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Appendix A

Physical Properties of Cotton Fibre

A.1 External radius of cotton fibre (r_s)

$r_s \times 10^3$ (cm)	frequency	cumulative frequency
0.891	1	1
0.907	1	2
0.923	2	4
0.939	4	8
0.955	2	10
0.970	4	14
0.987	4	18
1.002	5	23
1.018	6	29
1.034	6	35
1.050	5	40
1.066	6	46
1.082	4	50
1.098	4	54
1.114	3	57

A.1 External radius of cotton fibre (r_s)

$r_s \times 10^3$ (cm)	frequency	cumulative frequency
1.130	2	59
1.146	3	62
1.162	1	63

(r_s) average = 1.032×10^{-3} cm.

Sample standard deviation (σ_{n-1}) = 0.0655×10^{-3}

Coefficient of variation (C.V.) = 6.34 %

95 % confidence interval (μ_{95}) = $(1.032 \pm 0.0165) \times 10^{-3}$ cm.

A.2 Internal radius of cotton fibre ($r_{1,i}$)

$r_{1,i} \times 10^3$ (cm.)	frequency	cumulative frequency
0.334	1	1
0.350	3	4
0.366	2	6
0.382	4	10
0.397	4	14
0.414	5	19
0.429	8	27
0.445	7	34
0.462	9	43
0.477	5	48
0.493	4	52
0.509	4	56
0.525	2	58
0.541	3	61
0.557	1	62
0.573	1	63

$(r_{1,i})$ average $= 0.4477 \times 10^{-3}$

Sample standard deviation $(\sigma_{n-1}) = 0.0547 \times 10^{-3}$

Coefficient of variation = 12.2 %

95 % confidence interval $= (0.4477 \pm 0.013) \times 10^{-3}$

A.3 Density of alkali cellulose (ρ_{GLuONa})

$$\rho = \frac{M}{V}$$

$$= \frac{M}{n \pi r_s^2 l}$$

when n = number of full mercerized cotton fibre

r_s = radius of cotton fibre

l = length of cotton fibre

From the experiment

M = 0.0061 gm.

n = 1312 fibres

r_s = 1.032×10^{-3} cm.

l = 1 cm.

$$\rho = \frac{0.0061}{(1312)\ (\pi)\ (1.032 \times 10^{-3})^2 (1)}$$

$$= 1.389 \text{ gm./cm}^3$$

A.4 Molecular weight of alkali cellulose (M_{GLuONa})

Molecular formula is $C_6H_9O_5Na$

$$\text{Molecular weight} = 6(12)+9(1)+5(16)+23$$

$$= 184 \quad \text{gm/gm-mole}$$

Appendix B

Experimental Data and Results

B.1 Relationship between t and $r_1/r_{1,i}$

Exp. No 1. $(C_{Na^+})_b$ = 4.8×10^{-3} gm-mole/ml.

T = 303°K

S = 112,380 gm/cm^2

V_e = 80 rpm.

Run No.	t (second)	$r_1 \times 10^3$ (cm.)	$\frac{r_1}{r_{1,i}}$	$1-\frac{r_1}{r_{1,i}}$	$1-\left(\frac{r_1}{r_{1,i}}\right)^2 \cdot \left(1-\ln\left(\frac{r_1}{r_{1,i}}\right)^2\right)$
1	0	0.4477	1.0	0	0
2	155	0.375	0.837	0.163	0.050
3	453	0.313	0.699	0.301	0.152
4	556	0.303	0.675	0.324	0.185
5	747	0.278	0.621	0.379	0.248

B = 3006, slope between t and $1-(r_1/r_{1,i})^2(1-\ln(r_1/r_{1,i})^2)$

S.D.= 3.11

C_{or} = 0.999

D_e = 1.393×10^{-10}

B.2 Relationship between t and $r_1/r_{1,i}$

Exp. No. 2 $(C_{Na^+})_b = 4.8\times10^{-3}$ gm-mole/ml. $T = 303\,^{\circ}K$

$S = 112,380$ gm/cm^2 $V_e = 200$ rpm.

Run No.	t (second)	$r_1\times10^3$ (cm.)	$\frac{r_1}{r_{1,i}}$	$1-\frac{r_1}{r_{1,i}}$	$1-\left(\frac{r_1}{r_{1,i}}\right)^2 \cdot \left(1-\ln\left(\frac{r_1}{r_{1,i}}\right)^2\right)$
1	0	0.4477	1	0	0
2	182	0.371	0.828	0.172	0.055
3	484	0.315	0.703	0.207	0.157
4	600	0.295	0.658	0.342	0.204
5	720	0.290	0.647	0.353	0.216
6	848	0.275	0.614	0.386	0.255

B = 3206

S.D. = 27.61

C_{or} = 0.9986

D_e = 1.386×10^{-10}

B.3 Relationship between t and $r_1/r_{1,i}$

Exp. No.3 $(C_{Na^+})_b$ = 4.8×10^{-3} gm-mole/ml., T = 303°K

S = 122,380 gm/cm^2, V_e = 750 rpm.

Run. No.	t (second)	$r_1 \times 10^3$ (cm.)	$\frac{r_1}{r_{1,i}}$	$1-\frac{r_1}{r_{1,i}}$	$1-\left(\frac{r_1}{r_{1,i}}\right)^2 \cdot \left(1-\ln\left(\frac{r_1}{r_{1,i}}\right)^2\right)$
1	0	0.4477	1	0	0
2	129	0.376	0.839	0.161	0.048
3	420	0.330	0.737	0.263	0.125
4	643	0.284	0.634	0.366	0.231
5	758	0.280	0.625	0.375	0.242
6	860	0.266	0.594	0.406	0.279

B = 3036

S.D. = 34.73

C_{or} = 0.998

D_e = 1.3792×10^{-10}

B.4 Relationship between t and $r_1/r_{1,i}$

Exp. No.4 $(C_{Na^+})_b$ = 4.8×10^{-3} gm-mole/ml., T = 303 °K

S = 168,560 gm/cm^2, V_e = 200 rpm.

Run. No.	t (second)	$r_1 \times 10^3$ (cm.)	$\frac{r_1}{r_{1,i}}$	$1-\frac{r_1}{r_{1,i}}$	$1-\left(\frac{r_1}{r_{1,i}}\right)^2 \cdot \left(1-\ln\frac{r_1}{r_{1,i}}\right)^2$
1	0	0.4477	1	0	0
2	151	0.379	0.846	0.154	0.045
3	273	0.351	0.784	0.216	0.086
4	460	0.329	0.735	0.265	0.127
5	746	0.294	0.663	0.337	0.199
6	1,100	0.249	0.556	0.444	0.327

B = 3425

S.D. = 32.6

C_{or} = 0.9984

D_e = 1.2225×10^{-10}

B.5 Relationship between t and $r_1/r_{1,i}$

Exp. No. 5 $(C_{Na^+})_b$ = 4.8×10^{-3} gm-mole/ml., T = 303°K

S = 224,755 gm/cm^2, V_e = 200 rpm.

Run No.	t (second)	$r_1 \times 10^3$ (cm.)	$\frac{r_1}{r_{1,i}}$	$1-\frac{r_1}{r_{1,i}}$	$1-\left(\frac{r_1}{r_{1,i}}\right)^2 \cdot \left(1-\ln\left(\frac{r_1}{r_{1,i}}\right)^2\right)$
1	0	0.4477	1	0	0
2	140	0.383	0.855	0.145	0.0399
3	322	0.352	0.786	0.214	0.084
4	456	0.330	0.737	0.263	0.125
5	622	0.313	0.699	0.301	0.161
6	856	0.286	0.638	0.362	0.227

B = 3772

S.D. = 10.83

C_{or} = 0.999

D_e = 1.1101×10^{-10}

B.6 Relationship between t and $r_1/r_{1,i}$

Exp. No.6 $(C_{Na^+})_b$ = 4.8×10^{-3} gm-mole/ml., T = 303°K.

S = 280,940 gm/cm^2, V_e = 200 rpm.

Run No.	t (second)	$r_1 \times 10^3$ (cm.)	$\frac{r_1}{r_{1,i}}$	$1-\frac{r_1}{r_{1,i}}$	$1-\left(\frac{r_1}{r_{1,i}}\right)^2 \cdot \left(1-\ln\left(\frac{r_1}{r_{1,i}}\right)^2\right)$
1	0	0.4477	1	0	0
2	130	0.400	0.893	0.107	0.022
3	306	0.358	0.799	0.201	0.075
4	508	0.337	0.753	0.247	0.111
5	655	0.321	0.717	0.283	0.143

B = 4524

S.D. = 22.98

C_{or} = 0.998

D_e = 9.2557×10^{-11}

B. 7 Relationship between t and $r_1/r_{1,i}$

Exp. No.7 $(C_{Na^+})_b$ = 4.8×10^{-3} gm-mole/ml., T = 303°K

S = 337,130 gm/cm^2, V_e = 200 rpm.

Run. No.	t (second)	$r_1 \times 10^3$ (cm.)	$\frac{r_1}{r_{1,i}}$	$1-\frac{r_1}{r_{1,i}}$	$1-\left(\frac{r_1}{r_{1,i}}\right)^2 \cdot \left(1-\ln\left(\frac{r_1}{r_{1,i}}\right)^2\right)$
1	0	0.4477	1	0	0
2	150	0.396	0.884	0.116	0.0256
3	440	0.361	0.806	0.194	0.070
4	605	0.329	0.734	0.266	0.128
5	865	0.322	0.719	0.281	0.142

B = 5579

S.D. = 70.03

C_{or} = 0.992

D_e = 7.505×10^{-11}

B. 8 Relationship between t and $r_1/r_{1,i}$

Exp. No. 8 $(C_{Na^+})_b$ = 4.76×10^{-3} gm-mole/ml., T = 313°K

S = 168,560 gm/cm^2, V_e = 200 rpm.

Run No.	t (second)	$r_1 \times 10^3$ (cm.)	$\frac{r_1}{r_{1,i}}$	$1-\frac{r_1}{r_{1,i}}$	$1-\left(\frac{r_1}{r_{1,i}}\right)^2 \cdot \left(1-\ln\left(\frac{r_1}{r_{1,i}}\right)^2\right)$
1	0	0.4477	1	0	0
2	336	0.336	0.75	0.25	0.114
3	395	0.317	0.708	0.292	0.152
4	554	0.296	0.661	0.339	0.201
5	662	0.279	0.623	0.377	0.244

B = 2728

S.D. = 26.78

C_{or} = 0.999

D_e = 1.5478×10^{-10}

B.9 Relationship between t and $r_1/r_{1,i}$

Exp. No.9 $(C_{Na^+})_b$ = 4.74×10^{-3} gm-mole/ml., T = 323°K

S = 168,560 gm/cm^2, V_e = 200 rpm.

Run. No.	t (second)	$r_1 \times 10^3$ (cm.)	$\frac{r_1}{r_{1,i}}$	$1-\frac{r_1}{r_{1,i}}$	$1-\left(\frac{r_1}{r_{1,i}}\right)^2 \cdot \left(1-\ln\left(\frac{r_1}{r_{1,i}}\right)^2\right)$
1	0	0.4477	1	0	0
2	157	0.360	0.804	0.196	0.071
3	290	0.322	0.719	0.281	0.142
4	360	0.313	0.699	0.301	0.161
5	600	0.265	0.592	0.408	0.282

B = 2139

S.D. = 10.79

C_{or} = 0.996

D_e = 1.9823×10^{-10}

B.10 Relationship between t and $r_1/r_{1,i}$

Exp. No. 10 $(C_{Na^+})_b$ = 4.72×10^{-3} gm-mole/ml., T = 333°K

S = 168,560 gm/cm^2, V_e = 200 rpm.

Run. No.	t (second)	$r_1 \times 10^3$ (cm.)	$\frac{r_1}{r_{1,i}}$	$1-\frac{r_1}{r_{1,i}}$	$1-\left(\frac{r_1}{r_{1,i}}\right)^2 \cdot \left(1-\ln\left(\frac{r_1}{r_{1,i}}\right)^2\right)$
1	0	0.4477	1	0	0
2	140	0.359	0.802	0.198	0.0729
3	255	0.326	0.728	0.272	0.133
4	660	0.234	0.522	0.478	0.373

B = 1790

S.D. = 11,03

C_{or} = 0.999

D_e = 2.3789×10^{-10}

B. 11 Relationship between t and $r_1/r_{1,i}$

Exp. No. 11 $(C_{Na^+})_b$ = 4.69×10^{-3} gm-mole/ml., T = 343°K

S = 168,560 gm/cm^2 V_e = 200 rpm.

Run. No.	t (second)	$r_1 \times 10^3$ (cm.)	$\frac{r_1}{r_{1,i}}$	$1-\frac{r_1}{r_{1,i}}$	$1-\left(\frac{r_1}{r_{1,i}}\right)^2 \cdot \left(1-\ln\left(\frac{r_1}{r_{1,i}}\right)^2\right)$
1	0	0.4477	1	0	0.000
2	206	0.323	0.721	0.279	0.140
3	304	0.287	0.641	0.359	0.223
4	420	0.259	0.578	0.422	0.299
5	683	0.203	0.453	0.547	0.470

B = 1431

S.D. = 10.26

C_{or} = 0.999

D_e = 2.926×10^{-10}

B. 12 Relationship between t and $r_1/r_{1,i}$

Exp. No.12 $(C_{Na^+})_b$ = 1.278×10^{-2} gm-mole/ml., T = 303°K

S = 168,560 gm/cm^2, V_e = 200 rpm.

Run. No.	t (second)	$r_1 \times 10^3$ (cm)	$\frac{r_1}{r_{1,i}}$	$1-\frac{r_1}{r_{1,i}}$	$1-\left(\frac{r_1}{r_{1,i}}\right)^2 \cdot \left(1-\ln\left(\frac{r_1}{r_{1,i}}\right)^2\right)$
1	0	0.4477	1	0	0
2	247	0.281	0.627	0.373	0.239
3	316	0.258	0.576	0.424	0.302
4	440	0.220	0.491	0.509	0.415
5	568	0.176	0.393	0.607	0.557

B = 1035

S.D.= 6.86

C_{or} = 0.999

D_e = 1.529×10^{-10}

B.13 Relationship between t and $r_1/r_{1,i}$

Exp. No. 13. $(C_{Na^+})_b$ = 1.0653×10^{-2} gm-mole/ml., T = 303°K

S = 168,560 gm/cm^2, V_e = 200 rpm.

Run. No.	t (second)	$r_1 \times 10^3$ (cm.)	$\frac{r_1}{r_{1,i}}$	$1-\frac{r_1}{r_{1,i}}$	$1-\left(\frac{r_1}{r_{1,i}}\right)^2 \cdot \left(1-\ln\left(\frac{r_1}{r_{1,i}}\right)^2\right)$
1	0	0.4477	1	0	0.000
2	202	0.315	0.703	0.297	0.157
3	321	0.278	0.620	0.380	0.248
4	535	0.216	0.482	0.518	0.428
5	638	0.202	0.451	0.549	0.473

B = 1302

S.D. = 15.74

C_{or} = 0.9994

D_e = 1.456×10^{-10}

B. 14 Relationship between t and $r_1/r_{1,i}$

Exp. No. 14 $(C_{Na^+})_b$ = 7.969×10^{-3} gm-mole/ml., T = 303°K

S = 168,560 gm/cm^2, V_e = 200 rpm.

Run. No.	t (second)	$r_1 \times 10^3$ (cm.)	$\frac{r_1}{r_{1,i}}$	$1-\frac{r_1}{r_{1,i}}$	$1-\left(\frac{r_1}{r_{1,i}}\right)^2 \cdot \left(1-\ln\left(\frac{r_1}{r_{1,i}}\right)^2\right)$
1	0	0.4477	1	0	0.000
2	194	0.339	0.757	0.243	0.107
3	330	0.311	0.694	0.306	0.166
4	444	0.280	0.625	0.375	0.241
5	668	0.239	0.533	0.467	0.358

B = 1872

S.D. = 10.76

C_{or} = 0.9997

D_e = 1.3488×10^{-10}

B.15 Relationship between t and $r_1/r_{1,i}$

Exp. No.15 $(C_{Na^+})_b$ = 5.923×10^{-3} gm-mole/ml, T = 303°K
S = 168,560 gm/cm^2, V_e = 200 rpm.

Run No.	t (second)	$r_1 \times 10^3$ (cm)	$\frac{r_1}{r_{1,i}}$	$1-\frac{r_1}{r_{1,i}}$	$1-\left(\frac{r_1}{r_{1,i}}\right)^2 \cdot \left(1-\ln\left(\frac{r_1}{r_{1,i}}\right)^2\right)$
1	0.00	0.4477	1	0	0.000
2	70	0.390	0.871	0.129	0.0318
3	204	0.362	0.808	0.192	0.0687
4	423	0.313	0.699	0.301	0.1614
5	726	0.268	0.598	0.402	0.2746

B = 2648

S.D. = 13.31

C_{or} = 0.999

D_e = 1.281×10^{-10}

B.16 Relationship between D_e and V_e

Exp. No.	$D_e \times 10^{10}$	V_e
1	1.393	80
2	1.306	200
3	1.379	750

B.17 Relationship between D_e and S

Exp. No.	$D_e \times 10^{10}$	S
2	1.306	112,380
4	1.2225	168,560
5	1.1101	224,755
6	0.9225	280,940
7	0.7505	337,130

S.D. = 0.0322×10^{-10}

B.18 Relationship between D_e and T

Exp. No.	$D_e \times 10^{10}$	T
4	1.2225	303
8	1.5478	313
9	1.9823	323
10	2.3789	333
11	2.926	343

S.D. = 0.0327×10^{-10}

B.19 Relationship between D_e and $(C_{Na^+})_b$

Exp.No.	$D_e \times 10^{10}$	$(C_{Na^+})_b$
12	1.529	1.27×10^{-2}
13	1.456	1.06×10^{-2}
14	1.3488	7.96×10^{-3}
15	1.2821	5.92×10^{-3}
4	1.2225	4.80×10^{-3}

S.D. = 0.0106×10^{-10}

B.20 Regression analysis of D_e and V_e

Type of Regression	B	A	C_{or}
Linear	2.655×10^{-15}	1.350×10^{-10}	0.203
Logarithmic	-1.917×10^{-13}	1.3697×10^{-10}	-0.046
Power	-1.2914×10^{-3}	1.368×10^{-10}	-0.042
Exponential	2.011×10^{-5}	1.3194×10^{-10}	0.2072

B.21 Regression analysis of D_e and S

Type of Regression	B	A	C_{or}
Linear	-2.5112×10^{-16}	1.6267×10^{-10}	-0.988
Logarithmic	-4.9512×10^{-11}	7.1287×10^{-10}	-0.951
Power	-0.4820	3.828×10^{-8}	-0.928
Exponential	-2.473×10^{-6}	1.8162×10^{-10}	-0.975

B.22 Regression analysis of D_e and T

Type of Regression	B	A	C_{or}
Linear	4.2381×10^{-12}	-1.1677×10^{-9}	0.996
Logarithmic	1.3649×10^{-9}	-7.6836×10^{-9}	0.994
Power	7.0223	4.6333×10^{-28}	0.998
Exponential	0.0217	1.7058×10^{-13}	0.999

B.23 Regression analysis of D_e and $(C_{Na^+})_b$

Type of Regression	B	A	C_{or}
Linear	2.825×10^{-9}	1.0464×10^{-10}	0.998
Logarithmic	3.099×10^{-11}	2.869×10^{-10}	0.994
Power	0.227	4.1012×10^{-10}	0.999
Exponential	27.85	1.079×10^{-10}	0.997

B.24 Determination of K value

Exp.No.	$D_e \times 10^{10}$ (cm^2/sec)	S gm/cm^2	T (°K)	$(C_{Na^+})_b$ gm-mole/ml.	F
1	1.393	112,380	303	4.8×10^{-3}	176.37
2	1.306	112,380	303	4.8×10^{-3}	176.37
3	1.379	112,380	303	4.8×10^{-3}	176.37
4	1.2225	168,560	303	4.8×10^{-3}	157.86
5	1.1101	224,755	303	4.8×10^{-3}	139.35
6	0.5225	280,940	303	4.8×10^{-3}	120.84
7	0.7505	337,130	303	4.8×10^{-3}	102.34
8	1.5478	168,560	313	4.76×10^{-3}	195.75
9	1.9823	168,560	323	4.74×10^{-3}	242.96
10	2.3789	168,560	333	4.72×10^{-3}	301.54
11	2.9260	168,560	343	4.69×10^{-3}	374.08
12	1.529	168,560	303	1.27×10^{-2}	196.88
13	1.456	168,560	303	1.06×10^{-2}	188.97
14	1.3488	168,560	303	7.96×10^{-3}	177.07
15	1.2821	168,560	303	5.92×10^{-3}	165.56

$F = (1-1.5437 \times 10^{-6} S)\, e^{0.0217T}\, (C_{Na^+})_b^{0.227}$

$K = 7.8167 \times 10^{-13}$

$S.D. = 3.626 \times 10^{-12}$

B.25 Relationship between $\frac{-dN_{Na^+}}{dt}$, x and t

Exp. No.1 $(C_{Na^+})_b = 4.8 \times 10^{-3}$ gm-mole/ml., $T = 303^{\circ}K$

$S = 112.380$ gm/cm^2, $V_e = 80$ rpm

t	$\frac{r_1}{r_{1,i}}$	$1-\left(\frac{r_1}{r_{1,i}}\right)^2$	$\ln \frac{r_1}{r_{1,i}}$	$\frac{-2\pi D_e (C_{Na^+})_b}{\ln(r_1/r_{1,i})}$
0	1	0	0	∞
156	0.837	0.2994	-0.1779	2.38×10^{-11}
453	0.699	0.5114	-0.358	1.186×10^{-11}
556	0.676	0.543	-0.391	1.085×10^{-11}
747	0.621	0.6143	-0.476	8.92×10^{-12}

when $x = 1 - (r_1/r_{1,i})^2$

$$\frac{-dN_{Na^+}}{dt} = \frac{-2\pi D_e (C_{Na^+})_b}{\ln(r_1/r_{1,i})}$$

Appendix C

Sample of Calculation

C.1 Slope between t and $1-\left(\frac{r_1}{r_{1,i}}\right)^2\left(1-\ln\left(\frac{r_1}{r_{1,i}}\right)^2\right)$ (correlation coeffient, B)

$$\text{formula} \qquad y = Bx$$

$$B = \frac{\Sigma xy}{\Sigma x^2}$$

$$C_{or} = \frac{\Sigma xy}{\sqrt{\Sigma x^2 \cdot \Sigma y^2}}$$

when

$$y = t$$

$$x = 1-\left(\frac{r_1}{r_{1,i}}\right)^2\left(1-\ln\left(\frac{r_1}{r_{1,i}}\right)^2\right)$$

From Appendix B.1

n = 5		Σxy = 364.722	
Σx = 0.635		Σy = 1,911	
Σx^2 = 0.1213		Σy^2 = 1,096,379	

$$\therefore \quad B = \frac{364.722}{0.1213}$$

$$= 3006$$

$$C_{or} = \frac{634.722}{\sqrt{(0.1213)(1096379)}}$$

$$= 0.999$$

C.2 Effective diffusivity, D_e

$$D_e = \left(\frac{\rho}{M}\right)_{GLuONa} \frac{r_s^2}{4(\text{slope})\ (C_{Na^+})_b} \qquad (3.36)$$

From Appendix B.1

slope = 3006

ρ_{GLuONa} = 1.389 gm./ml. , M_{GLuONa} = 184 $\frac{gm}{gm\text{-}mole}$

r_s = 1.032×10^{-3} cm, $(C_{Na^+})_b$ = 4.8×10^{-3} $\frac{gm\text{-}mole}{ml.}$

$$D_e = \frac{1.389}{184} \cdot \frac{(1.032 \times 10^{-3})^2}{4(\ 3006\ )\ (4.8 \times 10^{-3})}$$

$$= 1.3929 \times 10^{-10} \quad \frac{cm^2}{sec.}$$

C.3 Regression analysis (between D_e and S)

3.1 Linear Regression

$$y = A + Bx$$

$$B = \frac{n \cdot \Sigma xy - \Sigma x \cdot \Sigma y}{n \cdot \Sigma x^2 - (\Sigma x)^2}$$

$$A = \frac{\Sigma y - B \cdot \Sigma x}{n}$$

$$C_{or} = \frac{n \cdot \Sigma xy - \Sigma x \cdot \Sigma y}{\sqrt{\left(n \cdot \Sigma x^2 - (\Sigma x)^2\right)\left(n \cdot \Sigma y^2 - (\Sigma y)^2\right)}}$$

From Appendix B.17

$y = D_e$ and $x = S$

$n = 5$ $\qquad$ $\Sigma xy = 1.114516 \times 10^{-4}$

$\Sigma x = 1,123,765$ $\qquad$ $\Sigma y = 5.3116 \times 10^{-10}$

$\Sigma x^2 = 2.8414 \times 10^{11}$ $\qquad$ $\Sigma y^2 = 5.846720 \times 10^{-20}$

$(\Sigma x)^2 = 1.26284 \times 10^{12}$ $\qquad$ $(\Sigma y)^2 = 2.8213094 \times 10^{-19}$

$$\therefore \quad B = \frac{5(1.114516 \times 10^{-4}) - (1,123,765)(5.3116 \times 10^{-10})}{5(2.8414 \times 10^{11}) - 1.26284 \times 10^{12}}$$

$$= -2.5112 \times 10^{-16}$$

$$A = \frac{5.3116 \times 10^{-10} - (-2.5112 \times 10^{-16})(1,123,765)}{5}$$

$$= 1.6267 \times 10^{-10}$$

$$C_{or} = \frac{5(1.114516 \times 10^{-4})-(1,123,765)(5.3116 \times 10^{-10})}{\sqrt{(5(2.8414 \times 10^{11})-(1.262847 \times 10^{12})(5(5.84672 \times 10^{-20})-2.8213094 \times 10^{-19})}}$$

$$= 0.998$$

3.2 Logarithmic regression

$$y = A + B \ln x$$

$$B = \frac{n \,.\, \Sigma(y\ln x) - \Sigma\ln x \,.\, \Sigma y}{n \,.\, \Sigma(\ln x)^2 - (\Sigma\ln x)^2}$$

$$A = \frac{\Sigma y - B \,.\, \Sigma(\ln x)}{n}$$

$$C_{or} = \frac{n \,.\, \Sigma(y\ln x) - \Sigma\ln x \,.\, \Sigma y}{\sqrt{\left(n \,.\, \Sigma(\ln x)^2 - (\Sigma\ln x)^2\right)\left(n \,.\, \Sigma y^2 - (\Sigma y)^2\right)}}$$

From Appendix B.17

$y = D_e$ $\quad$ $x = S$

$n = 5$ $\quad$ $\Sigma(y\ln x) = 6.4706781 \times 10^{-9}$

$\Sigma\ln x = 61.2615148$ $\quad$ $\Sigma y = 5.3116 \times 10^{-10}$

$\Sigma(\ln x)^2 = 731.3486801$ $\quad$ $\Sigma y^2 = 5.84672076 \times 10^{-20}$

$(\Sigma\ln x)^2 = 3752.980547$ $\quad$ $(\Sigma y)^2 = 2.8213094 \times 10^{-19}$

$$B = \frac{5(6.4706781 \times 10^{-9})-(61.2615148)(5.3116 \times 10^{-10})}{5(731.3486801) - (3752.980547)}$$

$$= -4.9512 \times 10^{-11}$$

$$A = \frac{5.3116 \times 10^{-10}-(-4.9512 \times 10^{-11})(61.2615148)}{5}$$

$$= 7.1287 \times 10^{-10}$$

$$C_{or} = \frac{5(6.4706781 \times 10^{-9})-(61.2615148)(5.3116 \times 10^{-10})}{\sqrt{(5(731.3486801)-(3751.980547))(5(5.84672076 \times 10^{-20})-(2.8213094 \times 10^{-19}))}}$$

$$= -0.951$$

3.3 Power regression

$$y = Ax^{B}$$

$$B = \frac{n \cdot \Sigma(\ln x \cdot \ln y) - \Sigma \ln x \cdot \Sigma \ln y}{n \cdot \Sigma(\ln x)^2 - (\Sigma \ln x)^2}$$

$$\ln A = \frac{\Sigma \ln y - B \cdot \Sigma \ln x}{n}$$

$$C_{or} = \frac{n \cdot \Sigma(\ln x \ln y) - \Sigma \ln x \cdot \Sigma \ln y}{\sqrt{\left(n \cdot \Sigma(\ln x)^2 - (\Sigma \ln x)^2\right)\left(n \cdot \Sigma(\ln y)^2 - (\Sigma \ln y)^2\right)}}$$

From Appendix B.17

y	$= D_e$	x	$= S$
n	$= 5$	$\Sigma(\ln x . \ln y)$	$= -1408.45545$
$\Sigma \ln x$	$= 61.261575$	$\Sigma \ln y$	$= -114.92462$
$\Sigma(\ln x)^2$	$= 751.34868$	$\Sigma(\ln y)^2$	$= 2641.73676$
$(\Sigma \ln x)^2$	$= 3752.9805$	$(\Sigma \ln y)^2$	$= 13207.66853$

$$B = \frac{5(-1408.45345)-(61.261575)(-114.92462)}{5(751.34868)-(3752.9805)}$$

$$= -0.4820$$

$$\ln A = \frac{(-114.92462)-(-0.4820)(61.261575)}{5}$$

$$= -17.078309$$

$$A = 3.828 \times 10^{-8}$$

$$C_{or} = \frac{5(-1408.45545)-(61.261575)(-114.92462)}{\sqrt{(5(751.34868)-(3752.9805))(5(2641.73676)-(13207.66853))}}$$

$$= 0.928$$

3.4 Exponential regression

$$y = Ae^{Bx}$$

$$B = \frac{n \cdot \Sigma(x\ln y) - \Sigma x \cdot \Sigma \ln y}{n \cdot \Sigma x^2 - (\Sigma x)^2}$$

$$\ln A = \frac{\Sigma \ln y - B \cdot \Sigma x}{n}$$

$$C_{or} = \frac{n \cdot \Sigma(x\ln y) - \Sigma x \cdot \Sigma \ln y}{\sqrt{\left(n \cdot \Sigma x^2-(\Sigma x)^2\right)\left(n \cdot \Sigma(\ln y)^2-(\Sigma \ln y)^2\right)}}$$

From Appendix B.17

y	=	D_e	x	=	S
n	=	5	$\Sigma(x\ln y)$	=	-25907728.7
Σx	=	1,123,765	$\Sigma \ln y$	=	-114.924621
Σx^2	=	2.841404×10^{11}	$\Sigma(\ln y)^2$	=	2641.73676
$(\Sigma x)^2$	=	1.2628477×10^{12}	$(\Sigma \ln y)^2$	=	13207.66853

$$B = \frac{5(-25907728.7)-(1,123,765)(-114.924621)}{5(2.84104 \times 10^{11})-(1.2628477 \times 10^{12})}$$

$$= -2.473 \times 10^{-6}$$

$$\ln A = \frac{(-114.924621)-(-2.473 \times 10^{-6})(1,123,765)}{5}$$

$$= -22.429106$$

$$A = 1.81619 \times 10^{-10}$$

$$C_{or} = \frac{5(-25907728.7)-(1,123,765)(-114.924621)}{\sqrt{(5(2.84140 \times 10^{11})-(1.262847 \times 10^{12}))(5(2641.73676)-(13027.66853))}}$$

$$= -0.975$$

C.4 Coefficient of variation (C.V.)

$$C.V. = \frac{\sigma_{n-1}}{\overline{X}}$$

From Appendix A.1

$$\sigma_{n-1} = 0.0655 \times 10^{-3}$$

$$\overline{X} = (r_s)_{average}$$

$$= 1.032 \times 10^{-3} \text{ cm.}$$

$$C.V. = \frac{0.0655 \times 10^{-3}}{1.032 \times 10^{-3}}$$

$$= 0.0634$$

$$= 6.34 \%$$

C.5 95 % confidence interval (μ_{95})

$$\mu_{95} = \overline{X} \pm \frac{2\sigma_{n-1}}{\sqrt{n}}$$

From Appendix A.1

$$\overline{X} = (r_s)_{average}$$
$$= 1.032 \times 10^{-3} \quad cm$$
$$\sigma_{n-1} = 0.0655 \times 10^{-3}$$
$$n = 63$$
$$\mu_{95} = 1.032 \times 10^{-3} \pm \frac{2(0.0655 \times 10^{-3})}{\sqrt{63}}$$
$$= 1.032 \times 10^{-3} \pm 1.65 \times 10^{-5}$$
$$= (1.032 \pm 0.0165) \times 10^{-5} \quad cm.$$

C.6 F value

$$F = (1-1.5437\times10^{-6}S)\ e^{0.0217T}\ (C_{Na^+})_b^{0.227}$$

From Appendix B.1

$$S = 112,380 \ gm/cm^2$$
$$T = 303°K \qquad (C_{Na^+})_b = 4.8 \times 10^{-3} \ gm\text{-}mole/ml$$
$$F = (1-1.5437\times10^{-6}\times112,380)\ e^{0.0217\times303}(4.8\times10^{-3})^{0.227}$$
$$= 176.37$$

C.7 K value

$$K = \frac{\Sigma(D_e F)}{\Sigma F^2}$$

From Appendix B.24

$$\Sigma(D_e F) = 4.8789536 \times 10^{-7} \qquad \Sigma F^2 = 624178.2499$$
$$K = \frac{4.8789536 \times 10^{-7}}{624178.2499}$$
$$= 7.8167 \times 10^{-13}$$

C.8 Standard deviation (S.D.)

Formula $$S.D. = \sqrt{\frac{(X-X_c)^2}{n-1}}$$

Form Appendix B.24

$$S.D. = \sqrt{\frac{(D_e-D_{e,c})^2}{n-1}}$$

when D_e = effective diffusivity

$D_{e,c}$ = calculated effective diffusivity

n = number of data

Run No	$D_e x10^{10}$	$(D_{e,c}=KF)x10^{10}$	$D_e-D_{e,c}x10^{10}$	$(D_e-D_{e,c})^2$
1	1.393	1.378	0.015	$2.25x10^{-24}$
2	1.306	1.378	-0.072	$5.184x10^{-23}$
3	1.379	1.378	0.001	$1.000x10^{-26}$
4	1.2225	1.233	-0.0105	$1.1025x10^{-24}$
5	1.1101	1.089	0.0211	$4.4521x10^{-24}$
6	0.9225	0.944	-0.0215	$4.6225x10^{-24}$
7	0.7505	0.799	-0.0485	$2.352x10^{-23}$
8	1.5478	1.530	0.0178	$3.7684x10^{-24}$
9	1.9823	1.899	0.0833	$6.9389x10^{-23}$
10	2.3789	2.357	0.0219	$4.796x10^{-24}$
11	2.926	2.925	-0.001	$1.000x10^{-26}$
12	1.529	1.538	-0.009	$8.1x10^{-25}$
13	1.456	1.477	-0.021	$4.41x10^{-24}$
14	1.3488	1.384	-0.0352	$1.239x10^{-23}$
15	1.2821	1.294	-0.0119	$1.4161x10^{-24}$

$\Sigma = 1.841x10^{-22}$

$$S.D. = \sqrt{\frac{(1.841x10^{-22}}{14}}$$

$$= 3.626x10^{-12}$$

C.9 Tension

Formula $$S = \frac{V(\rho_{wt} - \rho_{sol})}{2n\pi(r_s)^2}$$

S = tension

V = volume of weight

ρ_{wt} = density of weight

ρ_{sol} = density of solution

n = number of fiber/yarn

r_s = radius of cotton fibre

In Exp. No.1

V = 11 cm^3

ρ_{wt} = 8.09 gm/cm^3

ρ_{sol} = 1.07 gm/cm^3

n = 102.5 fibres/yarn

r_s = $1.032x10^{-3}$

$$\therefore S = \frac{11(8.09-1.07)}{2(102.5)(\pi)(1.032x10^{-3})^2}$$

$$= 112,380 \ gm/cm^2$$

Appendix D

Nomenclature

A, B	=	constant
C_{Na^+}	=	concentration of sodium ions $\frac{(\text{gm-mole})}{\text{ml}}$
$(C_{Na^+})_b$	=	concentration of sodium ions in bulk solution $\frac{(\text{gm-mole})}{\text{ml}}$
$(C_{Na^+})_c$	=	concentration of sodium ions at the reacting core $\frac{(\text{gm-mole})}{\text{ml}}$
$(C_{Na^+})_s$	=	concentration of sodium ions at fibre surface $\frac{(\text{gm-mole})}{\text{ml}}$
C_{or}	=	correlation coefficient
C.V.	=	coefficient of variation
D_e	=	effective diffusivity (cm^2/sec)
F	=	$(1-1.5437 \times 10^{-6}S)\ e^{0.0217T}\ (C_{Na^+})_b^{0.227}$
GLuOH,	=	anhydroglucose unit of cellulose
GLuONa	=	alkali-cellulose
H^+	=	Hydrogen ion
k_m	=	external mass transfer coefficient (cm/sec)
k	=	rate constant (cm/sec)
K	=	constant
l	=	length of cotton fibre
M_{GLuONa}	=	molecular weight of GLuONa (gm/gm-mole)
M_o	=	initial mass of cotton fibre (gm)
M	=	mass fraction of cotton fibre which is not mercerized
Na^+	=	sodium ion
$\frac{-dN_{Na^+}}{dt}$	=	flux of Na^+ per unit length of cotton fibre

n = number of data

p = percentage of unstained fibres

r = radius (cm)

r_c = radius of unreacted core of cotton fibre (cm)

r_1 = internal radius of cotton fibre (cm)

$r_{1,f}$ = final internal radius of cotton fibre (cm)

$r_{1,i}$ = initial internal radius of cotton fibre (cm)

r_s = external radius of cotton fibre (cm)

S = tension of cotton fibre (gm/cm^2)

t = mercerization time (second)

t^* = dimensionless time

T = temperature (°K)

V = volume (cm^3)

V_i = initial volume (cm^3)

V_f = final volume (cm^3)

V_e = speed of stirrer (rpm)

X = conversion

x = independent variable

$\bar{x}$ = average value of x

Y_1 = $\frac{D_e}{k_m r_s}$

Y_2 = $\frac{k r_s}{D_e}$

y = dependent variable

z = swelling of fibre diameter (cm)

μ	=	viscosity (centipoise)
μ_{95}	=	95 % confidence interval
ρ_{GLuONa}	=	density of alkali cellulose (gm/cm^3)
ρ_i	=	initial density of cotton fibre (gm/cm^3)
ρ_f	=	final density of mercerized cotton (gm/cm^3)
σ_{n-1}	=	sample standard deviation

Vita

Mr. Somporn Lieardkanchana recieved his Bachelor Degree of Science in Chemical Engineering from Faculty of Science, Chulalongkorn University in 1977.

He is working as an engineer in Textile Industry Division, Department of Industrial Promotion, Ministry of Industry. In 1983, he recieved Post Graduate Diploma in Production Management from Research Institute of Management, in Delft, The Netherlands.

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