

The diffusion of solute through wood saturated with water II

Effects of temperature on the diffusion of electrolytes

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Summary The effects of temperature on the diffusion of sodium pentachlorophenate (Na-PCP) and potassium chloride (KCl) through water-saturated wood have been measured in the three structural directions of Hinoki and Buna wood over a temperature range of 25–70°C.

The apparatus used in these experiments was the same as that described in a previous report¹⁾ except for some modifications in the design of the diffusion cell and electric circuit.

The test specimens were disks the size of 4 cm in diameter, and 1 cm (for longitudinal diffusion) or 0.15 cm (for transverse diffusion) in thickness.

The results obtained are as follows:

- (1) The deviations of measured values in the diffusion curves at each steady state, i.e. the coefficients of variation for regression coefficient in the amount of solute-transfer vs. time curves were less than 2 per cent (Fig. 2).
- (2) A plot of $\log D$ ($\text{cm}^2/\text{day} \times 10^{-3}$) against $1/T$ showed approximately linear relationship except for the diffusion of Na-PCP in R-direction of Hinoki (Fig. 3 and 4).
- (3) There was no difference in the diffusion coefficients between T- and R-directions of Hinoki, while the tangential diffusion coefficient of Buna was about twice as great as the radial value. The longitudinal diffusion coefficients of both the species were approximately 5–36 times as great as the transverse values (Table 3).
- (4) The diffusion rate of KCl was appreciably greater than that of Na-PCP in all cases. This tendency was especially more pronounced in the case of transverse diffusion (Table 4).
- (5) The apparent activation energy and the mean temperature coefficient in the diffusion process of Na-PCP were slightly greater than the corresponding values of KCl; further those of transverse diffusion were generally greater than values in longitudinal diffusion. In particular, these phenomena were remarkable in Hinoki (Table 5).
- (6) It was assumed that the apparent activation energy and the mean temperature coefficient in the diffusion process of electrolytes might be dependent upon the dimensions of the individual effective capillaries. Particularly they might be depend upon the mean free path of the solute traversed per unit distance in the diffusion direction, and also the number of capillaries whose radius was smaller than that of the mean free path.

Introduction

The exact nature of the diffusion behavior of an electrolyte solution through or into

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wood has not as yet been fully understood, because it involves many complicated problems such as the interaction between the wood capillary walls and the diffusing molecules or ions, the relative diffusibilities of anions or cations and undissociated molecules, and further the effects of temperature and of hydrogen ion concentration, etc.

In a series of experiments with respect to the diffusion of electrolytes through water-saturated wood, an attempt has been made to investigate some of these behaviors. In a previous report¹⁾ we discussed the application of an apparatus developed in this laboratory to simplify the measurement of the diffusion coefficient of electrolytes through water-saturated wood and still maintain a high degree of accuracy. From the experimental results, it was recognized that the apparatus could be used for many electrolyte solutions with the exception of some solutions of lower specific conductivity, such as boric acid; further that the accuracy of the measurement was comparatively high considering the variation of diffusion coefficients among the specimens.

On the basis of the results described above, the present paper deals with the effects of temperature on the diffusion of sodium pentachlorophenate and potassium chloride through wood saturated with water. These have been determined at various temperatures ranging from 25 to 70°C.

With regard to the temperature coefficients of diffusion of the electrolytes through wood, very few results have been reported up to present time. According to TOLLIDAY, WOODS and HARTUNG²⁾ who have determined the temperature coefficients of diffusion of electrolytes through membranes of copper ferrocyanide, the apparent activation energies in the diffusion process were values of 4-5 Kcal./mol., which are slightly greater than the values for diffusion in solution. CHRISTENSEN³⁾ has investigated the temperature coefficients of sodium chloride through heartwood samples of some Australian species over a range of temperatures from 20 to 50°C. He obtained results showing that the temperature coefficients for transverse diffusion in the two hardwoods tested were considerably greater than those for diffusion into solution. Furthermore, on the basis of the activation concept of diffusion, he suggested that high temperature coefficients might be indicative of the presence of narrow capillaries in the diffusion path.

This paper is concerned primarily with the effects of temperature on the diffusion rate in connection with the direction of diffusion and then with the apparent activation energy of the diffusion. The species used in these experiments were Hinoki wood (*Chamaecyparis obtusa* ENDL.) and Buna wood (*Fagus crenata* BLUME), and the measurements were carried out in each of the three different structural directions of the test specimens.

Experiments

(1) Specimens

The specimens were disks which were prepared from air-dried blocks of Hinoki heartwood and Buna sapwood. They were 4 cm in diameter and two different thicknesses, namely 1 cm for the longitudinal diffusion (L-direction) and 0.15 cm for the transverse diffusions (T- and R-directions). All specimens were thus closely matched and were submerged in distilled water until ready for use. The air-dried specific gravi-

ties of Hinoki and Buna were 0.44 and 0.60 g/cm³ on an average, respectively.

(2) Apparatus

The apparatus used for measurement of the diffusion rate was essentially the same as that described in our previous report¹⁾ except for some modifications in the design of the diffusion cell and of the electric circuit for the resistance measurement. The principal modifications were as follows:

(a) In the diffusion cell, vitreous cells were used instead of the plastic ones used in the previous study¹⁾, in order to prevent the changes of distance between the electrodes due to the clamping of the specimen inserted between the cells, and the fluctuation of temperature (see Fig. 1 in our previous report¹⁾).

(b) The combinations of variable resistance and resistances in the electric circuit were as shown in Table 1 (see Fig. 2 in our previous report¹⁾), because it was difficult to

Table 1 Set of resistances

Set	Variable resistance (K Ω)	Resistance (K Ω)
a	0—1	0.5
b	0—3	1
c	0—5	3
d	0—10	5
e	0—30	15
f	0—100	50

measure resistance at above 250 K Ω .

(c) Measurements were made with a dial graduated capable of being read to about 1/600 of full scale of the variable resistance, instead of the previous¹⁾.

(d) An ammeter with a range of 0–50 μ A was used to facilitate the detection of null-point instead of the 0–100 μ A ammeter used in the previous study¹⁾.

(3) Experimental procedure and calculation of diffusion coefficient

The measurements of the diffusion rate were made in a manner similar to those described in the previous report¹⁾, i. e. a water-saturated test specimen heated to the desired temperature was inserted between the cells, clamped in the usual manner, and the external surface of the specimen was then covered with a paraffin or a mixture of tin oxide and linseed oil to prevent the loss of solution from the specimen and the cell. Thereafter, in order to give a concentration gradient of the solute in the specimen, a solution of constant temperature with a given concentration was poured in one side of the diffusion cell (cell-A) and distilled water at the same temperature in the other (cell-B). These diffusion cells were then enclosed in a thermostat controlled to within 0.5°C of a desired temperature. All of the procedures described above were made as fast as possible to avoid fluctuation of the temperature of the solution in the cells and of the test specimen.

Using the electrical conductivity method at suitable time intervals, the transfer of the solutes from cell-A to cell-B resulting from the concentration gradient was thus determined by measuring the electric resistance of the solution in cell-B. The solutions used in these experiments were sodium pentachlorophenate (Na-PCP) and potassium chloride (KCl) at a concentration of 3 per cent, and the diffusion rate was measured at 15°C intervals in temperatures ranging from 25 to 70°C for all disks. The diffusion was allowed to continue at each temperature until five consecutive readings at a steady state were obtained. In this case, the deviations of measured values in the diffusion curves at each steady state, i. e. the coefficients of variation for regression coefficient in

the amount of solute-transfer vs. time curves were less than 2 per cent.

Besides the diffusion measurements described above, a calibration curve (i.e. the

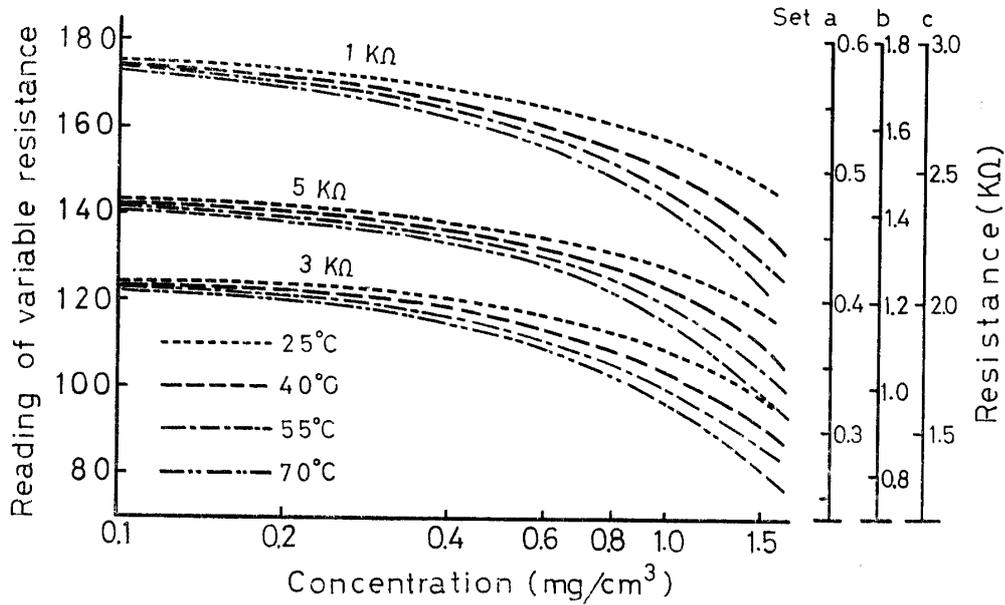


Fig. 1. An example of calibration curve for KCl

relation between the concentration of the solution and the electric resistance) at each temperature was preliminarily measured in relation to the individual cell-B. An example of a set of calibration curves is illustrated in Fig. 1. The total quantity (m) of solute diffusing through the test specimen at any time (t) could then be calculated by the product of concentration (g/cm^3) obtained by using the calibration curve and the volume of cell-B (about 36 cm^3). Examples of typical diffusion curves on the basis of the abovementioned calculation are shown in Fig. 2.

The linear portion of the diffusion curves shown in Fig. 2 shows that the transfer of solutes through the test specimen perhaps was under a

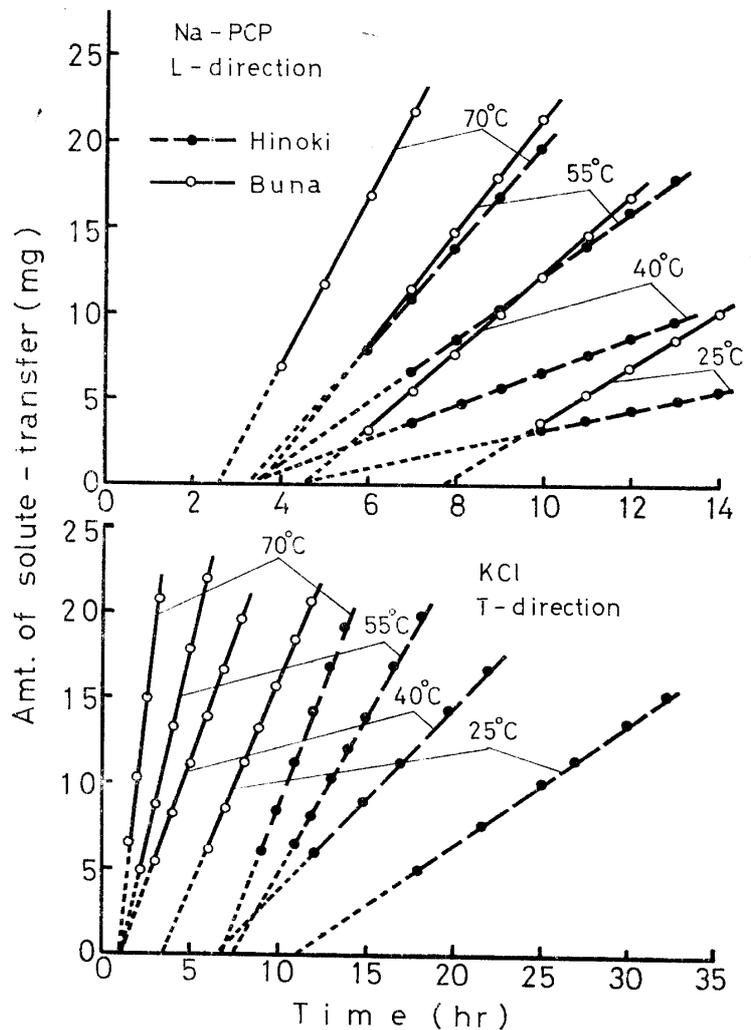


Fig. 2. Examples of diffusion curves.

steady-state condition. Using the Fick's Law as described in our previous report¹⁾, the diffusion coefficient (D) for the transfer of the solutes can hence be expressed by the following equation :

$$D = \frac{1}{A} \frac{l}{C_1 - C_2} \frac{dm}{dt} \dots\dots\dots(1)$$

in which A is the effective area of the test specimen (cm²), l its thickness in the direction of diffusion (cm), C₁ and C₂ the concentrations of the solutions in cell-A and cell-B (g/cm³) respectively and dm/dt the rate of transfer of solutes passing through the test specimen per unit time (g/sec).

Actually the concentration of solution in the diffusion cells changed because of the transfer of solutes, but this change was negligible and within the limits of experimental error due to the fact that only a small fraction (less than 2.5 per cent) of the total solute diffused during the course of measurements.

Results and discussion

(1) Diffusion coefficient

Table 2 shows the values of the diffusion coefficients of Na-PCP and KCl for both

Table 2 Diffusion coefficient (D) and standard deviation (σ) for each species, direction of diffusion, and temperature

(Unit ; cm²/sec×10⁻⁷)

Solute	Species	Direction	Temperature (°C)							
			25		40		55		70	
			D	σ	D	σ	D	σ	D	σ
Na-PCP	Hinoki	T	—	—	0.40	0.07	0.71	0.20	1.70	0.35
		R	—	—	0.36	0.08	0.60	0.15	1.86	0.45
		L	12.3	4.11	16.7	2.03	27.9	2.82	42.6	2.91
	Buna	T	1.40	0.39	1.90	0.22	3.06	0.26	4.83	1.09
		R	—	—	1.11	0.23	1.82	0.16	3.97	0.56
		L	24.4	6.92	34.9	8.51	49.7	10.14	82.1	21.41
KCl	Hinoki	T	1.73	0.30	3.20	0.19	5.28	0.75	8.16	0.96
		R	1.73	0.28	2.91	0.43	4.53	0.86	8.06	0.71
		L	31.4	5.93	55.0	5.41	74.0	7.70	115.2	10.11
	Buna	T	7.32	0.48	11.8	1.00	19.6	2.86	25.5	5.90
		R	2.83	0.58	4.74	0.67	9.22	0.20	15.2	2.52
		L	46.9	5.80	63.5	7.83	87.9	5.82	121.0	8.60

(Each value of D is the mean of five test specimens.)

the species in three directions of diffusion at various temperatures over a range of 25-70°C and the standard deviations. Each value of the diffusion coefficient is the mean of values from at least five test specimens. Since the beginning of the steady-state diffusion of Na-PCP in the T- and R-directions of Hinoki, and the R-direction of Buna has appeared too slowly to do the diffusion measurement at 25°C, these values are not shown in Table 2.

From the results shown in Table 2, it is seen that the variations of diffusion coef-

ficients among the test specimens are considerably greater and that the values of diffusion coefficient of Na-PCP at 40°C for both of the species and in all directions of diffusion are slightly smaller than the corresponding values in our previous report¹⁾.

As the diffusion coefficient of KCl into water in bulk is 185.7×10^{-7} cm²/sec at a temperature of 25°C, the diffusibility of KCl in the L-direction decreases by the wood structure to about 1/6 in Hinoki and 1/4 in Buna. The diffusion coefficients in R-direction decrease to about 1/107 in Hinoki and to about 1/66 in the case of Buna compared with the bulk diffusion coefficient, and the tangential diffusion coefficients decrease to about 1/107 in Hinoki and to 1/25 in Buna. The rates of diffusion of the solutes through wood, as mentioned above, are considerably smaller in comparison with the bulk diffusion rates. These phenomena are seen more clearly in the transverse diffusion than the longitudinal one for each species. Regarding this fact, it is assumed that the cause for these phenomena is probably dependent upon the dimension and the number of effective capillaries through which solute could diffuse, as will be shown later in this report. On the other hand, although the bulk diffusion coefficient of Na-PCP has not as yet been fully clarified, it may be expected from the results in Table 2 that the diffusibility of Na-PCP into wood probably will show a tendency similar to that of KCl.

Fig. 3 and 4 illustrate the plots of the logarithm of the diffusion coefficient ($\text{cm}^2/\text{day} \times 10^{-3}$) against the reciprocal of the absolute temperatures. As shown in these figures, although the values of diffusion coefficient and the angles of inclination of $\log D$

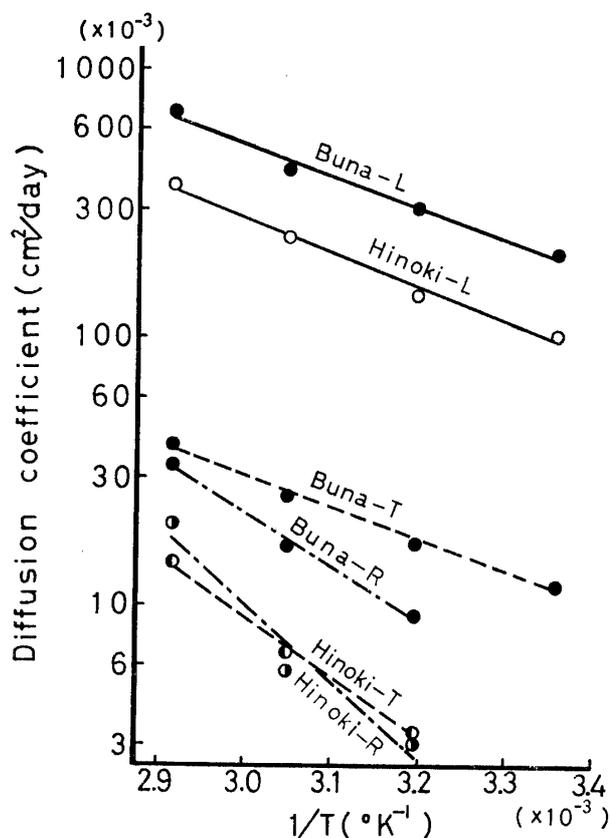


Fig. 3. Relationship between diffusion coefficient and $1/T$ for Na-PCP

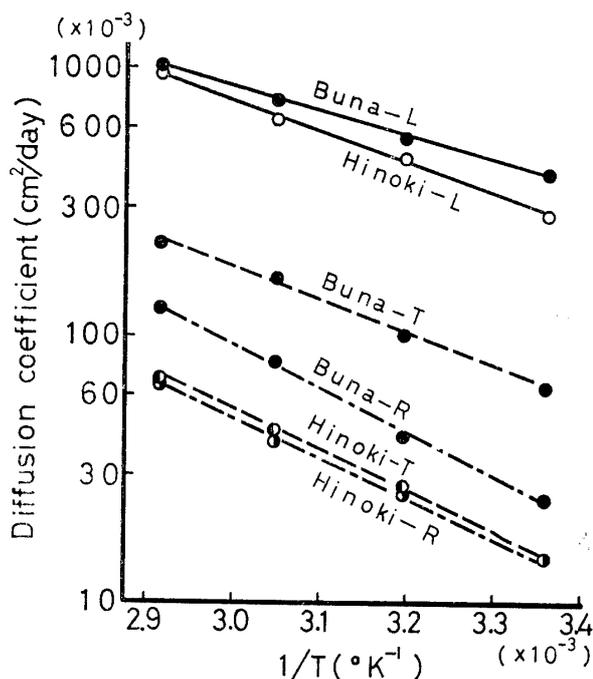


Fig. 4. Relationship between diffusion coefficient and $1/T$ for KCl

against $1/T$ of Na-PCP differ from those of KCl, $\log D$ decreases almost linearly with an increase in $1/T$ in all cases. This has been found previously by many investigators, and also the order of magnitude of the three structural directions is similar for both solutes, i. e. Buna-L > Hinoki-L > Buna-T > Buna-R > Hinoki-T > Hinoki-R. The $\log D-1/T$ curve for Na-PCP in the R-direction of Hinoki, however, exhibited some departure from linearity in the range of temperatures tested.

In order to compare the relative effects of the three structural directions in each species the diffusion coefficient in the T-direction was taken as unity in each case, and the diffusion coefficients in the other directions were calculated relative to this. These results are given in Table 3.

With regard to Hinoki, there is no difference between the diffusion rates in T- and R-directions in either Na-PCP or KCl. However, the longitudinal diffusion rates are 16

(KCl) to 36 (Na-PCP) times as great as the transverse values. In the case of Buna, the diffusion rates in T-direction are approximately twice as great as those in R-direction. There have not been enough data to explain the results in this stage. On the other hand, the diffusion rates in L-direction are 5 (KCl) and 18 (Na-PCP) times as great as those in T-direction. The difference in the diffusion rates between the longitudinal and the transverse directions is mainly due to the difference in the capillary structure of both directions, i. e. the diffusion in L-direction is greatly facilitated, by the coarse and effective capillaries such as vessels or tracheids which are orientated in that direction.

The ratios of the diffusion coefficient of KCl to that of Na-PCP for each temperature and structural direction are shown in Table 4. Table 4 shows that the diffusion of Na-PCP through or into wood

is extremely difficult compared with that of KCl. This is especially more conspicuous in the case of the transverse diffusion than the longitudinal one. The values of D_{KCl}/D_{Na-PCP} in transverse directions of Hinoki increase gradually with a decrease in temperature. These will be discussed later,

Table 3 Relative effects of diffusion in different structural directions

Species	Temperature (°C)	Na-PCP			KCl		
		T	R	L	T	R	L
Hinoki	25	—	—	—	1.00	1.00	18.2
	40	1.00	0.92	41.7	1.00	0.91	17.2
	55	1.00	0.85	39.5	1.00	0.86	14.0
	70	1.00	1.10	25.6	1.00	0.99	14.9
	Mean	1.00	0.96	35.6	1.00	0.94	16.1
Buna	25	1.00	—	17.4	1.00	0.38	6.4
	40	1.00	0.58	18.0	1.00	0.40	5.4
	55	1.00	0.59	19.5	1.00	0.47	4.5
	70	1.00	0.82	17.0	1.00	0.58	4.6
	Mean	1.00	0.66	17.9	1.00	0.46	5.2

Table 4 Ratio of the diffusion coefficient of KCl to that of Na-PCP

Species	Direction	Temperature (°C)				Mean
		25	40	55	70	
Hinoki	T	—	8.02	6.48	4.79	6.43
	R	—	8.00	7.51	4.32	6.61
	L	2.71	3.29	2.65	2.71	2.84
Buna	T	5.22	6.22	6.40	5.39	5.81
	R	—	4.30	5.04	3.84	4.39
	L	1.92	2.01	1.77	1.47	1.79

(2) Activation energy and temperature coefficient in the diffusion process

In order to make clear the effects of temperature on the diffusion of electrolytes, the apparent activation energy and the mean temperature coefficient of diffusion are considered below. The apparent activation energy is the minimum kinetic energy (E) that an ion or a molecule requires to diffuse from one position to the next, or in other words, that, it requires to overcome the forces holding it in position and to pass any energy barriers that may be present.

According to CHRISTENSEN³⁾, the relationship between the energy mentioned above and the diffusion coefficient can be expressed by using the Maxwell-Boltzmann's law of velocity distribution and the kinetic theory of gas as follows:

$$D = B\sqrt{T} \exp(-E/RT) \dots \dots \dots (2)$$

in which B is a constant, R the gas constant, T the absolute temperature. Therefore the following formula is obtained.

$$\log(D/\sqrt{T}) = -E/RT + \text{const.} \dots \dots \dots (3)$$

Since linear relationships of $\log(D/\sqrt{T})$ vs. $1/T$ are obtained as shown in Fig. 5 and 6, it is possible to calculate the apparent activation energy in the diffusion process from the slope of the straight line. On the other hand, the mean temperature coefficient is evaluated by the ratio of the diffusion rates at temperature differences of 10°C in accordance with the proposal of CHRISTENSEN³⁾. The relation between the apparent activation energy (E) and the mean temperature coefficient (Q_{10}) are given by the following equation, as was shown previously by him³⁾.

$$Q_{10} = (D_{t+10})/D_t = \sqrt{(T+10)/T} \exp[10E/RT(T+10)] \dots \dots \dots (4)$$

In Fig. 5 and 6 $\log(D/\sqrt{T})$ vs. $1/T$ curves are plotted by using $\log D-1/T$ relations

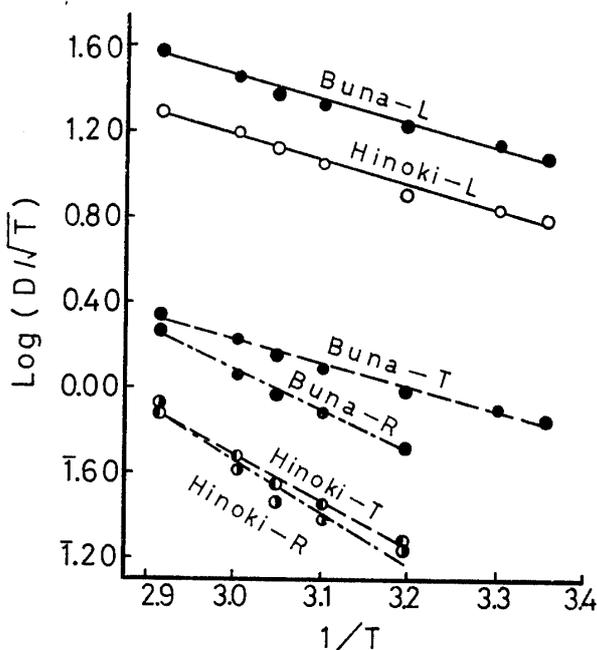


Fig. 5. Relationship between $\log(D/\sqrt{T})$ and $1/T$ for Na-PCP

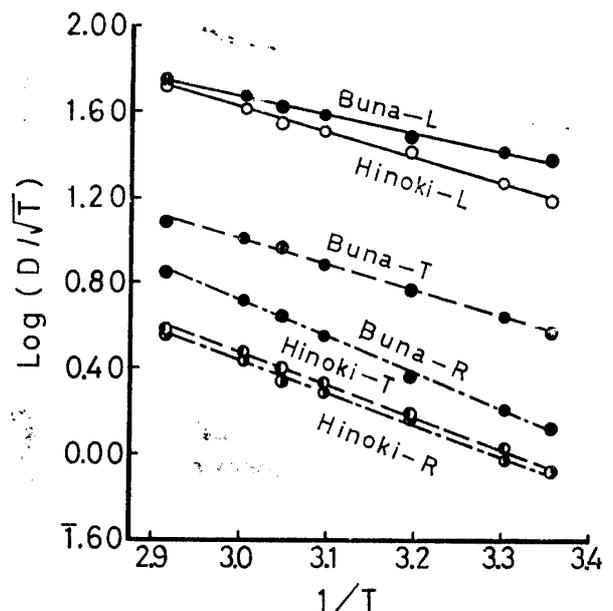


Fig. 6. Relationship between $\log(D/\sqrt{T})$ and $1/T$ for KCl

presented in Fig. 3 and 4. Fig. 5 and 6 show that $\log(D/\sqrt{T})-1/T$ curves are linear within variations of about 2 per cent in all cases except for the diffusion of Na-PCP in

R-direction of Hinoki. Values of the apparent activation energies and the mean temperature coefficients obtained from the diffusion measurements are shown in Table 5.

Table 5 Mean temperature coefficients (Q_{10}) and apparent activation energies (E: Kcal./mol.) in diffusion process

Solute	Species	Temperature (°C)	T		R		L	
			Q_{10}	E	Q_{10}	E	Q_{10}	E
Na-PCP	Hinoki	30—40	—	—	—	—	1.13	2.0
		40—50	1.47	7.4	1.40	6.0	1.32	6.1
		50—60	1.62	9.9	1.74	12.0	1.39	6.7
		60—70	1.79	12.8	2.05	15.9	1.31	5.8
		Mean	1.63	10.0	1.73	11.4	1.31	5.2
	Buna	30—40	1.21	3.2	—	—	1.26	4.0
		40—50	1.34	5.5	1.41	6.6	1.18	3.1
		50—60	1.37	6.3	1.51	8.4	1.30	5.3
		60—70	1.39	7.2	1.70	11.7	1.32	4.5
		Mean	1.33	5.6	1.54	8.9	1.27	4.5
KCl	Hinoki	30—40	1.48	7.2	1.39	6.0	1.45	6.8
		40—50	1.41	6.6	1.36	5.9	1.22	3.7
		50—60	1.36	6.2	1.43	7.3	1.29	5.1
		60—70	1.33	6.1	1.42	7.6	1.33	6.2
		Mean	1.40	6.5	1.40	6.7	1.32	5.4
	Buna	30—40	1.37	5.6	1.47	7.0	1.24	3.9
		40—50	1.37	5.9	1.49	7.7	1.24	3.9
		50—60	1.32	5.9	1.47	7.9	1.24	4.2
		60—70	1.21	3.6	1.40	7.2	1.24	4.5
		Mean	1.32	5.3	1.47	7.5	1.24	4.2

(Apparent activation energy of bulk diffusion of KCl into water is 3.96 Kcal./mol.)

As was previously pointed out, since the variation of diffusion coefficient for each specimen was about 2 per cent, the corresponding values of Q_{10} and E are 4–6 per cent. From the results shown in Table 5, it is seen that the variances of the mean temperature coefficients and the apparent activation energies between both the species and among the three structural directions are considerably great. The variances in these experiments are slightly greater than those of sodium chloride through some Australian timbers by CHRISTENSEN⁸⁾ already described.

According to Table 5, the apparent activation energy and the mean temperature coefficient in the case of the diffusion of Na-PCP are, with minor exceptions, slightly greater than the corresponding values of KCl. In particular, this tendency is more pronounced in Hinoki than Buna. Furthermore, Table 5 shows that the apparent activation energies and the mean temperature coefficients in T- and R-directions of both the species are generally greater than those in L-direction of the respective species. This tendency is appreciably more evident on Hinoki than Buna which is as described above. In addition, the apparent activation energy of KCl in L-direction of Buna is

similar to that of bulk diffusion of KCl into water (apparent activation energy of the diffusion of KCl into water in bulk is 3.96 Kcal./mol.). The apparent activation energy of Na-PCP in the bulk state has not as yet been examined rigorously, but it may be expected to behave somewhat similar to KCl.

(3) *Discussion*

In wood the solute diffuses mainly through cell cavities and pit membrane openings, and probably very little through transient capillaries developed in swollen cell walls. Since the radius of the cell cavities, 10^{-2} to 10^{-4} cm, is much larger than that of the mean free path of the solute under the diffusion conditions, the diffusion coefficient of the solute in the cell cavities is identically the same as the bulk diffusion coefficient.

On the contrary, the diameter of the pit membrane openings is very small; the average radius of these openings is known to be about 3×10^{-6} cm. In such openings the solute can no longer behave as a normal diffusion solute, for the capillary radius is smaller than the mean free path of the diffusing molecule or ion, and the rate of diffusion is influenced by very frequent collision with the walls. In addition, in such narrow paths the diffusing molecules or ions need kinetic energy to overcome the potential barriers which keep them bound to a particular site on the capillary wall at each collision. Thus the apparent activation energy and the mean temperature coefficient in the diffusion process might be dependent upon the dimension of the individual capillaries. In a certain capillary system the effect might be accentuated by increasing the size of diffusing solute.

In comparing the longitudinal and transverse diffusions, solute has to pass more frequently through the pit membrane openings during diffusion at a unit distance in the transverse direction than in the longitudinal direction. Taking this viewpoint, the experimental results will be discussed.

The results shown in Table 5 indicate that the apparent activation energy and the mean temperature coefficient in the transverse directions are generally greater than those in the longitudinal directions in all cases. This is probably due to a difference in the number of pit membrane openings where the solute passed through. Furthermore, the difference is, with minor exceptions, remarkable in the diffusion of Na-PCP. Perhaps the phenomena can be explained by the difference in size between undissociated molecules of KCl and Na-PCP, or ions dissociated from KCl and Na-PCP.

The effect of the size of molecule or ion on the diffusion appears in the result shown in Table 4. If the electrolytes diffused only through free paths, the diffusion ratio, $D_{\text{KCl}}/D_{\text{Na-PCP}}$, would not vary depending on the diffusion directions. However, experimental fact shows that the values of the diffusion ratio in the transverse directions are larger than those in the longitudinal direction. As mentioned above, in the transverse diffusion the molecules or ions have to pass through very many narrow paths compared with those in the longitudinal diffusion. Therefore, the influence of the hindrance on the diffusion rate appears more strongly in Na-PCP than in KCl because of a difference in their ion sizes. This leads to large $D_{\text{KCl}}/D_{\text{Na-PCP}}$ ratios in the transverse directions.

The interaction between the wall of the capillaries in wood and the diffusing molecules or ions, however, should be resolved by further study, since the more likely expla-

nations actually may not apply.

要 旨 前報¹⁾に続き、飽水木材中の溶質拡散に及ぼす温度の影響を2種の電解質 (Na-PCP, KCl) を用い、25~70°C の温度範囲にわたり、ヒノキおよびブナ材の3構造方向について検討した。

測定装置は拡散セルや電気抵抗の測定回路における若干の改良を除いては前報¹⁾のそれと全く同様であり、測定には直径4cm、厚さ1cm (拡散方向が繊維方向) および0.15cm (拡散方向が半径および切線方向) の円板形の試験片を供試した。

得られた結果を要約すると次の通りである。

(1) 時間—透過量曲線をプロットした場合、定常状態における測定値の変動は2.0%以下であった (Fig. 2)。

(2) $\log D-l/T$ 曲線をプロットした場合、ヒノキ材の R-方向における Na-PCP の拡散を除いては近似的に直線関係が得られた (Fig. 3, Fig. 4)。

(3) ヒノキ材では T-方向と R-方向の拡散係数に差異が認められなかったが、ブナ材の場合には T-方向の拡散速度は R-方向のその約2倍であった。また、両材の L-方向の拡散速度は T-および R-方向のその5~36倍であった (Table 3)。

(4) KCl の拡散係数は Na-PCP のそれよりもかなり大きく、とくにこの傾向は T- および R- 方向の拡散において顕著であった (Table 4)。

(5) 拡散の見かけの活性化エネルギーおよび平均の温度係数についてみると、一般に Na-PCP は KCl よりも、また T-および R-方向のそれは L-方向よりも

大きく、とくにこの傾向はヒノキ材において顕著であった (Table 5)。

(6) 木材中の溶質の拡散速度は拡散通路内に存在する有効毛管の毛管径とその数に支配される。また、拡散の見かけの活性化エネルギーや平均の温度係数は個々の有効毛管、とくに分子やイオンの自由拡散経路の寸法、および単位拡散距離中に通過する自由拡散経路の直径以下の毛管数に関係することが推測された。

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