl to the sugar solutions, whereas, the addition of KCl results in an increase in the value of T_2 .
- 3). The viscosity is found to increase in aqueous solutions of sugar with increase of NaCl/KCl concentration. The viscosity has higher values in aqueous solutions of sugars containing NaCl as compared to sugar solutions containing KCl.

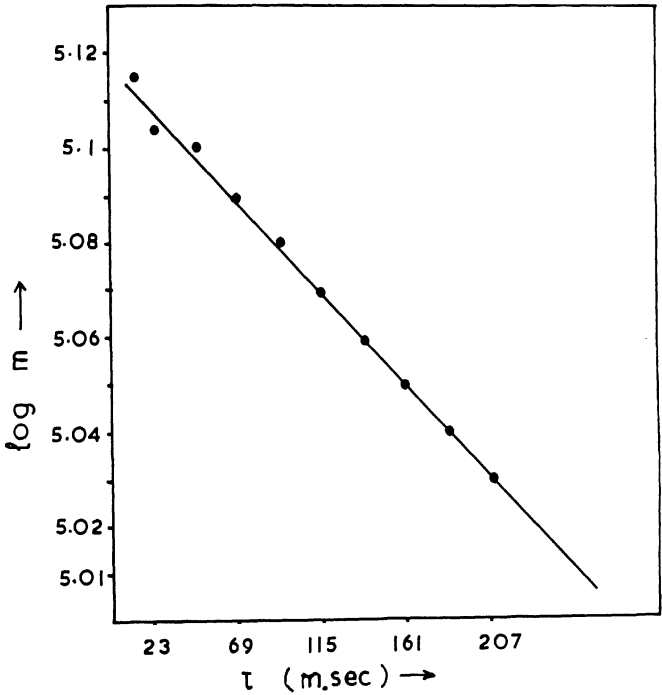


FIG. 5.11 \log VS τ OF GALACTOSE WITH NaCl

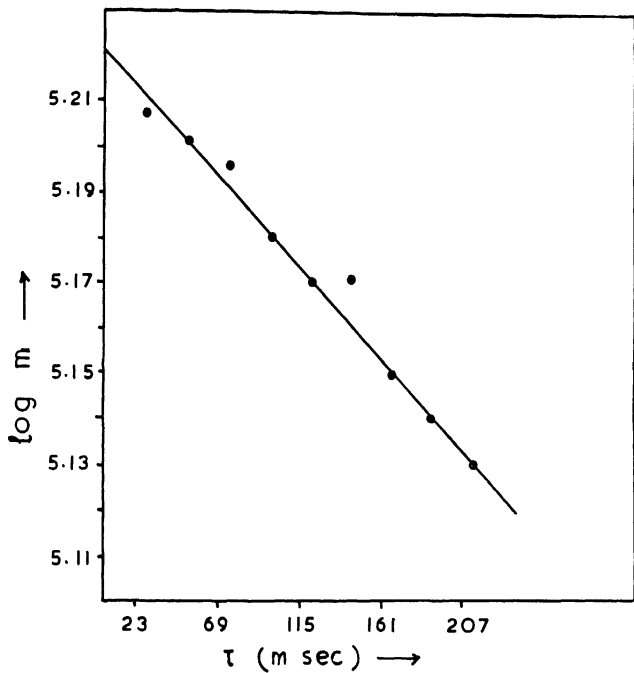


FIG. 5.12 $\log m$ VS τ OF GALACTOSE WITH KCl

DISCUSSION:

The results of the present study in aqueous solutions of sugars with the addition of alkali halide impurities indicate that the proton spin-lattice and spin-spin relaxation time (T_1 & T_2) are generally lower for solutions containing NaCl as compared to KCl. This result can be understood from the fact that the sodium ions are structure making (6) in the sense that their effect on a solution of water molecules is a restriction of their overall motional freedom. The potassium ions are termed as structure breaking implying that their effect in aqueous solution is to increase the freedom of movement of water molecules. The variation of T_1 and T_2 with increase of alkali halide concentration in these sugar solutions can be explained on the basis of two state fast exchange model proposed by Zimmerman and Brittin (18) and structure ordering and disordering effect proposed by Samailov (19).

It can be seen from the figures, the relaxation times T_1 and T_2 are generally higher value for 2% sugar solution as compared to 5% sugar solution. The decrease in the T_1 and T_2 values generally indicate a greater association of the molecules in these solutions. This results can be explained on the basis of two fraction fast exchange model (18). This model assumes that when substances of large molecular weight are dissolved in water, a small fraction of water is attached to macromolecules and is highly immobilised. The

rest of the water is like ordinary water (called bulk water) and rapid exchange between these two fractions would yield reduced average spin-lattice relaxation time T_1 weighted heavily by the small immobile fraction. If f is the fraction of water attached to the macromolecules, then the spin-lattice relaxation T_{1S} of the solution can be written as

$$\frac{1}{T_{1S}} = \frac{1-f}{T_{1W}} + \frac{f}{T_{1A}} \quad \text{----- (5.1)}$$

where T_{1W} is the relaxation time of the free water (bulk water) and T_{1A} is the relaxation time of the slow fraction attached to the macro molecules. T_{1A} being much shorter than T_{1W} . From the above equation, it can be seen that an increase in the value of f results in a decrease value of T_{1S} . The decrease in the value of spin-lattice relaxation time T_1 in (pure) aqueous solutions of sugar with increase of solute concentration can be explained as due to the increase in the fraction f of water attached to sugar molecules due to molecular association (20). This fraction f is likely to increase as the sugar concentration is increased which results in a further decrease of spin-lattice relaxation time T_1 . The same explanation is also applicable for the decreased value of spin-spin relaxation time T_2 at higher sugar concentration.

AQUEOUS SUCROSE SOLUTIONS CONTAINING POTASSIUM CHLORIDE

From figure 5.1(b) it can be seen that in 2% and 5% aqueous sucrose solutions containing KCl molecules, the PMR spin-lattice relaxation times T_1 generally increases with increase of KCl concentration and shows a maximum at 3.0 molar concentration. This increase could be explained as due to structure breaking effect of K^+ ions (20). The decrease in the values of T_1 when KCl concentration exceeds 3 molar can be understood by noting that the increased degree of motional freedom may increase the probability of molecular association between water and sucrose molecules. This association should result in an increase in the value of f which results in shortening of T_1 observed in both 2% and 5% aqueous sucrose solutions.

AQUEOUS SUCROSE SOLUTIONS CONTAINING SODIUM CHLORIDE

It can be seen from figure 5.1(a), that the PMR spin-lattice relaxation time T_1 in 2% and 5% aqueous solutions containing NaCl shows a maximum at 1 molar concentration but on further addition of NaCl it gradually decreases. The initial increase may be due to the fact that the macro-molecules water complex might have been disturbed by the introduction of Na^+ ions and thereby shedding some water molecules which result in increase in T_1 value. But on further addition of NaCl, the complex could have adjusted to the alkali environment and the structure making effect of

Na^+ ions are likely to be dominant and resulting in a characteristic decrease in the T_1 value (21). The same explanation also holds good for the variation of T_2 values observed in these solutions.

AQUEOUS GLUCOSE SOLUTIONS CONTAINING SODIUM AND POTASSIUM CHLORIDE

It can be seen from figure 5.3 (a), that PMR relaxation time T_1 in 2% and 5% aqueous glucose solution decreases with increase of sodium chloride concentration. This is to be expected because the sodium ions are structure makers and their effect is to restrict the overall motional freedom of solute water molecules. This restriction results in a decrease of bulk water fraction (increase in the value of f) which may be responsible for the decrease in the value of T_1 with increase in sodium chloride for any sugar concentration. The decrease in the value of T_1 with increase in D-glucose for any sodium chloride concentration has already been described.

The measured values of T_1 in the present case in aqueous glucose solutions have been explained on the basis of two state fast exchange model (equation.1). Equation.1 however, has to be modified for aqueous solutions of glucose containing sodium chloride.

It can be seen from figure 5.3(b) that the PMR relaxation time T_1 in both the two systems (2% and 5% glucose

solutions) increases with increase in the KCl concentration upto 3 molar but on further addition of KCl the T_1 value begins to decrease. This behaviour is similar to that as observed in sucrose solutions and the explanation proposed for sucrose solutions may also hold for the present case. The relaxation times T_2 observed for glucose solutions are shown in figures 5.4(a,b). The variation of T_2 with increase of NaCl concentration in the above solutions is similar to the variation of T_1 and hence the explanation proposed for the variation of T_1 may also hold good for the variation of T_2 with NaCl concentration.

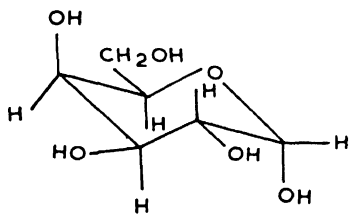
AQUEOUS FRUCTOSE, MALTOSE AND GALACTOSE SOLUTIONS WITH SODIUM AND POTASSIUM CHLORIDES

It can be seen from figure 5.5(b), the addition of KCl in 2% and 5% aqueous fructose solutions increases with increase of KCl concentration. The structure breaking effect of K^+ ions is predominantly observed in aqueous fructose solution containing KCl. The addition of NaCl molecules in 2% and 5% aqueous fructose solutions shows a slight increase in the relaxation time, but on further addition of NaCl gradually tend to decrease. This initial increase may be due to the disturbances in the structure due to the introduction of Na^+ ions, but the structure making interaction becomes predominant when the concentration of Na^+ ions is increased. This result is similar to the one observed in

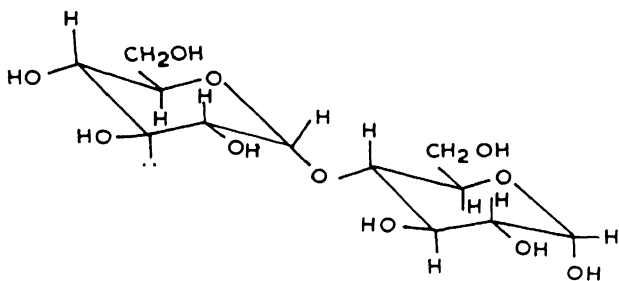
aqueous sucrose solutions. The explanation given for the variation of T_1 with increase of alkali halide concentration for glucose and sucrose solutions is also applicable for these solutions. From figures 5.7(b), 5.9(b), it can be seen that the influence of KCl on spin-lattice relaxation time T_1 in 2% and 5% aqueous maltose and galactose solutions is generally same as the other sugar solutions containing alkali halide impurities and the earlier explanation proposed may also hold for the present case.

It is also interesting to note that from the tables 5.1 to 5.10 that the T_1 and T_2 values in aqueous solutions of sugar are lower than that of water. The relaxation times T_1 and T_2 values are found to decrease as the concentrations of sugars are increased. However T_1 values are lower in maltose solutions than in galactose solutions for any particular solute concentration. The decrease in the values of T_1 or T_2 in any solution generally indicates a greater association of the molecules in them (20). The greater association may be brought either by the ionic hydration of the solute (22) or through hydrogen bonding between the solute and solvent molecules (23,24). In the present case, the increased cohesion between the molecules in the solution appears to be due to later effect. The maltose and galactose have different numbers of hydroxy groups which may be form hydrogen bonds with water molecules. The conductivity studies of sucrose solution (25) also suggestive of the

formation of hydrogen bonds between sucrose and water molecules. The effect of sugars on solution conductivity can be understood by a consideration of two components of solution viscosity, the macro and microviscosity. The macro viscosity results from the physical properties of the solute and is a function of the physical size and configuration of the solutes. These factors do not affect the ionic mobility and these do not depress conductivity. The microviscosity on the other hand results from chemical rather than physical forces. The depression of conductivity of sugars is dependent upon gram weight, not on molecular weight. This results from a structuring of water molecules caused by hydrogen bond formation between OH groups of sugars and oxygen of water. Hydrogen bonds then create a microscopic (or) molecular resistance to movement. The maltose molecules have nearly double the number of OH groups than the galactose as can be seen in the molecular formulae given in figure 5.13. Hence it is not unreasonable to expect a greater association in maltose solution as compared to galactose solutions. The greater association in maltose solutions will lead to lower T_1 values (20) in it as compared to galactose solution for any particular solute concentration. From the tables 5.7 to 5.10, it is observed that the T_1 values in pure maltose solutions are lower than pure galactose solutions. The possibility of greater association in maltose solutions through hydrogen bonding is also supported by the recent



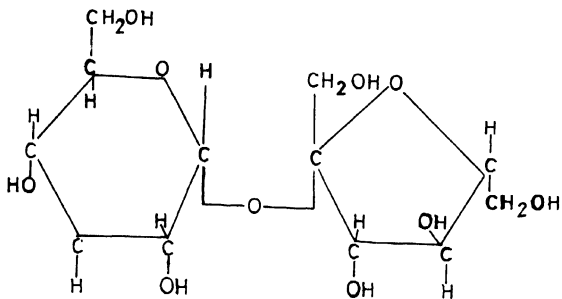
GALACTOSE



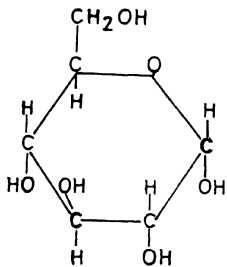
MALTOSE

Fig. 5.13

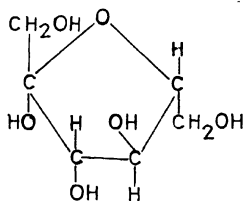
Structural formulae of sugar molecules.



SUCROSE



GLUCOSE



FRUCTOSE

Fig. 5.14

Structural formulae of sugar molecules

ionic conductivity studies (25) in aqueous sugar solutions. The molecular formulae of sucrose, glucose and fructose are shown in figure 5.14. From the figure it can be seen that sucrose molecules have nearly double the number of OH groups than the glucose and fructose solutions. The greater association in sucrose solutions will lead to lower T_1 values. From the tables 5.1 to 5.6, it is observed that sucrose shows lower values of T_1 or T_2 as compared to glucose and fructose solutions. The decrease in the T_1 values in these solutions is likely to hydrogen bond formation between water and sugar molecules.

The viscosity measurement in the above systems indicate that the viscosity is higher in aqueous solutions of sugars containing NaCl as compared to solution containing KCl. This is to be expected because the sodium ions are water structure makers and potassium are breakers. The increased cohesion brought about by NaCl may be responsible for the higher value of viscosity.

The present NMR study in the aqueous solutions of some sugars have generally established the water structure making and breaking properties of alkali ions. It is likely that the presence of alkali halide impurities may effect the flow characteristic of the solutions. Since the solutions are used in transfusion to patients in the hospitals, it is necessary to see that they do not contain any alkali halide impurities.

TABLE 5.1

PMR RELAXATION TIMES (T_1 & T_2) FOR AQUEOUS SOLUTIONS
OF 2% SUCROSE WITH SODIUM CHLORIDE

Molar concentration	T1 (sec)	T2 (sec)	P (g/cm ³)	$\eta \times 10^{-3}$ Nsec/m ²
0	3.5921	1.7216	0.9996	0.7431
1	3.7612	1.6216	1.0362	0.7692
2	3.7141	1.6011	1.0725	0.8638
3	3.7016	1.5112	1.1047	0.9767
4	3.5012	1.5012	1.1346	1.1284

PMR RELAXATION TIMES (T_1 & T_2) FOR AQUEOUS SOLUTIONS
OF 2% SUCROSE WITH POTASSIUM CHLORIDE

Molar concentration	T1 (sec)	T2 (sec)	P (g/cm ³)	$\eta \times 10^{-3}$ Nsec/m ²
0	3.5921	1.7216	0.9996	0.7431
1	3.8480	1.8957	1.0438	0.7468
2	4.1892	2.2811	1.0785	0.7504
3	4.2816	2.3015	1.1026	0.7812
4	4.0407	2.1930	1.1433	0.8587

TABLE 5.2

PMR RELAXATION TIMES (T_1 & T_2) FOR AQUEOUS
SOLUTIONS OF 5% SUCROSE WITH SODIUM CHLORIDE

Molar concentration	T_1 (sec)	T_2 (sec)	P (g/cm ³)	$\eta \times 10^{-3}$ Nsec/m ²
0	3.3912	1.5261	1.0092	0.7813
1	3.5041	1.5112	1.0519	0.8835
2	3.5042	1.4216	1.0827	0.9658
3	3.3517	1.4012	1.1149	1.0814
4	3.2016	1.3565	1.1436	1.1817

PMR RELAXATION TIMES (T_1 & T_2) FOR AQUEOUS
SOLUTIONS OF 5% SUCROSE WITH POTASSIUM CHLORIDE

Molar concentration	T_1 (sec)	T_2 (sec)	P (g/cm ³)	$\eta \times 10^{-3}$ Nsec/m ²
0	3.3912	1.5261	1.0092	0.7813
1	3.6376	1.5612	1.0613	0.8022
2	3.8517	1.6316	1.0999	0.8259
3	3.9742	1.7317	1.1331	0.9017
4	3.8201	1.6126	1.1666	0.9179

TABLE 5.3
 PMR RELAXATION TIMES (T_1 & T_2) FOR AQUEOUS SOLUTIONS
 OF 2% GLUCOSE WITH SODIUM CHLORIDE

Molar concentration	T_1 (sec)	T_2 (sec)	P (g/cm ³)	$\tau_2 \times 10^{-3}$ Nsec/m ²
0	3.8189	2.1491	0.9991	0.6899
1	3.5041	1.9422	1.0318	0.7875
2	3.3236	1.7923	1.0664	0.8459
3	3.1747	1.6871	1.0977	0.9403
4	2.9129	1.5512	1.1265	1.0809

PMR RELAXATION TIMES (T_1 & T_2) FOR AQUEOUS SOLUTIONS
 OF 2% GLUCOSE WITH POTASSIUM CHLORIDE

Molar concentration	T_1 (sec)	T_2 (sec)	P (g/cm ³)	$\tau_2 \times 10^{-3}$ Nsec/m ²
0	3.8189	2.1491	0.9911	0.7813
1	3.9341	2.2722	1.0409	0.7357
2	4.0862	2.4951	1.0760	0.7240
3	4.1572	2.7272	1.1105	0.7727
4	4.0591	2.7001	1.1460	0.7909

TABLE 5.4

PMR RELAXATION TIMES (T_1 & T_2) FOR AQUEOUS SOLUTIONS
OF 5% GLUCOSE WITH SODIUM CHLORIDE

Molar concentration	T_1 (sec)	T_2 (sec)	P (g/cm^3)	$\eta \times 10^{-3}$ Nsec/m ²
0	3.6891	2.1331	1.0085	0.7580
1	3.5421	2.0091	1.0403	0.8077
2	3.2931	1.7954	1.0731	0.8910
3	3.0011	1.5771	1.1042	0.9848
4	2.7072	1.4263	1.1315	1.1200

PMR RELAXATION TIMES (T_1 & T_2) FOR AQUEOUS SOLUTIONS
OF 5% GLUCOSE WITH POTASSIUM CHLORIDE

Molar concentration	T_1 (sec)	T_2 (sec)	P (g/cm^3)	$\eta \times 10^{-3}$ Nsec/m ²
0	3.6891	2.1331	1.0085	0.7580
1	3.7592	2.2212	1.0573	0.7871
2	3.8712	2.2854	1.0908	0.7924
3	3.9772	2.4962	1.1241	0.7985
4	3.9541	2.4121	1.1561	0.8887

TABLE 5.5

PMR RELAXATION TIMES (T_1 & T_2) FOR AQUEOUS SOLUTIONS
OF 2% FRUCTOSE WITH SODIUM CHLORIDE

Molar concentration	T_1 (sec)	T_2 (sec)	P (g/cm^3)	$\eta \times 10^{-3}$ Nsec/ m^2
0	3.6240	1.7965	1.0000	0.7187
1	3.6329	2.1314	1.0349	0.7995
2	3.6316	2.0154	1.0691	0.8590
3	3.5788	1.7940	1.1029	0.9796
4	3.2698	1.7624	1.1331	1.0887

PMR RELAXATION TIMES (T_1 & T_2) FOR AQUEOUS SOLUTIONS
OF 2% FRUCTOSE WITH POTASSIUM CHLORIDE

Molar concentration	T_1 (sec)	T_2 (sec)	P (g/cm^3)	$\eta \times 10^{-3}$ Nsec/ m^2
0	3.6240	1.7965	0.9960	0.7187
1	3.9460	2.0159	1.0416	0.7318
2	4.1391	2.4106	1.0798	0.7539
3	4.1655	2.5106	1.1147	0.7841
4	4.1926	2.6152	1.1471	0.9609

TABLE 5.6

PMR RELAXATION TIMES (T_1 & T_2) FOR AQUEOUS SOLUTIONS
OF 5% FRUCTOSE WITH SODIUM CHLORIDE

Molar concentration	T_1 (sec)	T_2 (sec)	P (g/cm^3)	$\eta \times 10^{-3}$ Nsec/m ²
0	3.4615	1.5615	1.0087	0.7804
1	3.4960	1.6197	1.0465	0.8830
2	3.3976	1.5917	1.0823	0.9517
3	3.2909	1.4517	1.1123	1.0341
4	3.1215	1.3716	1.1371	1.1396

PMR RELAXATION TIMES (T_1 & T_2) FOR AQUEOUS SOLUTIONS
OF 5% FRUCTOSE WITH POTASSIUM CHLORIDE

Molar concentration	T_1 (sec)	T_2 (sec)	P (g/cm^3)	$\eta \times 10^{-3}$ Nsec/m ²
0	3.4615	1.5615	1.0087	0.7804
1	3.7825	1.8891	1.0568	0.7659
2	3.8282	2.1234	1.0955	0.8202
3	3.9505	2.2701	1.1252	0.9020
4	4.0838	2.2615	1.1572	0.8699

TABLE 5.7

PMR RELAXATION TIMES (T_1 & T_2) FOR AQUEOUS SOLUTIONS
OF 2% MALTOSE WITH SODIUM CHLORIDE

Molar concentration	T_1 (sec)	T_2 (sec)	P (g/cm^3)	$\eta \times 10^{-3}$ Nsec/ m^2
0	3.5290	2.0681	1.0038	0.7255
1	3.8530	1.7061	1.0380	0.7929
2	3.6723	1.6502	1.0747	0.9116
3	3.4924	1.5163	1.1044	0.9892
4	3.2872	1.4123	1.1351	1.0914

PMR RELAXATION TIMES (T_1 & T_2) FOR AQUEOUS SOLUTIONS
OF 2% MALTOSE WITH POTASSIUM CHLORIDE

Molar concentration	T_1 (sec)	T_2 (sec)	P (g/cm^3)	$\eta \times 10^{-3}$ Nsec/ m^2
0	3.5290	2.0681	1.0038	0.7255
1	3.9102	2.4611	1.0400	0.7373
2	4.0492	2.5122	1.0793	0.7535
3	4.0994	2.6123	2.6122	0.7611
4	3.9211	2.5512	1.1483	0.8390

TABLE 5.8

PMR RELAXATION TIMES (T_1 & T_2) FOR AQUEOUS SOLUTIONS
OF 5% MALTOSE WITH SODIUM CHLORIDE

Molar concentration	T_1 (sec)	T_2 (sec)	P (g/cm^3)	$\eta \times 10^{-3}$ Nsec/ m^2
0	3.3295	1.9561	1.0105	0.7682
1	3.6160	1.6511	1.0523	0.9477
2	3.4923	1.5122	1.0816	0.9569
3	3.3271	1.4264	1.1100	1.0690
4	3.1590	1.3123	1.1438	1.3551

PMR RELAXATION TIMES (T_1 & T_2) FOR AQUEOUS SOLUTIONS
OF 5% MALTOSE WITH POTASSIUM CHLORIDE

Molar concentration	T_1 (sec)	T_2 (sec)	P (g/cm^3)	$\eta \times 10^{-3}$ Nsec/ m^2
0	3.3295	1.9561	1.0105	0.7682
1	3.6852	2.3261	1.0599	0.7854
2	3.8512	2.4261	1.0874	0.8058
3	3.9404	2.5123	1.1259	0.8608
4	3.8142	2.4151	1.1525	0.8919

TABLE 5.9

PMR RELAXATION TIMES (T_1 & T_2) FOR AQUEOUS SOLUTIONS
OF 2% GALACTOSE WITH SODIUM CHLORIDE

Molar concentration	T_1 (sec)	T_2 (sec)	P (g/cm^3)	$\eta \times 10^{-3}$ Nsec/ m^2
0	3.5861	2.1212	0.9997	0.6554
1	3.7732	2.0621	1.0384	0.7081
2	3.6301	2.0510	1.0756	0.8211
3	3.5192	2.0114	1.1103	0.9392
4	3.4122	1.8565	1.1423	1.0084

PMR RELAXATION TIMES (T_1 & T_2) FOR AQUEOUS SOLUTIONS
OF 2% GALACTOSE WITH POTASSIUM CHLORIDE

Molar concentration	T_1 (sec)	T_2 (sec)	P (g/cm^3)	$\eta \times 10^{-3}$ Nsec/ m^2
0	3.5861	2.1211	0.9997	0.6554
1	3.7342	2.1311	1.0417	0.6654
2	4.0472	2.4412	1.0820	0.7005
3	4.0924	2.4624	1.1133	0.7503
4	3.9642	2.2112	1.1354	0.7804

TABLE 5.10

PMR RELAXATION TIMES (T_1 & T_2) FOR AQUEOUS SOLUTIONS
OF 5% GALACTOSE WITH SODIUM CHLORIDE

Molar concentration	T_1 (sec)	T_2 (sec)	P (g/cm^3)	$\eta \times 10^{-3}$ Nsec/ m^2
0	3.3888	2.0282	1.0111	0.7151
1	3.5321	1.6861	1.0484	0.7874
2	3.4693	1.6333	1.0854	0.8571
3	3.3672	1.5214	1.1189	0.9668
4	3.1784	1.4562	1.1468	1.0536

PMR RELAXATION TIMES (T_1 & T_2) FOR AQUEOUS SOLUTIONS
OF 5% GALACTOSE WITH POTASSIUM CHLORIDE

Molar concentration	T_1 (sec)	T_2 (sec)	P (g/cm^3)	$\eta \times 10^{-3}$ Nsec/ m^2
0	3.3888	2.0281	1.0111	0.7150
1	3.6322	1.9661	1.0522	0.7338
2	3.8492	2.0122	1.0905	0.7568
3	3.9374	2.2124	1.1200	0.8086
4	3.8182	1.8152	1.1547	0.8598

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