REFERENCES

1. Hixson, A. W., and S. J. Baum, "Agitation Mass Transfer Coefficients in Liquid-Solid Agitation Systems," Ind. Eng. Chem., 33, 478-485, 1941.
2. ________. "Agitation Performance of Propellers in Liquid-Solid Systems," Ind. Eng. Chem., 34, 120-125, 1942.
3. ________. "Agitation Heat and Mass Transfer Coefficients in Liquid-Solid Systems," Ind. Eng. Chem., 33, 1433-1439, 1941.
4. Nagata, S., M. Adachi, and I. Yamaguchi, Mem. Fac. Eng., Kyoto Univ., 20, 72, 1958.
5. Nagata, S., I. Yamaguchi, and S. Yabuta, "Mass Transfer in Agitated Liquid-Solid Systems," Mem. Fac. Eng., Kyoto Univ., 22, 86, 1960.
6. Barker, J. J., and R. E. Treybal, "Mass Transfer Coefficients for Solid Suspended in Agitated Liquids," AIChE. J., 6, 289-295, 1960.
7. Askew, W. S., and R. B. Beckmann, "Heat and Mass Transfer in an Agitated Vessel," Ind. Eng. Chem. Proc. Des. Dev., 4, 311-318, 1965.
8. Keey, R. B., and J. B. Glen, AIChE. J., 12, 401, 1966.
9. Weinspach, P. M., Chem. Eng. Tech., 39, 231, 1967.
10. Syke, P., and A. Gomezplata, "Particle Liquid Mass Transfer in Stirred Tanks," Can. J. Chem. Eng., 45, 189-197, 1967.
11. Levins, D. M., "Mass Transfer in Stirred Vessel," Ph.D. Thesis, University of Sydney, 1969.

12. Miller, D. N., "Scale-Up of Agitated Vessels, Ind. Eng. Chem. Proc. Des. Dev., 10, 365-375, 1971.

13. Sano, Y., N. Yamaguchi, and T. Adachi, "Mass Transfer Coefficients for Suspended Particles in Agitated Vessels and Bubble Columns," J. Chem. Eng. Japan, 7, 255-261, 1974.

14. Humphrey, D. W., and H.C. Van Ness., "Mass Transfer in a Continuous - flow Mixing Vessel," AIChE. J., 3, 283-286, 1957.

15. Johnson, A. J., and C. J. Hung, "Mass Transfer Studies in an Agitated Vessel," AIChE. J., 2, 412-419, 1956.

16. Boon-Long, S., C. Laguerie, and J. P. Couderc, "Mass Transfer from Suspended Solids to a Liquid in Agitated Vessels," Chem. Eng. Sci., 33, 813-819, 1978.

17. Oldshue, J. Y., Fluid Mixing Technology, McGraw-Hill, New York, 1985.

18. Harriott, P., "Mass Transfer to Particles: Part I Suspended in Agitated Tanks," AIChE. J., 8, 93-102, 1962.

19. Higbie, R., Trans. Am. Inst. Chem. Eng., 31, 365, 1939.

20. Hinze, J. O., Turbulence, McGraw-Hill, New York, 1959.

21. Suvachittanont, S., "The Determination of Diffusion Coeffcients of α -Naphthol in Water," Master Thesis, Chulalongkorn University, 1980.

22. Bird, R. B., W. E. Steward, and E. W. Lightfoot, Transport Phenomena, 502-503, John Wiley & Sons, New York, 1960.

23. Gordon, R. J., Series Editor, AIChE MI Modern Instruction: Series C, Transport: Volume 5, Mass Transfer, 40-45, New York, 1984.

24. Miller, D. N., "Liquid Film Controlled Mass Transfer in Agitated Vessels," Ind. Eng. Chem., 56, 18-27, 1964.

25. Saetun, P., "Influence of Important Parameters on Mass Transfer in Agitated Vessel," Master Thesis, Chulalongkorn University, 1983.

26. Danckwert, P. V., Ind. Eng. Chem., 43, 1460, 1951.

27. Harriott, P., Chem. Eng. Sci., 17, 149, 1962.

28. Boon-long, S., Thèse, Contribution à l' étude du transfert de matière en cuve agitée, 1976.

29. Cheacharoen, S., and S. Suputtitada, "Characterization of Agitation," Senior Project, Dept. of Chem. Tech., Chulalongkorn University, 1977.

30. Charmikorn, A., and W. Chomchan, "Study of Fluid Mixing," Senior Project, Dept. of Chem. Tech., Chulalongkorn University, 1975.

31. Holland, F. A., and F.S. Chapman, Liquid Mixing and Processing in Stirred Tanks, 12-13, Lever Brothers Company, New York, 1966.

32. Heilbron, Dictionary of Organic Compounds, Vol.1, 4th ed., 1968.

33. Perry, R. H., D. W. Green, and J. M. Maloney, Perry's Chemical Engineers' Handbook, McGraw-Hill, New York, 6th ed., 1984.

34. Chen, J. C. P., Cane Sugar Handbook, John Wiley & Sons, New York, 11th ed., 1985.

35. Vanadurongwan, V., Thesis Docteur de Spécialité, Université Paul Sabatier, Toulouse, 32-33, 1975.

36. Vanadurongwan, V., C. Laguerie, and J. P. Couderc, "Diffusivité moyenne de l' acide benzoique dans l' eau entre la dilution infinie et la saturation influence de la temperature," Can. J. Chem. Eng., 54, 460-463, 1976.

37. Seidell, A., Solubilities of Inorganic and Organic Compounds, Van Nostrand Co., New York, 1956.

APPENDIX A

METHOD OF COATING SAMPLE SPHERES

In order to produce sample spheres of different densities, benzoic acid is coated on glass beads, polystyrene spheres, plastic particles type 1 and type 2. The procedures of coating sample spheres are described as follow:

Materials such as glass beads are put in the equipment for coating sample spheres. A little binding, gelatin solution about 4 % - 5 % bases on total weight of benzoic acid and gelatin, is mixed then benzoic acid powder is added quickly. The pan of the equipment rolls continuously. Such processes are done until the particles of solid spheres are in the desired appearance. The solid spheres are passed sieved number 4 to obtain particle diameter of 4.76 mm.

APPENDIX B

DETERMINATION OF DENSITY OF SOLID PARTICLES [25]

In this work the densities of solid particles are measured at room temperature (30 °C) by using water displacement principle in pycnometer, as follows: The weight of the empty dried pycnometer is m_1 and after filling with distilled water is m_2. Ten pellets of solid particles weighing m_3 are carefully dropped into the filled pycnometer. The water displacement of solid particles which overflowed from the pycnometer is wiped off using a clean towel. The final weight of the pycnometer with solid particles and distilled water is m_4. The density value can then be easily calculated, as follows:

Weight of empty dried pycnometer, m_1	=	22.6870	g
Weight of pycnometer + water, m_2	=	47.7853	g
Weight of ten solid particles, m_3	=	1.2975	g
Weight of pycnometer + water + solid particles, m_4	=	48.1600	g
Density of water at 30 °C	=	0.995647	g/cc
Volume of solid particles by water displacement, $m_2-(m_4-m_3)$/Density of water at 30 °C [33], v	=	0.9268	g/cc
Density of solid particles	=	m_3/v	
	=	1.3999	g/cc

The value 1.3999 g/cc is one of five experimental results. The density value is obtained from five experimental results of which the maximum error is within ± 0.5 %.

The Density Value for Each Sample Spheres

Sample Spheres	Density (g/cc)
Benzoic acid coated on glass beads	1.4020
Benzoic acid coated on polystyrene spheres	1.2367
Benzoic acid coated on plastic particles type 1	1.1866
Benzoic acid coated on plastic particles type 2	1.1239

APPENDIX C

SOLUBILITY VS TEMPERATURE [32]

Accurate values of saturation concentration (solubility) are essential for a proper calculation of mass diffusion.

Solubility of Benzoic Acid vs Temperature [32]

Temperature (°C)	Solubility (g of solute/1,000 cc of water)
4	1.8
10	2.1
18	2.7
31	4.2
40	5.5
60	12.0
70	17.8
75	22.0

Solubility of benzoic acid vs temperature fitted by POLYFIT PROGRAM:

THE BEST FITTING POLYNOMIAL EQUATION IS:

$$Y = A0 + A1*X + A2*X^2 + A3*X^3 + A4*X^4$$

A0 = 1.66148572

A1 = .0237563197

A2 = 2.50677532E-03

A3 = -4.6411662E-05

A4 = 7.58313377E-07

THE COEFFICIENT OF DETERM.,R^2 IS:.999

THE CORRELLATION COEFFICIENT IS:.999

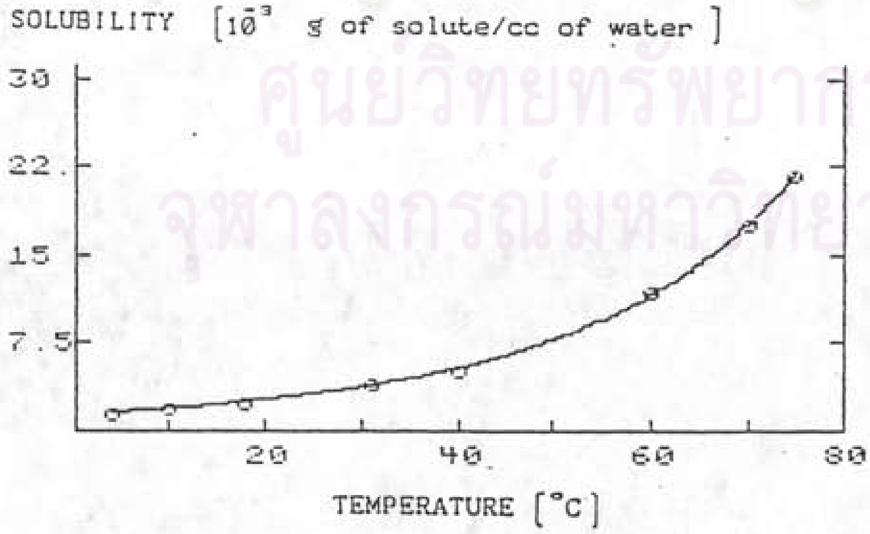
REAL X	REAL Y	MODEL Y	RESIDUAL
4	1.8	1.793	6E-03
10	2.1	2.11	-.011
18	2.7	2.71	-.011
31	4.2	4.124	.075
40	5.5	5.593	-.094
60	12	11.914	.085
70	17.8	17.895	-.096
75	22	21.957	.042

THE RESIDUAL SUM OF SQUARES IS:.033

THE RESIDUAL MEAN SQUARE IS:.011

THE STANDARD ERROR OF THE REGRESSION ESTIMATE:.1048

THE VALUE OF F IS:388883.69



SOLUBILITY OF BENZOIC ACID VS TEMPERATURE

APPENDIX D

VISCOSITY OF WATER VS TEMPERATURE [33]

Temperature ($^{\circ}C$)	Viscosity x 10^2 (poise)
20	1.05
25	0.95
30	0.85
35	0.77
40	0.72
45	0.65
50	0.60

Viscosity of water vs temperature fitted by POLYFIT PROGRAM:

THE BEST FITTING POLYNOMIAL EQUATION IS:
Y = A0 + A1*X + A2*X^2 + A3*X^3
A0 = .0172831934

A1 = -4.57446484E-04

A2 = 6.85678174E-06

A3 = -4.44415171E-08

THE COEFFICIENT OF DETERM.,R^2 IS:.998

THE CORRELLATION COEFFICIENT IS:.999

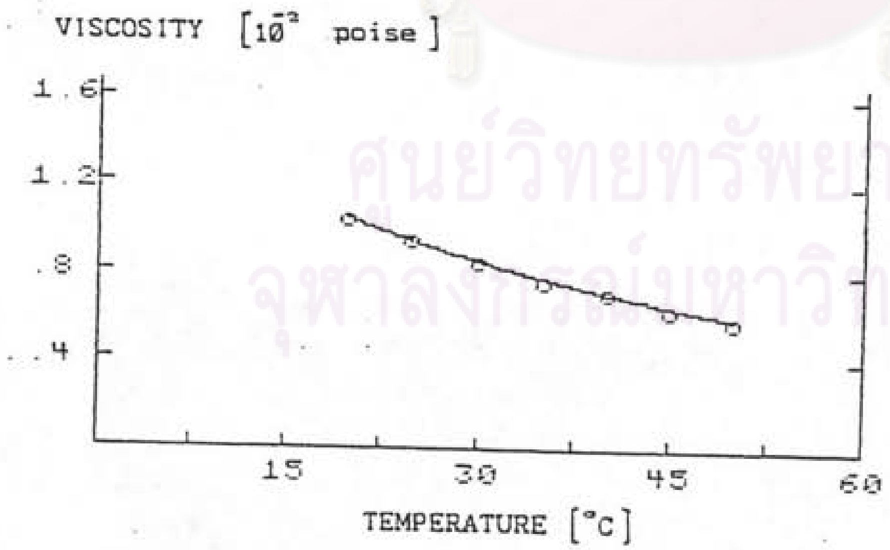
REAL X	REAL Y	MODEL Y	RESIDUAL
20	.0105	.01	-1E-03
25	9.5E-03	9E-03	0
30	8.5E-03	8E-03	-1E-03
35	7.7E-03	7E-03	-1E-03
40	7.2E-03	7E-03	0
45	6.5E-03	6E-03	-1E-03
50	6E-03	5E-03	0

THE RESIDUAL SUM OF SQUARES IS:0

THE RESIDUAL MEAN SQUARE IS:0

THE STANDARD ERROR OF THE REGRESSION ESTIMATE:0

THE VALUE OF F IS:25379.69



VISCOSITY OF WATER VS TEMPERATURE

APPENDIX E

DENSITY OF WATER VS TEMPERATURE [33]

Temperature ($^{\circ}C$)	Density x 10^3 (g/cm^3)
15	999.099
20	998.204
25	997.045
30	995.647
35	994.032
40	992.215
45	990.213
50	988.037

Density of water vs temperature fitted by POLYFIT PROGRAM:

THE BEST FITTING POLYNOMIAL EQUATION IS:
Y = A0 + A1*X + A2*X^2 + A3*X^3
A0 = 1.000081

A1 = 2.76928768E-05

A2 = -6.56054908E-06

A3 = 2.37806148E-08

THE COEFFICIENT OF DETERM.,R^2 IS:.965

THE CORRELLATION COEFFICIENT IS:.982

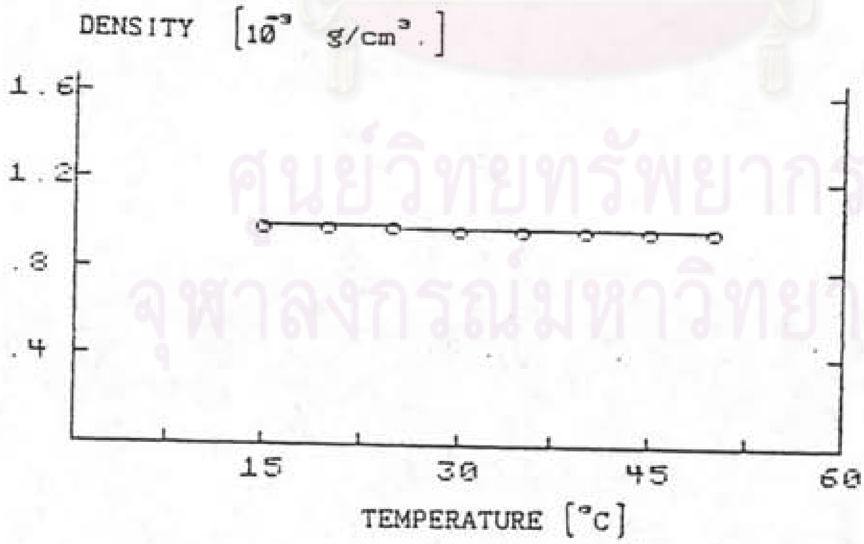
REAL X	REAL Y	MODEL Y	RESIDUAL
15	.999099	.999	-1E-03
20	.998204	.998	0
25	.997045	.997	0
30	.995647	.995	-1E-03
35	.994032	.994	-1E-03
40	.992215	.992	0
45	.990213	.99	0
50	.988037	.988	0

THE RESIDUAL SUM OF SQUARES IS:0

THE RESIDUAL MEAN SQUARE IS:0

THE STANDARD ERROR OF THE REGRESSION ESTIMATE:0

THE VALUE OF F IS:115605170



DENSITY OF WATER VS TEMPERATURE

APPENDIX F

VISCOSITY OF SUCROSE VS TEMPERATURE [34]

F.1 Viscosity of 13 wt % Sucrose in Water vs Temperature

Temperature (°C)	Viscosity x 10^2 (poise)
0	2.8355
5	2.3805
10	2.0246
15	1.7436
20	1.5209
25	1.3350
30	1.1826
35	1.0558
40	0.9516

Viscosity of 13 wt % sucrose in water vs temperature fitted by POLYFIT PROGRAM:

THE BEST FITTING POLYNOMIAL EQUATION IS:

Y = A0 + A1*X + A2*X^2 + A3*X^3 + A4*X^4

A0 = .0283550253

A1 = -1.02789344E-03

A2 = 2.55337449E-05

A3 = -4.13598901E-07

A4 = 3.08389364E-09

THE COEFFICIENT OF DETERM.,R^2 IS:.999

THE CORRELLATION COEFFICIENT IS:.999

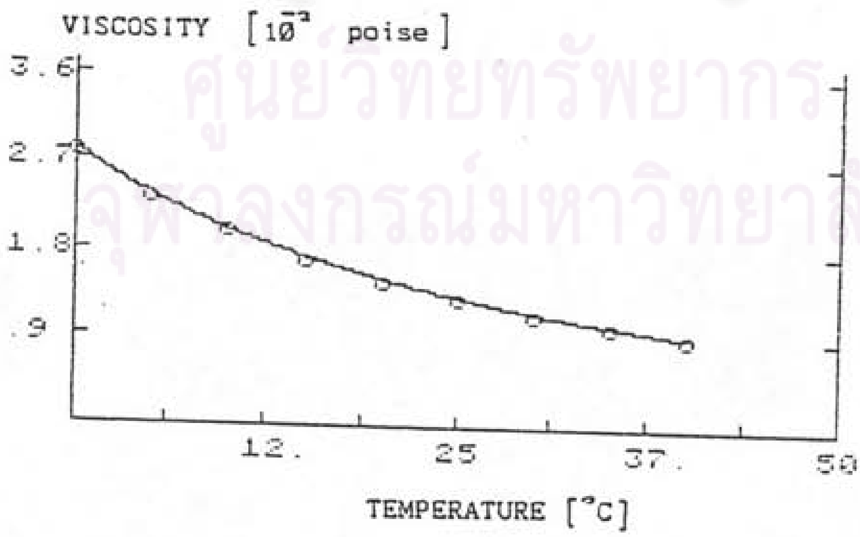
REAL X	REAL Y	MODEL Y	RESIDUAL
0	.028355	.029	-1E-03
5	.023805	.023	0
10	.020246	.02	-1E-03
15	.017436	.017	-1E-03
20	.015209	.015	0
25	.01335	.013	-1E-03
30	.011826	.011	-1E-03
35	.010558	.01	0
40	9.516E-03	9E-03	-1E-03

THE RESIDUAL SUM OF SQUARES IS:0

THE RESIDUAL MEAN SQUARE IS:0

THE STANDARD ERROR OF THE REGRESSION ESTIMATE:0

THE VALUE OF F IS:38050554.5



VISCOSITY OF 13 WT % SUCROSE VS TEMPERATURE

F.2 Viscosity of 20 wt % Sucrose in Water vs Temperature

Temperature (°C)	Viscosity x 10^2 (poise)
0	3.782
5	3.137
10	2.642
15	2.254
20	1.945
25	1.695
30	1.493
35	1.325
40	1.184

Viscosity of 20 wt % sucrose in water vs temperature fitted by POLYFIT PROGRAM:

THE BEST FITTING POLYNOMIAL EQUATION IS:
Y = A0 + A1*X + A2*X^2 + A3*X^3 + A4*X^4 + A5*X^5

A0 = .0378185203

A1 = -1.47451591E-03

A2 = 4.11547917E-05

A3 = -8.93341508E-07

A4 = 1.30791591E-08

A5 = -8.9396407E-11

THE COEFFICIENT OF DETERM.,R^2 IS:.999

THE CORRELLATION COEFFICIENT IS:.999

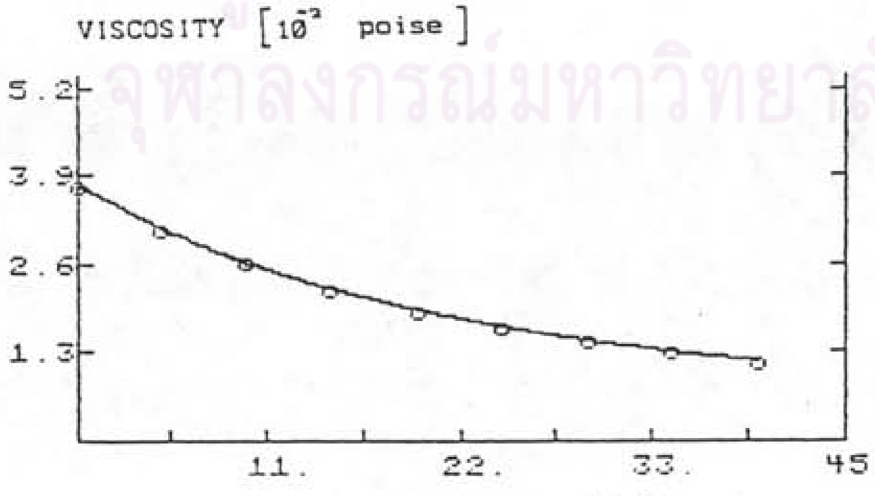
REAL X	REAL Y	MODEL Y	RESIDUAL
0	.03782	.037	0
5	.03137	.031	-1E-03
10	.02642	.026	0
15	.02254	.022	0
20	.01945	.019	0
25	.01695	.016	-1E-03
30	.01493	.014	0
35	.01325	.013	-1E-03
40	.01184	.011	-1E-03

THE RESIDUAL SUM OF SQUARES IS:0

THE RESIDUAL MEAN SQUARE IS:0

THE STANDARD ERROR OF THE REGRESSION ESTIMATE:0

THE VALUE OF F IS:197525919



VISCOCITY OF 20 WT % SUCROSE VS TEMPERATURE

F.3 Viscosity of 35.5 wt % Sucroses in Water vs Temperature

Temperature (°C)	Viscosity x 10^2 (poise)
0	9.9265
5	7.9395
10	6.4615
15	5.3390
20	4.4720
25	3.7920
30	3.2515
35	2.8165
40	2.4610

Viscosity of 35.5 wt % sucrose in water vs temperature fitted by POLYFIT PROGRAM:

THE BEST FITTING POLYNOMIAL EQUATION IS:

Y = A0 + A1*X + A2*X^2 + A3*X^3 + A4*X^4 + A5*X^5

A0 = .0992612124

A1 = -4.60384951E-03

~~A2 = 1.40832046E-04~~

~~A3 = -3.11134886E-06~~

~~A4 = 4.37209096E-08~~

A5 = -2.79592294E-10

THE COEFFICIENT OF DETERM.,R^2 IS:.999

THE CORRELLATION COEFFICIENT IS:.999

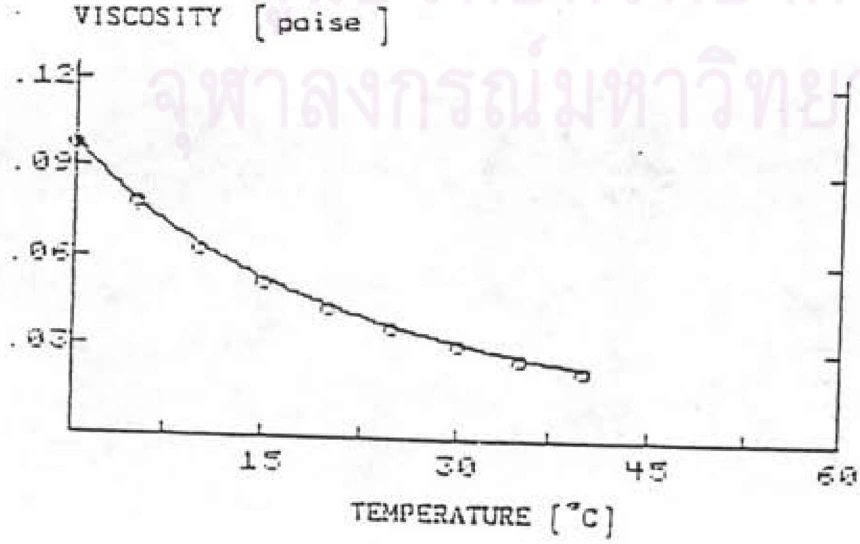
REAL X	REAL Y	MODEL Y	RESIDUAL
0	.099265	.099	0
5	.079395	.079	-1E-03
10	.064615	.064	0
15	.05339	.053	-1E-03
20	.04472	.044	-1E-03
25	.03792	.037	0
30	.032515	.032	0
35	.028165	.028	-1E-03
40	.02461	.024	0

THE RESIDUAL SUM OF SQUARES IS:0

THE RESIDUAL MEAN SQUARE IS:0

THE STANDARD ERROR OF THE REGRESSION ESTIMATE:0

THE VALUE OF F IS:499095080



VISCOSITY OF 35.5 WT % SUCROSE VS TEMPERATURE

APPENDIX G

DENSITY OF SUCROSE VS TEMPERATURE

G.1 Density of 13 wt % Sucrose in Water vs Temperature

Temperature (°C)	Density (g/cm^3)
30	1.0467
35	1.0447
40	1.0426
45	1.0402

Density of 13 wt % sucrose in water vs temperature fitted by POLYFIT PROGRAM:

THE BEST FITTING POLYNOMIAL EQUATION IS:
Y = A0 + A1*X + A2*X^2
A0 = 1.05425166

A1 = -1.32018933E-04

A2 = -3.9990482E-06

THE COEFFICIENT OF DETERM.,R^2 IS:1.414

THE CORRELLATION COEFFICIENT IS:1.189

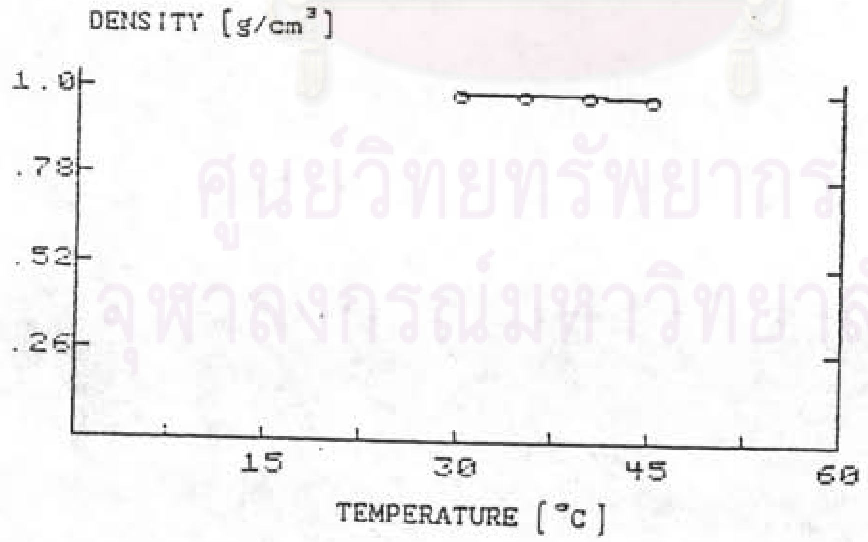
REAL X	REAL Y	MODEL Y	RESIDUAL
30	1.0467	1.046	0
35	1.0447	1.044	-1E-03
40	1.0426	1.042	0
45	1.0402	1.04	-1E-03

THE RESIDUAL SUM OF SQUARES IS:0

THE RESIDUAL MEAN SQUARE IS:0

THE STANDARD ERROR OF THE REGRESSION ESTIMATE:0

THE VALUE OF F IS:163469.03



DENSITY OF 13 WT % SUCROSE VS TEMPERATURE

G.2 Density of 20 wt % Sucrose in Water vs Temperature

Temperature (°C)	Density (g/cm³)
30	1.0777
35	1.0772
40	1.0754
45	1.0739

Density of 20 wt % sucrose in water vs temperature fitted by POLYFIT PROGRAM:

THE BEST FITTING POLYNOMIAL EQUATION IS:
$Y = A0 + A1*X + A2*X^2$

A0 = 1.0722023

A1 = 4.85956902E-04

A2 = -9.99859548E-06

THE COEFFICIENT OF DETERM.,R^2 IS:2.262

THE CORRELLATION COEFFICIENT IS:1.504

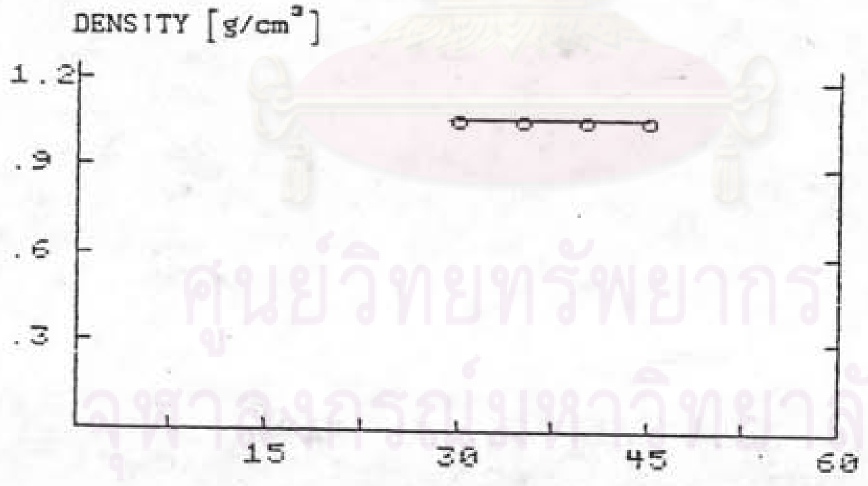
REAL X	REAL Y	MODEL Y	RESIDUAL
30	1.0777	1.077	-1E-03
35	1.0772	1.076	0
40	1.0754	1.075	-1E-03
45	1.0739	1.073	0

THE RESIDUAL SUM OF SQUARES IS:0

THE RESIDUAL MEAN SQUARE IS:0

THE STANDARD ERROR OF THE REGRESSION ESTIMATE:0

THE VALUE OF F IS:1606.59



DENSITY OF 20 WT % SUCROSE VS TEMPERATURE

G.3 Density of 35.5 wt % Sucrose in Water vs Temperature

Temperature (°C)	Density (g/cm³)
30	1.1510
35	1.1491
40	1.1484
45	1.1466

Density of 35.5 wt % sucrose in water vs temperature fitted by POLYFIT PROGRAM:

THE BEST FITTING POLYNOMIAL EQUATION IS:
Y = A0 + A1*X + A2*X^2
A0 = 1.16057517

A1 = -3.52974981E-04

A2 = 1.00095349E-06

THE COEFFICIENT OF DETERM.,R^2 IS:2.118

THE CORRELLATION COEFFICIENT IS:1.455

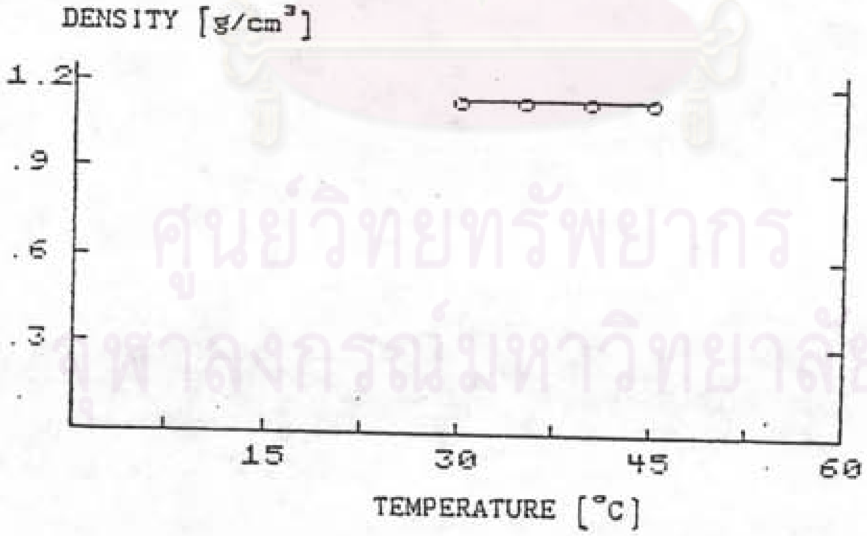
REAL X	REAL Y	MODEL Y	RESIDUAL
30	1.151	1.15	0
35	1.1491	1.149	-1E-03
40	1.1484	1.148	0
45	1.1466	1.146	-1E-03

THE RESIDUAL SUM OF SQUARES IS:0

THE RESIDUAL MEAN SQUARE IS:0

THE STANDARD ERROR OF THE REGRESSION ESTIMATE:0

THE VALUE OF F IS:795.04



DENSITY OF 35.5 WT % SUCROSE VS TEMPERATURE

APPENDIX H

DIFFUSION COEFFICIENT VS TEMPERATURE

H.1 Diffusion Coefficient of Benzoic Acid in Water vs Temperature [35,36]

Temperature ($^{\circ}C$)	$D \times 10^{7}$ (cm^{2}/S)
10	65.86
15	74.41
20	82.48
25	92.78
30	104.31
35	111.80
40	134.80
44	155.30
50	195.10

Values are fitted by POLYFIT PROGRAM:

THE BEST FITTING POLYNOMIAL EQUATION IS:

Y = A0 + A1*X + A2*X^2 + A3*X^3

A0 = 2.7960042E-06

A1 = 5.10097908E-07

A2 = -1.67640045E-08

A3 = 2.63830587E-10

THE COEFFICIENT OF DETERM.,R^2 IS:.997

THE CORRELLATION COEFFICIENT IS:.998

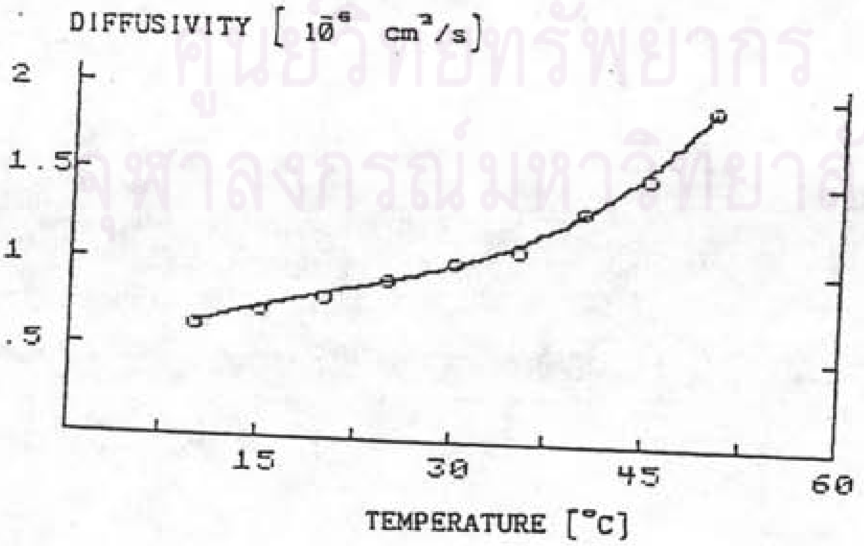
REAL X	REAL Y	MODEL Y	RESIDUAL
10	6.586E-06	0	
15	7.441E-06	0	0
20	8.248E-06	0	-1E-03
25	9.278E-06	0	-1E-03
30	1.0431E-05	0	0
35	1.118E-05	0	0
40	1.348E-05	0	-1E-03
45	1.553E-05	0	0
50	1.951E-05	0	-1E-03
			0

THE RESIDUAL SUM OF SQUARES IS:0

THE RESIDUAL MEAN SQUARE IS:0

THE STANDARD ERROR OF THE REGRESSION ESTIMATE:0

THE VALUE OF F IS:18992.49



DIFFUSIVITY OF BENZOIC ACID IN WATER VS TEMPERATURE

H.2 Diffusion Coefficient of Benzoic Acid into 13 wt % Sucrose vs Temperature [1]

Temperature (°C)	$D \times 10^7$ (cm^2/S)
0	31.0848
5	31.0262
10	43.5350
15	50.5510
20	57.9532
25	66.0232
30	74.5315
35	83.4827
40	92.6240

Values are fitted by POLYFIT PROGRAM:

THE BEST FITTING POLYNOMIAL EQUATION IS:

Y = A0 + A1*X + A2*X^2 + A3*X^3 + A4*X^4 + A5*X^5

A0 = 3.10769741E-06

A1 = 1.12196915E-07

A2 = 1.54102597E-09

A3 = -4.29823954E-11

A4 = 1.43153545E-12

A5 = -1.67296732E-14

THE COEFFICIENT OF DETERM.,R^2 IS:.999

THE CORRELLATION COEFFICIENT IS:.999

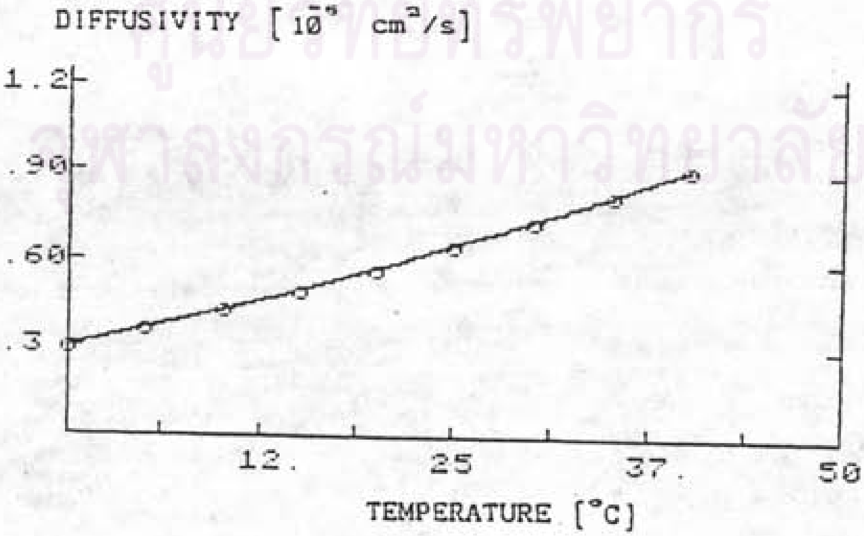
REAL X	REAL Y	MODEL Y	RESIDUAL
0	3.10848E-060		0
5	3.70262E-060		-1E-03
10	4.3535E-060		0
15	5.0551E-060		0
20	5.79532E-060		-1E-03
25	6.60232E-060		0
30	7.45315E-060		0
35	8.34827001E-060		-1E-03
40	9.26240001E-060		0

THE RESIDUAL SUM OF SQUARES IS:0

THE RESIDUAL MEAN SQUARE IS:0

THE STANDARD ERROR OF THE REGRESSION ESTIMATE:0

THE VALUE OF F IS:30673629.6



DIFFUSIVITY OF 13 WT % SUCROSE VS TEMPERATURE

H.3 Diffusion Coefficient of Benzoic Acid into 20 wt % Sucrose vs Temperature [1]

Temperature (°C)	D x 10^7 (cm^2/S)
0	23.3054
5	28.0972
10	33.3615
15	39.1043
20	45.3167
25	52.0006
30	59.0362
35	66.5215
40	74.4434

Values are fitted by POLYFIT PROGRAM:

THE BEST FITTING POLYNOMIAL EQUATION IS:

Y = A0 + A1*X + A2*X^2 + A3*X^3 + A4*X^4 + A5*X^5

A0 = 2.33223011E-06

A1 = 8.13657373E-08

A2 = 3.44070461E-09

A3 = -2.10538504E-10

A4 = 7.15700936E-12

A5 = -8.49680366E-14

THE COEFFICIENT OF DETERM.,R^2 IS:.999

THE CORRELLATION COEFFICIENT IS:.999

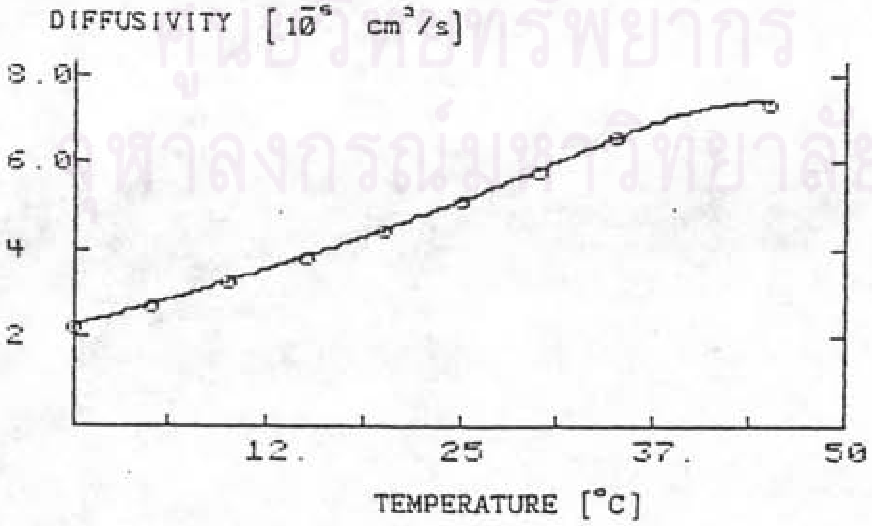
REAL X	REAL Y	MODEL Y	RESIDUAL
0	2.33054E-060		-1E-03
5	2.80972E-060		0
10	3.33615E-060		-1E-03
15	3.9104E-060		-1E-03
20	4.53167E-060		0
25	5.20006E-060		0
30	5.903632E-060		-1E-03
35	6.65215E-060		0
45	7.44434E-060		-1E-03

THE RESIDUAL SUM OF SQUARES IS:0

THE RESIDUAL MEAN SQUARE IS:0

THE STANDARD ERROR OF THE REGRESSION ESTIMATE:0

THE VALUE OF F IS:1667835.36



DIFFUSIVITY OF 20 WT % SUCROSE VS TEMPERATURE

H.4 Diffusion Coefficient of Benzoic Acid into 35.5 wt % Sucrose vs Temperature [1]

Temperature ($^{\circ}C$)	D x 10^{7} (cm^{2}/S)
0	8.8794
5	11.1016
10	13.6409
15	16.5089
20	19.7095
25	23.2439
30	27.1078
35	31.2945
40	35.8151

Values are fitted by POLYFIT PROGRAM:

THE BEST FITTING POLYNOMIAL EQUATION IS:
Y = A0 + A1*X + A2*X^2 + A3*X^3 + A4*X^4

A0 = 8.88008835E-07

A1 = 4.12159851E-08

A2 = 6.29821639E-10

A3 = 1.11251286E-12

A4 = -1.33409451E-14

THE COEFFICIENT OF DETERM.,R^2 IS:1

THE CORRELLATION COEFFICIENT IS:1

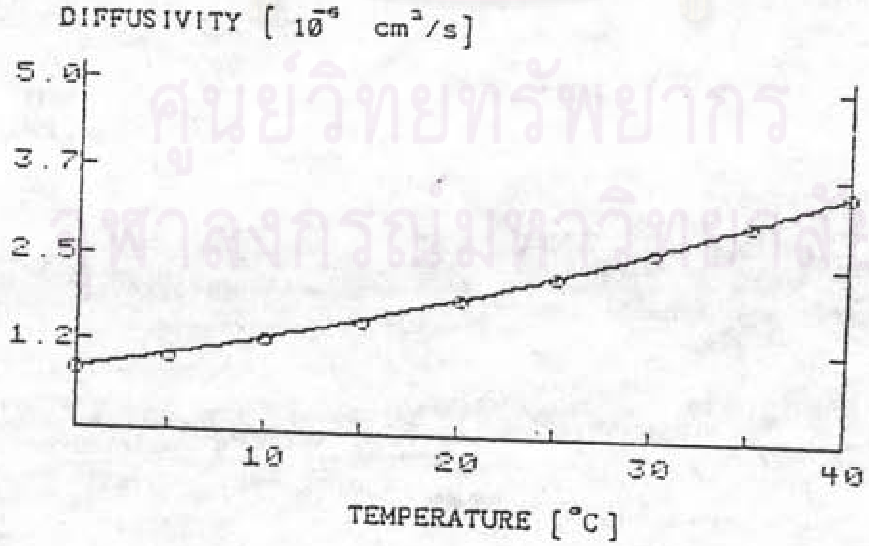
REAL X	REAL Y	MODEL Y	RESIDUAL
0	8.8794E-070		-1E-03
5	1.11016E-060		0
10	1.36409E-060		-1E-03
15	1.65089E-060		-1E-03
20	1.97095E-060		-1E-03
25	2.32437E-060		0
30	2.71078E-060		0
35	3.12945E-060		-1E-03
40	3.58151E-060		0

THE RESIDUAL SUM OF SQUARES IS:0

THE RESIDUAL MEAN SQUARE IS:0

THE STANDARD ERROR OF THE REGRESSION ESTIMATE:0

THE VALUE OF F IS:1.05458802E+09



DIFFUSIVITY OF 35.5 WT % SUCROSE VS TEMPERATURE

APPENDIX I

SAMPLE CALCULATION FOR Sh_p, Re_p, Sc AND Mv

Benzoic acid coated on glass beads - water, speed 450 rpm, temperature 35 °C.

Particle diameter	=	0.476	cm
Time	=	300	s
Weight before run	=	1.3329	g
Weight after run	=	1.2699	g
Mass dissolved	=	1.3329-1.2699	
	=	0.063	g
Mass dissolved /time, m	=	2.1×10^{-4}	g/s
Number of particle	=	10	
Area of particles	=	$n\pi d_p^2$	
	=	$10\times\pi\times(0.476)^2$	
	=	7.1181	cm^2
Liquid volume	=	$\pi r^2 h$	
	=	$\pi(10)^2(20)$	
	=	6283.19	cm^3
c	=	Mass dissolved/Liquid volume	
	=	0.063/6283.19	
	=	1.002675×10^{-5}	g/cm^3

c_o is the initial concentration is equal zero

c_s is the saturation concentration [FROM POLYFIT PROGRAM APPENDIX C]

For benzoic acid and water c_s at 35 °C is 4.7118×10^{-3} g/cm^3

Δc_{ML} $= c_f - c_o / \ln(c_s - c_o / c_s - c_f)$

$= 4.7068 \times 10^{-3}$ g/cm^3

Mass transfer coefficient, k

$= m/A\Delta c_{ML}$

$= 6.268 \times 10^{-3}$ cm/s

Diffusivity of benzoic acid into water at 35 °C, D_v

$= 1.15349 \times 10^{-5}$ cm^2/s

[FROM POLYFIT PROGRAM APPENDIX H.1]

Sherwod number, Sh_p $= kd_p/D_v$

$= 258.66$

Reynolds number, Re_p $= d_p T\omega\rho_1/\mu$

$= d_p T2\pi N\rho_1/\mu$

N is rotation speed (sec^{-1})

Then $Re_p = d_p T2\pi N\rho_1/60\mu$

Density of water at 35 °C, ρ_1 is 0.994033 g/cm^3

[FROM POLYFIT PROGRAM APPENDIX E]

Viscoity of water at 35 °C, μ is 0.776671×10^{-2} poise

[FROM POLYFIT PROGRAM APPENDIX D]

$Re_p = (0.476)(20)(2\pi \times 450)(0.994033)/60 \times 0.77667 \times 10^{-2}$

$= 5.74 \times 10^4$

Schmidt number, $Sc = \mu/\rho_1 D_v$

$= 677.36$

Density group, $Mv = (\rho_s - \rho_1)/\rho_1$

Density of Benzoic coated on glass beads is 1.4020 g/cm^3

$Mv = 0.4104$

APPENDIX J

BLANK TEST

To check whether the drying process has an effect on the mass dissolved in each run or not, ten pellets of solid particles are first weighed and then dried in the oven at a temperature of 60 °C for one hour and a half. After that they are weighed again. The weight differences are determined. The results are shown below

Weight before drying (g)	Weight after drying (g)	Weight loss (%)
1.3433	1.3419	0.104
1.2949	1.2937	0.093
1.3121	1.3110	0.084
1.3040	1.3030	0.077
1.3121	1.3112	0.069
1.3120	1.3111	0.069

The test shows that there are some effects on mass of benzoic acid dissolved in the experiment. If the weight loss in the experiment is about 1 percent, this effect should not be ignored. The mass disolved in each run should be corrected by the weight loss from in the blank test.

APPENDIX K

CALCULATION OF PRECISION

Before analyzing the results and comparing them with previous work. It is necessary to evaluate the precision of various measurements and calculate the percent errcr of each group of data.

In the course of this study correlation in terms of dimensionless groups is in the form

$$Sh_p = f(Re_p, Sc)$$

K.1 Reynolds Number

$$Re_p = d_p T 2\pi N\rho/60\mu$$

$$\Delta Re_p/Re_p = (\Delta d_p/d_p)+(\Delta T/T)+(\Delta N/N)+(\Delta \rho/\rho)+(\Delta\mu/\mu)$$

The temperature, T, liquid viscosity, μ, diameter, T, pacticle diameter, d_p are known exactly.

$$\Delta Re_p/Re_p = (\Delta N/N)+(\Delta \rho/\rho)$$

The speed of rotation measurement error take about $\pm$ 2 rpm.

$$(\Delta N/N) = (\Delta \omega/\omega) \leqslant 2\times100/270 = 0.74\ \%$$

From Appendix B and G, the relative error measurement in density take about 0.5 %.

$$\Delta Re_p/Re_p = 0.74+0.5 = 1.24\ \%$$

K.2 Schmidt Number

$$Sc = \mu/\rho D_v$$

$$\Delta Sc/Sc = (\Delta\rho/\rho)+(\Delta D_v/D_v)$$

The maximum error $\Delta D_v/D_v$ of diffusion coefficient is 5.36 % [35]

$$\Delta Sc/Sc \leqslant 0.5+5.36 = 5.86\%$$

K.3 Sherwood Number

$$Sh_p = kd_p/D_v$$

$$\Delta Sh_p/Sh_p = (\Delta k/k)+(\Delta D_v/D_v)$$

The mass transfer coefficient k is determined by the relation

$$k = m/A\Delta c_{ML}$$

$$k = (m_o-m_f)/tA\Delta c_{ML}$$

$$\Delta k/k = \Delta(m_o-m_f)/(m_o-m_f)+(\Delta t/t)+(\Delta A/A)+\Delta(\Delta c_{ML})/\Delta c_{ML}$$

The area A is determined by the diameter, d_p and the number of particle n.

$$A = d_p^2 \pi n$$

$$\Delta A/A = 0$$

Δc_{ML} is determined from the initial concentration c_o, the final concentration c_f and the saturated concentration c_s, by the relation

$$\Delta c_{ML} = (c_s - c_o) - (c_s - c_f)/\ln[(c_s - c_o)/(c_s - c_f)]$$
$$= c_f/\ln[c_s/(c_s - c_f)]$$

$$\Delta(\Delta c_{ML})/\Delta c_{ML} = (\Delta c_f/c_f) + \Delta[\ln(c_s/(c_s - c_f)]/\ln[c_s/(c_s - c_f)]$$

c_f, the final concentration is obtained by calculation from the initial mass m_o and the final mass m_f of solid exchange, and the total volume, v of the liquid in the vessel

$$c_f = (m_o - m_f)/v$$

$$\Delta c_f/c_f = [\Delta(m_o - m_f)/(m_o - m_f)] + (\Delta v/v)$$

The vessel diameter, T is known exactly

$$\Delta c_f/c_f = [\Delta(m_o - m_f)/(m_o - m_f)] + (\Delta H/H)$$

$$\Delta \ln[c_s/(c_s - c_f)] = \Delta c_f/(c_s - c_f)$$

$$\Delta(\Delta c_{ML})/c_{ML} = [\Delta(m_o-m_f)/(m_o-m_f)]+(\Delta H/H) +[\Delta c_f/(c_s-c_f)]/\ln[c_s/(c_s-c_f)]$$

$$= \Delta(m_o-m_f)/(m_o-m_f)+(\Delta H/H) +[\Delta c_f/[c_f(c_s-c_f)][c_f/\ln(c_s/(c_s-c_f)]$$

$$= \Delta(m_o-m_f)/(m_o-m_f)+(\Delta H/H) +[\Delta(m_o-m_f)/(m_o-m_f)+(\Delta H/H)][\Delta c_{ML}/(c_s-c_f)]$$

$$\Delta Sh_{r}/Sh_{P} = 2\Delta(m_o-m_f)/(m_o-m_f)+(\Delta t/t)+(\Delta H/H)+(\Delta D_v/D_v) +[\Delta(m_o-m_f)/(m_o-m_f)+(\Delta H/H)][\Delta c_{ML}/(c_s-c_f)]$$

t is the drainage time which is about 30 secs

$$(\Delta t/t) \leqslant 30\text{x}100/300 = 10\ \%$$

The height of liquid measurement erorr in the agitated vessel take about + 0.2 cm

$$(\Delta H/H) \leqslant 0.2\text{x}100/20 = 1\ \%$$

The mass m_o and m_f measured by weight balance + 0.0001 g by using minimum value of (m_o-m_f) thus

$$\Delta(m_o-m_f)/(m_o-m_f) \leqslant 0.0001\text{x}100/0.0121 = 0.826\ \%$$

c_s at the lowest temperature, 25 °C, is 3.3930 g/1000 cm^3. c_f calculated form the maximum value of (m_o-m_f) and the volume of 6,283 cm^3

$$c_f = 0.0787/6{,}283 = 1.2525\times10^{-4}$$

$$c_s - c_f = 3.3804\times10^{-3}\ g/cm^3$$

$$\begin{aligned}\Delta c_{ML} &= c_f/\ln(c_s/(c_s-c_f)) \\ &= 1.2525\times10^{-5}/\ln(3.3930/3.3804) \\ &= 3.3865\times10^{-3}\end{aligned}$$

$$\begin{aligned}\Delta Sh_p/Sh_p &= 2\times(0.826)+10+1+1.826\times3.3865/3.3804+5.36 \\ &= 19.67\ \%\end{aligned}$$

From Table 5.3, the measured values of Sh_p for the system using glass beads are 520, 510, 500, 550, 590. The average value is 534. This data set gives the maximum relative error in this work.

The maximum relative error of $\Delta Sh_{exp}/Sh_{exp}$ = (maximum-minimum)/minimum

$$\begin{aligned}\Delta Sh_{exp}/Sh_{exp} &= (590-500)\times100/500 \\ &= 18\ \%\end{aligned}$$

Hence all sets of data are acceptable.

APPENDIX L

REPEATABILITY OF DATA

To find the repeatability of the experiment data are collected at the same conditions i.e. at constant speed, temperature, solid - liquid system and time. The maximum relative error is calculated. Data of the system of benzoic acid - water are collected at the temperature of 40 °C, the rotation speed of 450 rpm and the experimental period 5 mins. They are shown below

Run no.	Weight of dissolved benzoic acid (g)
1	0.0752
2	0.0801
3	0.0774
4	0.0713
5	0.0777
6	0.0755
7	0.0757
Average	0.0761

The maximum relative error of repeatability in this experiment is

$$[(0.0801-0.0713)/0.0713]\times 100 = 12.34\ \%$$

APPENDIX M

CURVE FITTING

To draw the curve in order to correlate two variables least-squares method is used. Because the logarithmic functions of Sherwood number and Reynolds number or Schmidt number or Density group are in straight lines. The slope of each straight line indicates whether the variable has influence on Sherwood number or not.

M.1 The Influence of Reynolds Number on Sherwood Number

Figures 5.1-5.11 demonstrate the influence of Reynolds number on Sherwood number. The curves are drawn by least-squares method. Data from Tables 5.1-5.9 are calculated. Each set of data of one table has one straight line with its slope and intercept. The average value of the slopes is obtained. Table M.1 is the summary of the slope and intercept of each least-squares line. The average slope is 1.21. This is the exponent of Reynolds number in the correlation. This average slope is used to draw all curves again as shown in Figures 5.1-5.11.

Table M.1 Slopes and Intercepts by Least-Squares Method for the Relation between Reynolds Numbers and Sherwood Numbers

Data from Tables	Slope	Intercept
5.1	1.177	-3.156
5.2	1.167	-2.800
5.3	1.247	-2.928
5.4	1.172	-2.017
5.5	1.279	-2.516
	Average = 1.21	

Tables M.2-M.10 show the calculation of least-squares lines by using the average slope. Y_{cal} are calculated by least-squares method using its slope i.e. 1.177, 1.167, 1.247 etc. The relative errors between Y and Y_{cal} are shown in term of % Error. All least-squares lines have the average slope 1.21. AO_{cal} is the intercept of each point by using the slope 1.21. Y_{avg} are calculated by least-squares method using the average slope 1.21 and the average intercept AO_{cal}. The relative errors between Y and Y_{avg} are given in the last column of the Tables.

M.2 The Influence of Schmidt Number on Sherwood Number

Figures 5.12-5.16 demonstrate the influence of Schmidt number on Sherwood number. The curves are drawn by least-squares method. Data from Tables 5.10-5.13 are calculated. The details

Table M.2 Calculation of Least-Squares Line by Using the Average Slope

Data from Table 5.1

	Re	Sh_p	X LOG(Re)	Y LOG(Sh_p)	Y Cal	% ERROR	A0 Cal	Y Avg	% ERROR
GLASS BEADS	51058.00	240.00	4.7081	2.3802	2.3860	-0.24	-3.3095	2.3864	-0.26
	57440.00	262.00	4.7592	2.4183	2.4462	-1.14	-3.3332	2.4483	-1.22
	63822.00	320.00	4.8050	2.5051	2.5001	0.20	-3.3016	2.5036	0.06
	70204.00	402.00	4.8464	2.6042	2.5488	2.18	-3.2526	2.5536	1.98
POLYSTYRENE SHPERES	35102.00	145.00	4.5453	2.1614	2.1944	-1.51	-3.3316	2.1898	-1.30
	38292.00	186.00	4.5831	2.2695	2.2389	1.37	-3.2691	2.2354	1.52
	44675.00	220.00	4.6501	2.3424	2.3177	1.07	-3.2771	2.3163	1.13
	51058.00	225.00	4.7081	2.3522	2.3860	-1.42	-3.3375	2.3864	-1.44
	57440.00	287.00	4.7592	2.4579	2.4462	0.48	-3.2936	2.4483	0.39
	63822.00	290.00	4.8050	2.4624	2.5001	-1.51	-3.3444	2.5036	-1.64
PLASTIC PARTICLES TYPE 1	35102.00	137.00	4.5453	2.1367	2.1944	-2.63	-3.3563	2.1898	-2.42
	38293.00	168.00	4.5831	2.2253	2.2389	-0.61	-3.3134	2.2354	-0.45
	44675.00	219.00	4.6501	2.3404	2.3177	0.98	-3.2791	2.3163	1.04
	51058.00	265.00	4.7081	2.4232	2.3860	1.56	-3.2664	2.3864	1.54
	57440.00	270.00	4.7592	2.4314	2.4462	-0.61	-3.3201	2.4483	-0.69
	63822.00	300.00	4.8050	2.4771	2.5001	-0.92	-3.3297	2.5036	-1.06
PLASTIC PARTICLES TYPE 2	35088.00	168.00	4.5452	2.2253	2.1942	1.42	-3.2675	2.1896	1.63
	38278.00	189.00	4.5829	2.2765	2.2387	1.69	-3.2620	2.2352	1.84
	44657.00	208.00	4.6499	2.3181	2.3175	0.02	-3.3013	2.3161	0.08
	51037.00	242.00	4.7079	2.3838	2.3858	-0.08	-3.3056	2.3862	-0.10
	57417.00	280.00	4.7590	2.4472	2.4460	0.05	-3.3041	2.4480	-0.04
	63796.00	310.00	4.8048	2.4914	2.4949	-0.34	-3.3152	2.5033	-0.46
						Avg	-3.303221		

Table M.3 Calculation of Least-Squares Line by Using the Average Slope

Data from Table 5.2

	Re	Sh_p	LOG(Re)	LOG(Sh_p)	Y Cal	% ERROR	AO Cal	Y Avg	% ERROR
GLASS BEADS	34525.00	299.00	4.5381	2.4757	2.4935	-0.71	-3.0086	2.4910	-0.61
	39458.00	373.00	4.5961	2.5717	2.5612	0.41	-2.9827	2.5611	0.42
	44390.00	432.00	4.6473	2.6355	2.6208	0.56	-2.9807	2.6229	0.48
	49322.00	498.00	4.6930	2.6972	2.6742	0.86	-2.9743	2.6782	0.71
PLASTIC PARTICLES TYPE 1	29593.00	206.00	4.4712	2.3139	2.4154	-4.20	-3.0895	2.4101	-3.99
	34525.00	342.00	4.5381	2.5340	2.4935	1.63	-2.9503	2.4910	1.73
	39458.00	400.00	4.5961	2.6021	2.5612	1.60	-2.9523	2.5611	1.60
	44390.00	475.00	4.6473	2.6767	2.6208	2.13	-2.9395	2.6229	2.05
	49322.00	513.00	4.6930	2.7101	2.6742	1.34	-2.9614	2.6782	1.19
PLASTIC PARTICLES TYPE 2	29593.00	284.00	4.4712	2.4533	2.4154	1.57	-2.9501	2.4101	1.79
	34525.00	320.00	4.5381	2.5051	2.4935	0.47	-2.9792	2.4910	0.57
	39458.00	385.00	4.5961	2.5855	2.5612	0.95	-2.9689	2.5611	0.95
	44390.00	381.00	4.6473	2.5809	2.6208	-1.52	-3.0353	2.6229	-1.60
	49332.00	345.00	4.6931	2.5378	2.6743	-5.10	-3.1338	2.6783	-5.24
						Avg	-2.993331		

Table M.4 Calculation of Least-Squares Line by Using the Average Slope

Data from Table 5.3

	Re	Sh_r	LOG(Re)	LOG(Sh_r)	Y Cal	% ERROR	AO Cal	Y Avg	% ERROR
GLASS BEADS	25194.00	373.00	4.4013	2.5717	2.5617	0.39	-2.7472	2.5640	0.30
	28794.00	438.00	4.4593	2.6415	2.6341	0.28	-2.7476	2.6341	0.28
	32393.00	534.00	4.5105	2.7275	2.6979	1.10	-2.7233	2.6959	1.17
	35992.00	591.00	4.5562	2.7716	2.7549	0.60	-2.7346	2.7512	0.74
POLYSTYRENE SHPERES	21595.00	325.00	4.3344	2.5119	2.4782	1.36	-2.7262	2.4831	1.16
	25194.00	345.00	4.4013	2.5378	2.5617	-0.93	-2.7811	2.5640	-1.02
	28794.00	451.00	4.4593	2.6542	2.6341	0.76	-2.7349	2.6341	0.76
	32393.00	520.00	4.5105	2.7160	2.6979	0.67	-2.7348	2.6959	0.75
	35992.00	630.00	4.5562	2.7993	2.7549	1.61	-2.7068	2.7512	1.75
PLASTIC PARTICLES TYPE 1	21595.00	308.00	4.3344	2.4886	2.4782	0.42	-2.7495	2.4831	0.22
	25194.00	363.00	4.4013	2.5599	2.5617	-0.07	-2.7590	2.5640	-0.16
	28794.00	411.00	4.4593	2.6138	2.6341	-0.77	-2.7752	2.6341	-0.77
	32393.00	460.00	4.5105	2.6628	2.6979	-1.30	-2.7881	2.6959	-1.23
	35992.00	561.00	4.5562	2.7490	2.7549	-0.22	-2.7572	2.7512	-0.08
PLASTIC PARTICLES TYPE 2	21595.00	284.00	4.3344	2.4533	2.4782	-1.00	-2.7847	2.4831	-1.20
	25194.00	361.00	4.4013	2.5575	2.5617	-0.16	-2.7614	2.5640	-0.25
	28794.00	431.00	4.4593	2.6345	2.6341	0.02	-2.7546	2.6341	0.02
	32393.00	441.00	4.5105	2.6444	2.6979	-1.98	-2.8064	2.6959	-1.91
	35992.00	542.00	4.5562	2.7340	2.7549	-0.76	-2.7721	2.7512	-0.62
						Avg	-2.754984		

Table M.5 Calculation of Least-Squares Line by Using the Average Slope -

Data from Table 5.4

	Re	Sh_p	LOG(Re)	$LOG(Sh)_p$	Y Cal	% ERROR	A0 Cal	Y Avg	% ERROR
GLASS BEADS	13671.00	636.00	4.1358	2.8035	2.8313	-0.98	-2.1946	2.8310	-0.97
	15380.00	780.00	4.1870	2.8921	2.8913	0.03	-2.1678	2.8928	-0.02
	17089.00	880.00	4.2327	2.9445	2.9449	-0.01	-2.1707	2.9481	-0.12
	18778.00	967.00	4.2736	2.9854	2.9929	-0.25	-2.1792	2.9975	-0.40
POLYSTYRENE SHPERES	10253.00	478.00	4.0109	2.6794	2.6848	-0.20	-2.1677	2.6800	-0.02
	11962.00	572.00	4.0778	2.7574	2.7633	-0.21	-2.1706	2.7609	-0.13
	13671.00	700.00	4.1358	2.8451	2.8313	0.49	-2.1530	2.8310	0.50
	15380.00	810.00	4.1870	2.9085	2.8913	0.60	-2.1514	2.8928	0.54
	17089.00	920.00	4.2327	2.9638	2.9449	0.64	-2.1514	2.9481	0.53
PLASTIC PARTICLES TYPE 1	10253.00	460.00	4.0109	2.6628	2.6848	-0.82	-2.1843	2.6800	-0.64
	11962.00	590.00	4.0778	2.7709	2.7633	0.27	-2.1571	2.7609	0.36
	13671.00	649.00	4.1358	2.8122	2.8313	-0.67	-2.1858	2.8310	-0.66
	15380.00	780.00	4.1870	2.8921	2.8913	0.03	-2.1678	2.8928	-0.02
	17089.00	945.00	4.2327	2.9754	2.9449	1.04	-2.1398	2.9481	0.93
PLASTIC PARTICLES TYPE 2	10253.00	507.00	4.0109	2.7050	2.6848	0.75	-2.1421	2.6800	0.93
	11962.00	620.00	4.0778	2.7924	2.7633	1.05	-2.1356	2.7609	1.14
	13671.00	673.00	4.1358	2.8280	2.8313	-0.12	-2.1701	2.8310	-0.10
	15380.00	749.00	4.1870	2.8745	2.8913	-0.58	-2.1854	2.8928	-0.63
	17089.00	821.00	4.2327	2.9143	2.9449	-1.04	-2.2009	2.9481	-1.14
						Avg	-2.167129		

Table M.6 Calculation of Least-Squares Line by Using the Average Slope

Data from Table 5.5

	Re	Sh_r	LOG(Re)	LOG(Sh_r)	Y Cai	% ERROR	A0 Cai	Y Avg	% ERROR
GLASS BEADS	15050.00	690.00	4.1775	2.8368	2.8279	0.39	-2.2097	2.8286	0.36
	16931.00	828.00	4.2287	2.9180	2.8934	0.85	-2.1923	2.8904	0.96
	18812.00	894.00	4.2744	2.9513	2.9519	-0.02	-2.2143	2.9457	0.19
	20693.00	980.00	4.3158	2.9912	3.0048	-0.45	-2.2244	2.9957	-0.15
POLYSTYRENE SHPERES	11287.00	450.00	4.0526	2.6532	2.6681	-0.56	-2.2443	2.6776	-0.91
	13168.00	550.00	4.1195	2.7404	2.7537	-0.49	-2.2380	2.7585	-0.66
	15050.00	720.00	4.1775	2.8573	2.8279	1.04	-2.1912	2.8286	1.02
	16931.00	770.00	4.2287	2.8865	2.8934	-0.24	-2.2238	2.8904	-0.14
	18812.00	910.00	4.2744	2.9590	2.9519	0.24	-2.2066	2.9457	0.45
PLASTIC PARTICLES TYPE 1	11287.00	462.00	4.0526	2.6646	2.6681	-0.13	-2.2329	2.6776	-0.48
	13168.00	590.00	4.1195	2.7709	2.7537	0.62	-2.2076	2.7585	0.45
	15050.00	705.00	4.1775	2.8482	2.8279	0.72	-2.2003	2.8286	0.69
	16931.00	744.00	4.2287	2.8716	2.8934	-0.75	-2.2388	2.8904	-0.65
	18812.00	880.00	4.2744	2.9445	2.9519	-0.25	-2.2211	2.9457	-0.04
PLASTIC PARTICLES TYPE 2	11287.00	474.00	4.0526	2.6758	2.6681	0.29	-2.2217	2.6776	-0.07
	13168.00	519.00	4.1195	2.7152	2.7537	-1.40	-2.2632	2.7585	-1.57
	15050.00	690.00	4.1775	2.8388	2.8279	0.39	-2.2097	2.8286	0.36
	16931.00	800.00	4.2287	2.9031	2.8934	0.34	-2.2072	2.8904	0.44
	18821.00	860.00	4.2746	2.9345	2.9522	-0.60	-2.2314	2.9459	-0.39
						Avg	-2.219926		

Table M.7 Calculation of Least-Squares Line by Using the Average Slope

Data from Table 5.6

TEMPERATURE	Re	Sh_P	X LOG(Re)	Y LOG(Sh_P)	Y Cal	% ERROR	A0 Cal	Y Avg	% ERROR
25	42143	237	4.6247	2.3747	2.3705	0.18	-3.2142	2.392797	-0.75
	47411	279	4.6759	2.4456	2.4483	-0.11	-3.2052	2.454616	-0.37
	52679	323	4.7216	2.5092	2.5178	-0.34	-3.1969	2.509914	-0.03
	57947	387	4.7630	2.5877	2.5808	0.27	-3.1684	2.559938	1.08
						Avg	-3.196151		
30	46559	245	4.6680	2.3892	2.3882	0.04	-3.2521	2.3810	0.34
	52379	278	4.7192	2.4440	2.4449	-0.03	-3.2590	2.4428	0.05
	58199	312	4.7649	2.4942	2.4956	-0.06	-3.2642	2.4981	-0.16
	64019	349	4.8063	2.5428	2.5415	0.05	-3.2656	2.5482	-0.21
						Avg	-3.260221		
35	51058	240	4.7081	2.3802	2.3603	0.84	-3.3095	2.3905	-0.43
	57440	262	4.7592	2.4183	2.4436	-1.04	-3.3332	2.4523	-1.39
	63822	320	4.8050	2.5051	2.5182	-0.52	-3.3016	2.5076	-0.10
	70204	402	4.8464	2.6042	2.5856	0.72	-3.2526	2.5576	1.82
						Avg	-3.299205		
40	55656	247	4.7455	2.3927	2.3809	0.50	-3.3422	2.3773	0.65
	62613	257	4.7967	2.4099	2.4401	-1.24	-3.3868	2.4391	-1.19
	69570	329	4.8424	2.5172	2.4931	0.97	-3.3348	2.4944	0.91
	76527	343	4.8838	2.5353	2.5410	-0.23	-3.3668	2.5444	-0.36
						Avg	-3.357656		
45	38545	140	4.5860	2.1461	2.1382	0.37	-3.3960	2.1262	0.94
	45347	165	4.6565	2.2175	2.2194	-0.09	-3.4099	2.2115	0.27
	52905	195	4.7235	2.2900	2.2965	-0.28	-3.4183	2.2924	-0.10
	60462	226	4.7815	2.3541	2.3632	-0.38	-3.4243	2.3625	-0.35
	75578	305	4.8784	2.4843	2.4747	0.39	-3.4112	2.4796	0.19
						Avg	-3.415922		

Table M.8 Calculation of Least-Squares Line by Using the Average Slope

Data from Table 5.7

TEMPERATURE	Re	Sh_p	X LOG(Re)	Y LOG(Sh_p)	Y Cal	% ERROR	AO Cal	Y Avg	% ERROR
30	30883	348	4.4897	2.5416	2.5341	0.30	-2.8842	2.5381	0.14
	35295	386	4.5477	2.5866	2.6071	-0.79	-2.9093	2.6082	-0.83
	39707	489	4.5989	2.6893	2.6715	0.67	-2.8684	2.6700	0.72
	44118	530	4.6446	2.7243	2.7292	-0.18	-2.8887	2.7253	-0.04
						Avg	-2.887652		
35	34525	299	4.5381	2.4757	2.4600	0.64	-3.0086	2.4977	-0.88
	39458	373	4.5961	2.5717	2.5474	0.95	-2.9827	2.5678	0.15
	44390	432	4.6473	2.6355	2.6246	0.42	-2.9807	2.6296	0.22
	49322	498	4.6930	2.6972	2.6936	0.14	-2.9743	2.6849	0.46
						Avg	-2.986581		

Table M.9 Calculation of Least-Squares Line by Using the Average Slope

Data from Table 5.8

TEMPERATURE	Re	Sh_p	X LOG(Re)	Y LOG(Sh_p)	Y Cal	% ERROR	AO Cal	Y Avg	% ERROR
25	22192	361	4.3462	2.5575	2.5596	-0.08	-2.6948	2.553845	0.14
	25362	406	4.4042	2.6085	2.6255	-0.65	-2.7139	2.323922	-0.59
	28533	533	4.4553	2.7267	2.6837	1.60	-2.6575	2.685754	1.53
	31703	515	4.5011	2.7118	2.7357	-0.87	-2.7277	2.741046	-1.07
						Avg	-2.698502		
30	25194	373	4.4013	2.5717	2.6611	-3.36	-2.7472	2.6292	-2.19
	28794	438	4.4593	2.6415	2.6854	-1.64	-2.7476	2.6993	-2.14
	22393	534	4.3501	2.7275	2.6396	3.33	-2.5295	2.5674	6.24
	35992	591	4.5562	2.7716	2.7261	1.67	-2.7346	2.8164	-1.59
						Avg	-2.689721		
35	28319	380	4.4521	2.5798	2.5798	.00	-2.8005	2.5695	0.40
	32365	451	4.5101	2.6542	2.6425	0.44	-2.7962	2.6396	0.55
	36411	471	4.5612	2.6730	2.6978	-0.92	-2.8392	2.7015	-1.05
	40457	576	4.6070	2.7604	2.7473	0.48	-2.8071	2.7568	0.13
						Avg	-2.810758		
40	31604	389	4.4997	2.5899	2.5906	-0.03	-2.8480	2.5843	0.22
	36119	451	4.5577	2.6542	2.6561	-0.07	-2.8538	2.6543	-0.01
	40634	525	4.6089	2.7202	2.7139	0.23	-2.8497	2.7162	0.15
	45149	578	4.6546	2.7619	2.7656	-0.13	-2.8632	2.7715	-0.34
						Avg	-2.853651		

Table M.10 Calculation of Least-Squares Line by Using the Average Slope

Data from Table 5.9

TEMPERATURE	Re	Sh_p	X LOG(Re)	Y LOG(Sh_p)	Y Cal	% ERROR	AO Cal	Y Avg	% ERROR
25	10488	541	4.0207	2.7332	2.7408	-0.28	-2.1258	2.741421	-0.30
	11987	656	4.0787	2.8169	2.8148	0.07	-2.1122	2.811536	0.19
	13485	725	4.1299	2.8603	2.8801	-0.69	-2.1306	2.873338	-0.45
	14983	880	4.1756	2.9445	2.9385	0.20	-2.1017	2.928624	0.54
						Avg	-2.117557		
30	13671	636	4.1358	2.8035	2.8128	-0.33	-2.1946	2.8198	-0.58
	15380	780	4.1870	2.8921	2.8797	0.43	-2.1678	2.8817	0.36
	17089	880	4.2327	2.9445	2.9395	0.17	-2.1707	2.9370	0.26
	18798	967	4.2741	2.9854	2.9935	-0.27	-2.1798	2.9870	-0.05
						Avg	-2.178244		
35	15050	690	4.1775	2.8388	2.8481	-0.33	-2.2097	2.8384	0.02
	16931	828	4.2287	2.9180	2.9029	0.52	-2.1923	2.9002	0.62
	18812	894	4.2744	2.9513	2.9520	-0.02	-2.2143	2.9555	-0.14
	20693	980	4.3158	2.9912	2.9963	-0.17	-2.2244	3.0055	-0.47
						Avg	-2.210170		
40	15750	714	4.1973	2.8537	2.8491	0.16	-2.2187	2.8277	0.92
	17718	790	4.2484	2.8976	2.8956	0.07	-2.2366	2.8894	0.28
	19687	827	4.2942	2.9175	2.9371	-0.67	-2.2720	2.9448	-0.93
	21650	972	4.3355	2.9877	2.9746	0.44	-2.2517	2.9946	-0.23
						Avg	-2.244731		

are the same as in M.1. The fitted curves of data are enclosed. For this case the average slope is 0.50. This is the exponent of Schmidt number in the correlation.

Table M.11 Slopes and Intercepts by Least-Squares Method for the Relation between Schmidt Numbers and Sherwood Numbers

Data from Tables	Slope	Intercept
5.10	0.561	0.843
5.12	0.535	0.859
5.13	0.412	1.223
	Average = 0.502	

The calculation of least-squares lines by using the average slope, 0.50 are not shown here.

M.3 The Influence of Density Group on Sherwood Number

Figure 5.17 demonstrates the influence of Density number on Sherwood number. The curves are drawn by least-squares method. Data from Tables 5.14-5.18 are calculated. The details are the same as in M.1. The fitted curves of data are enclosed. For this case the average slope is negligible. Then Density group has insignificant influence on Sherwood number.

Table M.12 Slopes and Intercepts by Least-Squares Method for the Relation between Density Groups and Sherwood Numbers

Data from Tables	Slope	Intercept
5.14	-0.035	2.36
5.15	-0.026	2.56
5.16	0.016	2.65
5.17	-0.001	2.89
5.18	-0.012	2.83
	Average = -0.012	

The calculation of least-squares lines by using the average slope are not shown here.

Data from Table 5.10

THE BEST FITTING POLYNOMIAL EQUATION IS:
Y = A0 + A1*X
A0 = .843034551

A1 = .561082317

THE COEFFICIENT OF DETERM.,R^2 IS:.998

THE CORRELLATION COEFFICIENT IS:.999

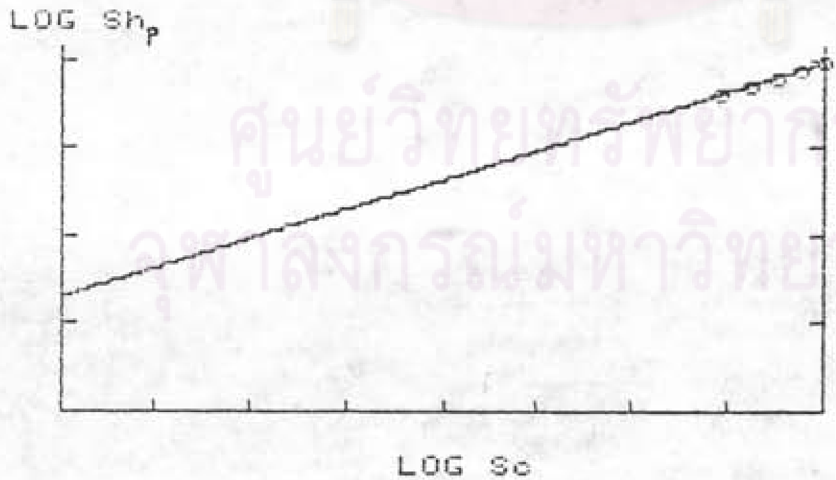
REAL X	REAL Y	MODEL Y	RESIDUAL
3.0137	2.5378	2.533	3E-03
2.9253	2.48	2.484	-5E-03
2.8306	2.4314	2.431	0
2.7267	2.3711	2.372	-2E-03
2.6138	2.3118	2.309	2E-03

THE RESIDUAL SUM OF SQUARES IS:0

THE RESIDUAL MEAN SQUARE IS:0

THE STANDARD ERROR OF THE REGRESSION ESTIMATE:0

THE VALUE OF F IS:22443.84



LOG Sh_p VS LOG Sc

Data from Table 5.12

THE BEST FITTING POLYNOMIAL EQUATION IS:
Y = A0 + A1*X
A0 = .859122135

A1 = .535095973

THE COEFFICIENT OF DETERM.,R^2 IS:.998

THE CORRELLATION COEFFICIENT IS:.999

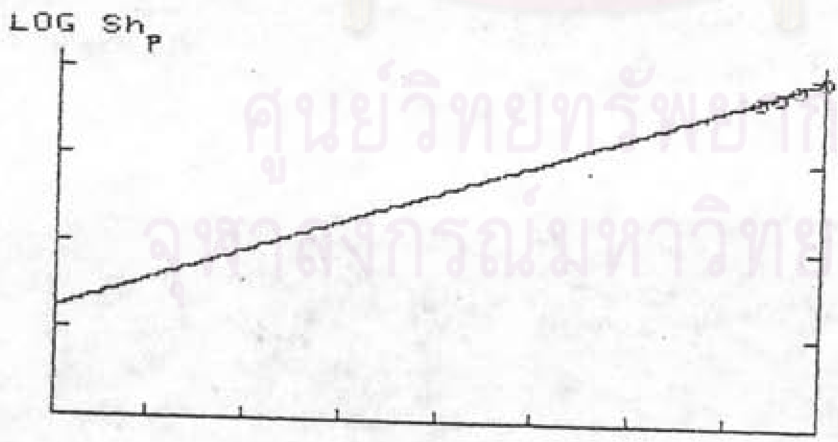
REAL X	REAL Y	MODEL Y	RESIDUAL
3.4833	2.7202	2.723	-3E-03
3.372	2.6675	2.663	4E-03
3.2714	2.6107	2.609	1E-03
3.1872	2.5623	2.564	-3E-03

THE RESIDUAL SUM OF SQUARES IS:0

THE RESIDUAL MEAN SQUARE IS:0

THE STANDARD ERROR OF THE REGRESSION ESTIMATE:0

THE VALUE OF F IS:9198.75



LOG Sh_p VS LOG Sc

Data from Table 5.13

THE BEST FITTING POLYNOMIAL EQUATION IS:
Y = A0 + A1*X
A0 = 1.22319908

A1 = .411933612

THE COEFFICIENT OF DETERM.,R^2 IS:.983

THE CORRELLATION COEFFICIENT IS:.991

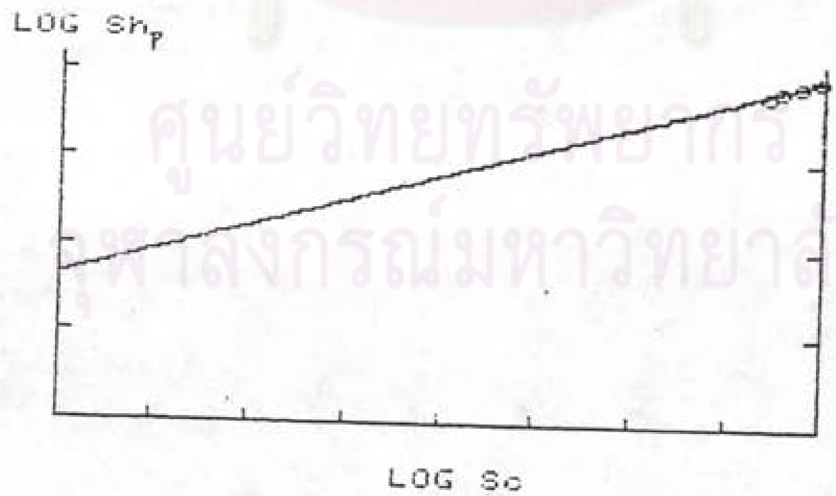
REAL X	REAL Y	MODEL Y	RESIDUAL
4.1559	2.9294	2.935	-6E-03
4.032	2.8921	2.884	7E-03
3.9278	2.8451	2.841	3E-03
3.8495	2.8028	2.808	-7E-03

THE RESIDUAL SUM OF SQUARES IS:0

THE RESIDUAL MEAN SQUARE IS:0

THE STANDARD ERROR OF THE REGRESSION ESTIMATE:0

THE VALUE OF F IS:1197.74



LOG Sh_p VS LOG Sc

Data from Table 5.14

THE BEST FITTING POLYNOMIAL EQUATION IS:
Y = A0 + A1*X
A0 = 2.36172078

A1 = -.0356382509

THE COEFFICIENT OF DETERM.,R^2 IS:.064

THE CORRELLATION COEFFICIENT IS:.253

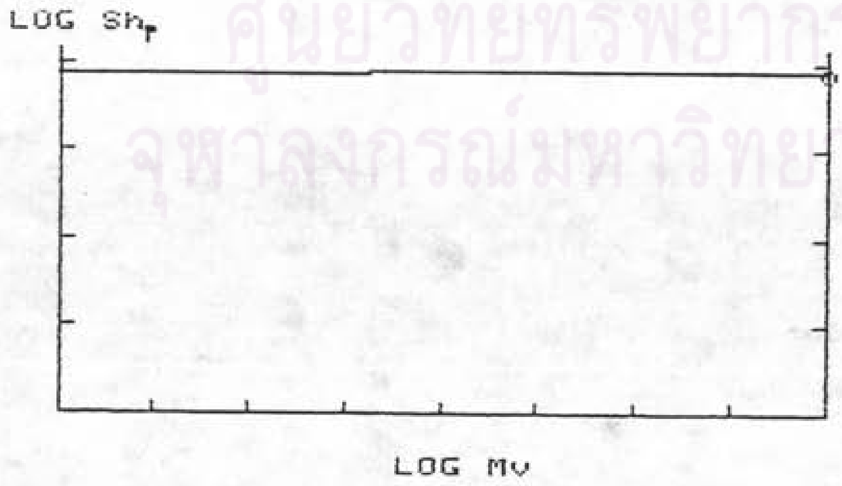
REAL X	REAL Y	MODEL Y	RESIDUAL
-.3867	2.3802	2.375	4E-03
-.6124	2.3522	2.383	-.032
-.7128	2.4232	2.387	.036
-.8841	2.3838	2.393	-.01

THE RESIDUAL SUM OF SQUARES IS:2E-03

THE RESIDUAL MEAN SQUARE IS:1E-03

THE STANDARD ERROR OF THE REGRESSION ESTIMATE:.0316

THE VALUE OF F IS:1.37



LOG Sh_p VS LOG Mv

Data from Table 5.15

THE BEST FITTING POLYNOMIAL EQUATION IS:
Y = A0 + A1*X
A0 = 2.56512386

A1 = -.0260581413

THE COEFFICIENT OF DETERM.,R^2 IS:.319

THE CORRELLATION COEFFICIENT IS:.564

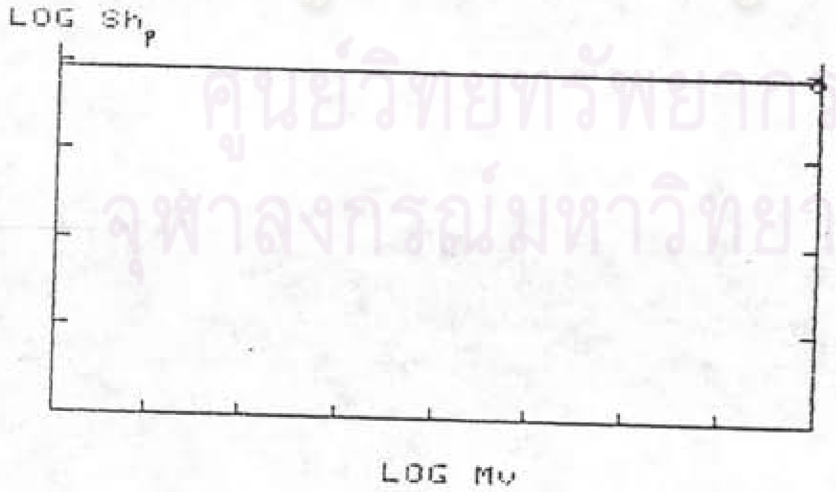
REAL X	REAL Y	MODEL Y	RESIDUAL
-.4659	2.5717	2.577	-6E-03
-.8671	2.6021	2.587	.014
-1.1203	2.5855	2.594	-9E-03

THE RESIDUAL SUM OF SQUARES IS:0

THE RESIDUAL MEAN SQUARE IS:0

THE STANDARD ERROR OF THE REGRESSION ESTIMATE:0

THE VALUE OF F IS:4.68



LOG Sh_p VS LOG Mv

Data from Table 5.16

THE BEST FITTING POLYNOMIAL EQUATION IS:
Y = A0 + A1*X
A0 = 2.65127849

A1 = .0165268995

THE COEFFICIENT OF DETERM.,R^2 IS:.119

THE CORRELLATION COEFFICIENT IS:.345

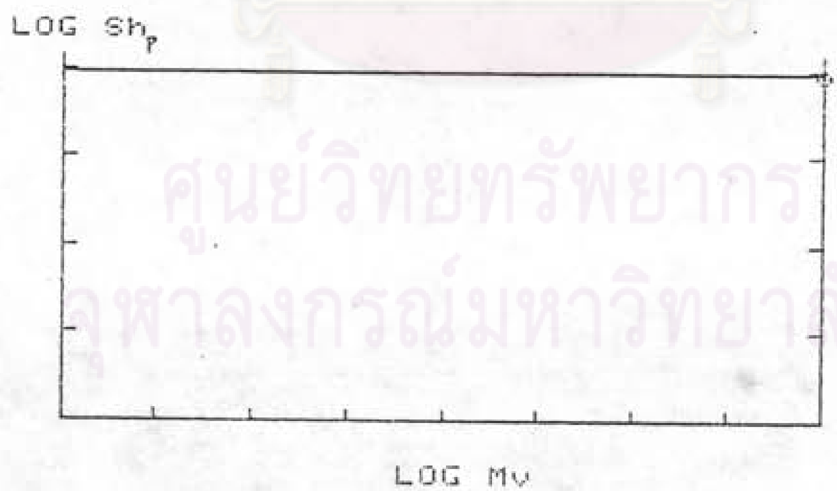
REAL X	REAL Y	MODEL Y	RESIDUAL
-.5216	2.6414	2.642	-2E-03
-.8312	2.6541	2.637	.016
-.9957	2.6138	2.634	-.022
-1.3675	2.6344	2.628	5E-03

THE RESIDUAL SUM OF SQUARES IS:0

THE RESIDUAL MEAN SQUARE IS:0

THE STANDARD ERROR OF THE REGRESSION ESTIMATE:0

THE VALUE OF F IS:2.7



LOG Sh_p VS LOG Mv

Data from Table 5.17

THE BEST FITTING POLYNOMIAL EQUATION IS:
Y = A0 + A1*X
A0 = 2.89616413

A1 = -1.27538294E-03

THE COEFFICIENT OF DETERM.,R^2 IS:3E-03

THE CORRELLATION COEFFICIENT IS:.055

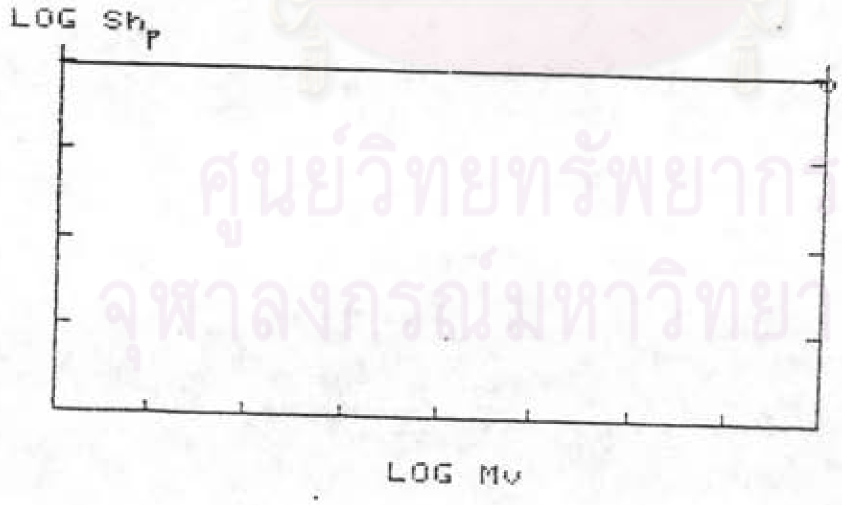
REAL X	REAL Y	MODEL Y	RESIDUAL
-.6613	2.8921	2.897	-5E-03
-1.1278	2.9085	2.897	.01
-1.51	2.8921	2.898	-6E-03

THE RESIDUAL SUM OF SQUARES IS:0

THE RESIDUAL MEAN SQUARE IS:0

THE STANDARD ERROR OF THE REGRESSION ESTIMATE:0

THE VALUE OF F IS:.03



LOG Sh_p VS LOG Mv

Data from Table 5.18

THE BEST FITTING POLYNOMIAL EQUATION IS:
Y = A0 + A1*X
A0 = 2.83449467

A1 = -.0125125673

THE COEFFICIENT OF DETERM.,R^2 IS:.315

THE CORRELLATION COEFFICIENT IS:.561

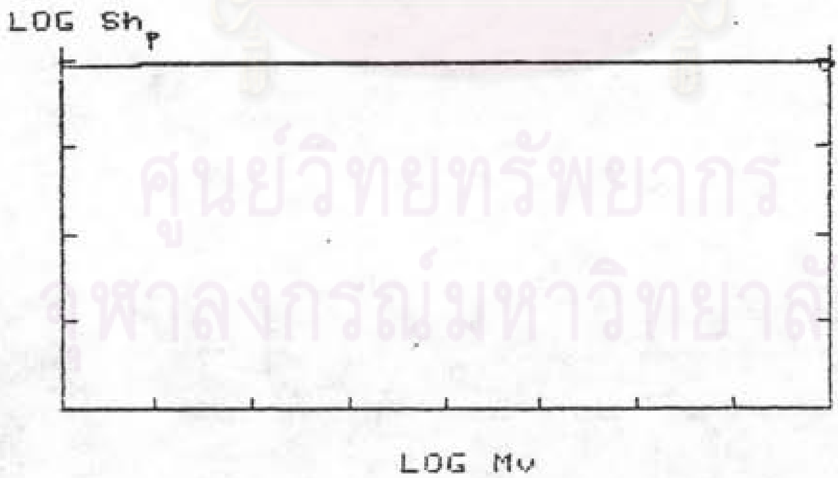
REAL X	REAL Y	MODEL Y	RESIDUAL
-.6573	2.8388	2.842	-4E-03
-1.118	2.8573	2.848	8E-03
-1.4867	2.8482	2.853	-5E-03

THE RESIDUAL SUM OF SQUARES IS:0

THE RESIDUAL MEAN SQUARE IS:0

THE STANDARD ERROR OF THE REGRESSION ESTIMATE:0

THE VALUE OF F IS:4.61



LOG Sh_p VS LOG Mv

APPENDIX N

DETERMINATION OF THE CONSTANT, r IN THE CORRELATIONS

From the results the correlations are expressed in the form

$$Sh_p = rRe_p^{1.21}Sc^{0.50}$$

The value of r depends on the solid - liquid systems. To determine the constant r the terms $Sh_p/Sc^{0.50}$ and Re_p are plotted on log-log scale, see Figure N.1. The relations are in straight line having the same slope, 1.21. The constants, r are obtained by calculating the values of anti-logarithmic of the intercepts. Tables N.1-N.4 show the results by least-squares method as described in Appendix M. The average values of AO_{cal} are the intercepts of least-squares lines. From Tables N.1-N.4 the constant, r obtained as follows:

Systems	Constant, r
Benzoic acid coated on various materials - water	1.90×10^{-5}
Benzoic acid coated on various materials - 13 wt % sucrose solution	3.00×10^{-5}
Benzoic acid coated on various materials - 20 wt % sucrose solution	3.57×10^{-5}
Benzoic acid coated on various materials - 35.5 wt % sucrose solution	6.48×10^{-5}

Table N.1 Calculation of Least-Squares Line to Evaluate the Constant, r

Data from Table 5.6

RPM	Sc	Re	Sh	cRe = Sh/Sc^.502	X LOG(Re)	Y LOG(cRe)	A0 Cal	Y Avg	% ERROR
400	1032.63	42143	237	7.2736	4.6247	0.8617	-4.7272	0.8679	-0.71
450	1032.63	47411	279	8.5626	4.6759	0.9326	-4.7182	0.9297	0.31
500	1032.63	52679	323	9.9129	4.7216	.0.9962	-4.7099	0.9850	1.13
550	1032.63	57947	387	11.8771	4.7630	1.0747	-4.6814	1.0351	3.83
400	842.31	46559	245	8.3287	4.6680	0.9206	-4.7207	0.9202	0.04
450	842.31	52379	278	9.4506	4.7192	0.9755	-4.7276	0.9820	-0.67
500	842.31	58199	312	10.6064	4.7649	1.0256	-4.7328	1.0373	-1.13
550	842.31	64019	349	11.8642	4.8063	1.0742	-4.7342	1.0874	-1.21
400	677.36	51052	240	9.1021	4.7081	0.9591	-4.7305	0.9686	-0.98
450	677.36	57440	262	9.9364	4.7592	0.9972	-4.7542	1.0304	-3.22
500	677.36	63822	320	12.1361	4.8050	1.0841	-4.7227	1.0857	-0.15
550	677.36	70204	402	15.2460	4.8464	1.1832	-4.6736	1.1358	4.17
400	533.66	55656	247	10.5587	4.7455	1.0236	-4.7113	1.0139	0.96
450	533.66	62613	257	10.9562	4.7967	1.0408	-4.7559	1.0757	-3.24
500	533.66	69570	329	14.0640	4.8424	1.1481	-4.7039	1.1310	1.51
550	533.66	76527	343	14.6625	4.8833	1.1662	-4.7358	1.1810	-1.25
255	411	38545	140	6.8231	4.5860	0.8340	-4.7081	0.8211	1.57
300	411	45347	165	8.0415	4.6565	0.9053	-4.7221	0.9064	-0.11
350	411	52905	195	9.5036	4.7235	0.9779	-4.7304	0.9873	-0.95
400	411	60452	226	11.0144	4.7815	1.0420	-4.7364	1.0574	-1.46
500	411	75578	305	14.8645	4.8784	1.1722	-4.7234	1.1745	-0.20
						Avg	-4.721032		

Table N.2 Calculation of Least-Squares Line to Evaluate the Constant, r

Data from Table 5.7

RPM	Sc	Re	Sh	cRe = Sh/Sc^.502	X LOG(Re)	Y LOG(cRe)	AO Cal	Y Avg	% ERROR
350	1210	34525	299	8.4745	4.5381	0.9281	-4.5562	0.9616	-3.48
400	1210	39458	373	10,5718	4.5961	1.0242	-4.5302	1.0317	-0.73
450	1210	44390	432	12.2441	4.6473	1.0879	-4.5263	1.0935	-0.51
500	1210	49322	498	14.1147	4.6930	1.1497	-4.5218	1.1486	0.08
300	1210	29593	206	5.8386	4.4712	0.7663	-4.6371	0.8307	-12.99
350	1210	34525	342	9.6932	4.5381	0.9865	-4.4978	0.9616	2.59
400	1210	39458	400	11.3371	4.5961	1.0545	-4.4999	1.0317	2.21
450	1210	44390	475	13.4628	4.6473	1.1291	-4.4871	1.0935	3.26
500	1210	49322	513	14.5396	4.6930	1.1626	-4.5089	1.1488	1.20
300	1210	29593	284	8.0493	4.4712	0.9058	-4.4976	0.8807	2.85
350	1210	34525	320	9.0697	4.5381	0.9576	-4.5267	0.9616	-0.41
400	1210	39458	385	10.9120	4.5961	1.0379	-4.5165	1.0317	0.60
450	1210	44390	381	10.7986	4.6473	1.0334	-4.5828	1.0935	-5.50
500	1210	49332	435	12.3291	4.6931	1.0909	-4.5807	1.1489	-5.04
350	1516	30883	348	8.8078	4.4897	0.9449	-4.4809	0.9031	4.63
400	1516	35295	386	9.7696	4.5477	0.9899	-4.5060	0.9731	1.72
450	1516	39707	489	12.3765	4.5989	1.0926	-4.4651	1.0350	5.57
500	1516	44118	530	13.4142	4.6446	1.1276	-4.4854	1.0903	3.42
						Avg	-4.522734		

Table N.3 Calculation of Least-Squares Line to Evaluate the Constant, r

Data from Table 5.8

RPM	Sc	Re	Sh	cRe = Sh/Sc^.502	X LOG(Re)	Y LOG(cRe)	A0 Cal	Y Avg	% ERROR
350	3043	22192	361	6.4401	4.3462	0.8089	-4.4435	0.8050	0.49
400	3043	25362	406	7.2428	4.4042	0.8599	-4.4625	0.8750	-1.73
450	3043	28533	533	9.5084	4.4553	0.9781	-4.4061	0.9369	4.40
500	3043	31703	515	9.1873	4.5011	0.9632	-4.4764	0.9922	-2.92
350	2355	25194	373	7.5678	4.4013	0.8790	-4.4400	0.8716	0.85
400	2355	28794	438	8.8866	4.4593	0.9487	-4.4403	0.9417	0.75
450	2355	32393	534	10.8343	4.5105	1.0348	-4.4160	1.0035	3.12
500	2355	35992	591	11.9908	4.5562	1.0788	-4.4273	1.0588	1.90
350	1868	28319	380	8.6607	4.4521	0.9376	-4.4428	0.9329	0.50
400	1868	32365	451	10.2789	4.5101	1.0119	-4.4384	1.0030	0.89
450	1868	36411	471	10.7347	4.5612	1.0308	-4.4814	1.0648	-3.20
500	1868	40457	576	13.1278	4.6070	1.1182	-4.4493	1.1201	-0.17
350	1539	31604	389	9.7714	4.4997	0.9900	-4.4480	0.9905	-0.06
400	1539	36119	451	11.3288	4.5577	1.0542	-4.4538	1.0606	-0.61
450	1539	40634	525	13.1976	4.6089	1.1202	-4.4496	1.1224	-0.20
500	1539	45149	578	14.5189	4.6546	1.1619	-4.4632	1.1777	-1.34
						Avg	-4.447384		

Table N.4 Calculation of Least-Squares Line to Evaluate the Constant, r

Data from Table 5.9

RPM	Sc	Re	Sh	cRe = Sh/Sc^.502	X LOG(Re)	Y LOG(cRe)	A0 Cal	Y Avg	% ERROR
400	10764	13671	636	6.0174	4.1358	0.7794	-4.2187	0.8100	-3.77
450	10764	15380	780	7.3798	4.1870	0.8680	-4.1919	0.8718	-0.43
500	10764	17089	880	8.3259	4.2327	0.9204	-4.1948	0.9271	-0.72
550	10764	18798	967	9.1490	4.2741	0.9614	-4.2039	0.9771	-1.61
400	8469	15050	690	7.3634	4.1775	0.8671	-4.1814	0.8604	0.77
450	8469	16931	828	8.8361	4.2287	0.9463	-4.1641	0.9222	2.61
500	8469	18812	894	9.5404	4.2744	0.9796	-4.1861	0.9775	0.21
550	8469	20693	--	0.0000	-	-	-	-	-
400	7072	15750	714	8.3412	4.1973	0.9212	-4.1512	0.8843	4.18
450	7072	17718	790	9.2290	4.2484	0.9652	-4.1690	0.9461	2.02
500	7072	19687	827	9.6613	4.2942	0.9350	-4.2045	1.0014	-1.63
550	7072	21656	972	11.3552	4.3356	1.0552	-4.1843	1.0514	0.36
400	14318	10438	-	0.0000	-	-	-	-	-
450	14318	11937	686	5.6243	4.0787	0.7501	-4.1790	0.7410	1.23
500	14318	13435	725	5.9441	4.1299	0.7741	-4.2168	0.8029	-3.58
550	14318	14953	880	7.2149	4.1756	0.8582	-4.1830	0.8581	0.02
						Avg	-4.188106		

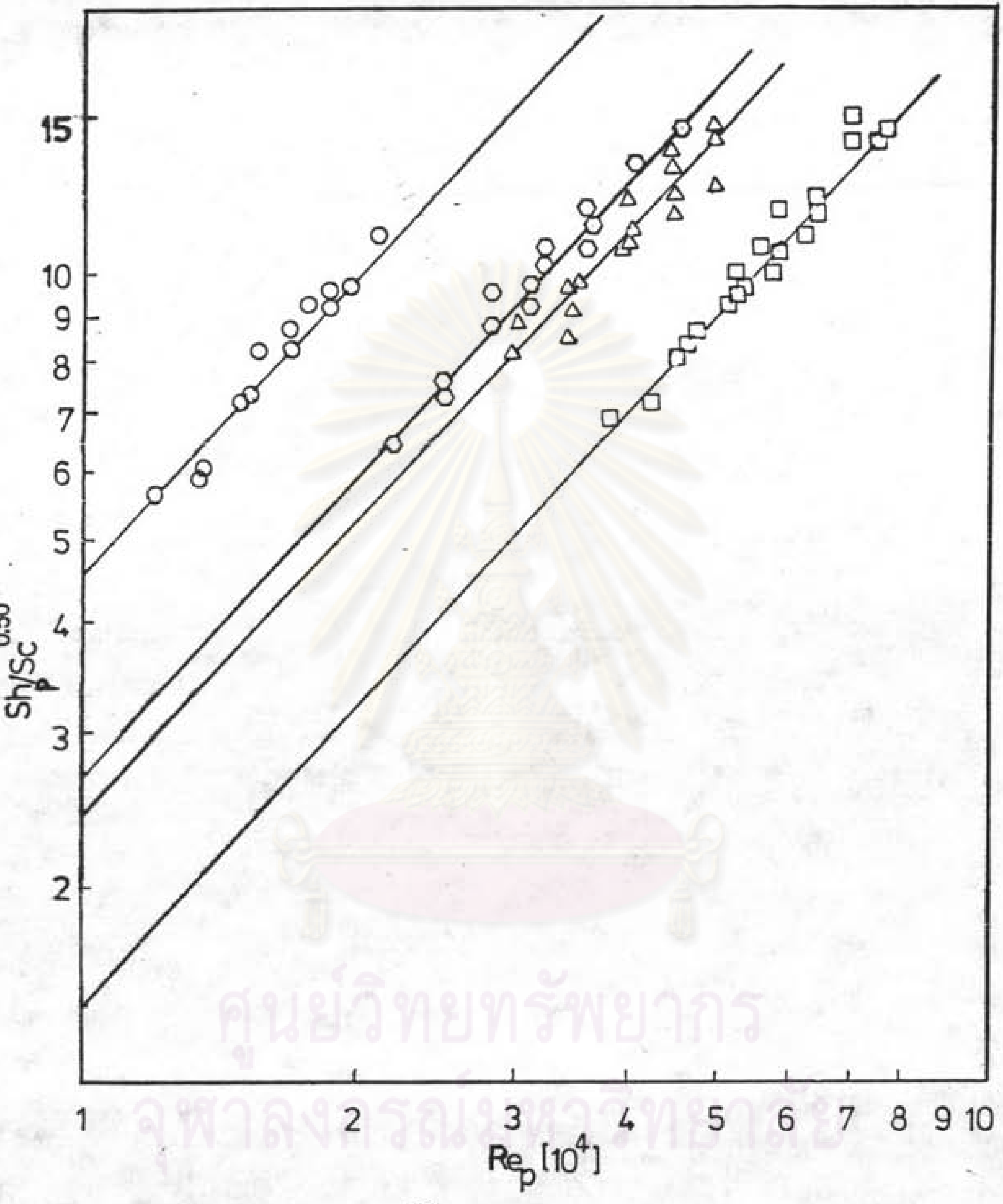


Figure N.1 $Sh_p/Sc^{0.50}$ vs Re_p of the systems of benzoic acid coated on glass beads - various solutions

□ water

△ 13 wt % sucrose

⬡ 20 wt % sucrose

○ 35.5 wt % sucrose

APPENDIX O

PREDICTION ACCURACY OF THE PRESENT GENERAL CORRELATIONS

Tables O.1-O.9 show the relative errors between the experimental Sherwood numbers and the calculated Sherwood numbers. The calculated Sherwood numbers are obtained from the correlations. The relative errors are based on the experimental Sherwood numbers.

Table 0.1 Prediction Accuracy of Data from Table 5.1 by the Correlation $Sh_p = 1.90\times10^{-5} Re_p^{1.21} Sc^{0.60}$

Materials	Rotation speed (rpm)	$Re_p \times 10^{-4}$	Mv	Sh_p		$\%\Delta Sh_p/Sh_p = [(Sh_{exp} - Sh_{cal})/Sh_{exp}]\times100$
				Experiment	Calculation	
Glass beads	400	5.1058	0.4104	240	243	-1.25
	450	5.7440		262	280	-6.87
	500	6.3822		320	318	0.625
	550	7.0204		402	358	10.95
Polystyrene shperes	275	3.5102	0.2441	145	154	-6.21
	300	3.8292		186	172	7.53
	350	4.4675		220	207	5.91
	400	5.1058		225	243	-8.00
	450	5.7440		287	280	2.44
	500	6.3822		290	318	-9.66
Plastic particles type 1	275	3.5102	0.1937	137	154	-12.41
	300	3.8293		168	172	-2.38
	350	4.4675		219	207	5.48
	400	5.1058		265	243	8.30
	450	5.7440		270	280	-3.70
	500	6.3822		300	318	-5.45
Plastic particles type 2	270	3.5088	0.1306	168	154	8.33
	300	3.8278		189	172	-1.59
	350	4.4657		208	207	0.481
	400	5.1037		242	243	-4.13
	450	5.7417		280	281	-0.36
	500	6.3796		310	318	-2.58

Table 0.2 Prediction Accuracy of Data from Table 5.2 by the Correlation

$Sh_p = 3.00 \times 10^{-5} Re_p^{1.21} Sc^{0.50}$

Materials	Rotation speed (rpm)	$Re_p \times 10^{-4}$	Mv	Sh_p Experiment	Sh_p Calculation	$\% \Delta Sh_p/Sh_p = [(Sh_{exp} - Sh_{cal})/Sh_{exp}] \times 100$
Glass beads	350	3.4525	0.3520	299	309	-3.34
	400	3.9458		373	364	2.41
	450	4.4390		432	419	3.01
	500	4.9322		498	476	4.42
Plastic particles type 1	350	3.4525		342	309	9.65
	400	3.9458		400	363	9.25
	450	4.4390		475	419	11.79
	500	4.9322		513	476	7.21
Plastic particles type 2	300	2.9593	0.0758	284	257	9.51
	350	3.4525		320	309	3.44
	400	3.9458		385	364	5.45
	450	4.4390		381	419	9.97

Table 0.3 Prediction Accuracy of Data from Table 5.3 by the Correlation $Sh_p = 3.57 \times 10^{-5} Re_p^{1.21} Sc^{0.50}$

Materials	Rotation speed (rpm)	$Re_p \times 10^{-4}$	Mv	Sh_p		$\% \Delta Sh_p/Sh_p = [(Sh_{exp} - Sh_{cal})/Sh_{exp}] \times 100$
				Experiment	Calculation	
Glass beads	350	2.5194	0.3009	373	366	1.87
	400	2.8794		438	430	1.83
	450	3.2395		534	456	14.61
	500	3.5992		591	563	4.97
Polystyrene spheres	300	2.1595	0.1475	325	304	6.46
	350	2.5194		345	366	-6.09
	400	2.8794		451	430	4.65
	450	3.2393		520	496	4.61
	500	3.5992		630	563	10.63
Plastic particles type 1	300	2.1595	0.1010	308	304	1.29
	350	2.5194		363	366	-0.826
	400	2.8794		411	430	-4.62
	450	3.2393		460	496	-7.83
	500	3.5992		561	563	-0.36
Plastic particles type 2	300	2.1595	0.0492	284	304	-7.04
	350	2.5194		361	366	-1.39
	400	2.8794		431	430	0.232
	450	3.2393		441	496	-12.47
	500	3.5992		542	563	-3.87

Table D.4 Prediction Accuracy of Data from Table 5.4 by the Correlation

$$Sh_p = 6.48\times10^{-5} Re_p^{1.21} Sc^{0.50}$$

Materials	Rotation speed (rpm)	$Re_p\times10^{-4}$	Mv	Sh_p Experiment	Sh_p Calculation	$\%\Delta Sh_p/Sh_p = [(Sh_{exp}-Sh_{cal})/Sh_{exp}]\times100$
Glass beads	400	1.3671	0.2181	636	677	-6.44
	450	1.5380		780	781	-0.128
	500	1.7089		880	889	-1.02
	550	1.8778		967	994	-2.79
Polystyrene spheres	300	1.0253	0.0745	478	479	-0.21
	350	1.1962		572	576	-0.699
	400	1.3671		700	677	3.29
	450	1.5380		810	781	3.58
	500	1.7089		920	994	-8.04
Plastic particles type 1	300	1.0253	0.0309	460	478	-3.91
	350	1.1962		590	576	2.37
	400	1.3671		649	677	-4.31
	450	1.5380		780	781	-0.13
	500	1.7089		945	994	-5.19
Plastic particles type 2	300	1.0253	-0.0235	507	478	5.27
	350	1.1962		620	576	7.09
	400	1.3671		673	677	-0.59
	450	1.5380		749	781	-4.27
	500	1.7089		821	994	-21.07

Table 0.5 Prediction Accuracy of Data from Table 5.5 by the Correlation $Sh_p = 6.48\times10^{-5}Re_p^{1.21}Sc^{0.50}$

Materials	Rotation speed (rpm)	$Re_p\times10^{-4}$	Mv	Sh_p		$\%\,\Delta Sh_p/Sh_p = [(Sh_{exp}-Sh_{cal})/Sh_{exp}]\times100$
				Experiment	Calculation	
Glass beads	400	1.5050	0.2201	690	673	2.46
	450	1.6931		828	776	6.28
	500	1.8812		894	882	1.34
	550	2.0693		980	990	1.02
Polystyrene spheres	300	1.1287	0.0762	450	475	-5.56
	350	1.3168		550	573	-4.18
	400	1.5050		720	673	6.53
	450	1.6931		770	776	-0.77
	500	1.8812		910	882	3.08
Plastic particles type 1	300	1.1287	0.0326	462	475	-2.81
	350	1.3168		590	573	2.88
	400	1.5050		705	673	4.54
	450	1.6931		744	776	-4.30
	500	1.8812		880	882	-0.23
Plastic particles type 2	300	1.1287	-0.0219	474	475	-0.21
	350	1.3168		519	573	-10.40
	400	1.5050		690	673	2.46
	450	1.6931		800	776	2.73
	500	1.8812		860	882	-2.56

Table 0.6 Prediction Accuracy of Data from Table 5.6 by the Correlation $Sh_p = 1.90 \times 10^{-5} Re_p^{1.21} Sc^{0.50}$

T (°C)	Sc	Rotation speed (rpm)	$Re_p \times 10^{-4}$	Mv	Sh_p		$\%\Delta Sh_p/Sh_p = [(Sh_{exp}-Sh_{cal})/Sh_{exp}]\times 100$
					Experiment	Calculation	
25	1,033	400	4.2143	0.4061	237	247	-4.22
		450	4.7411		279	284	-1.79
		500	5.2679		323	324	-0.31
		550	5.7947		387	362	6.46
30	842	400	4.6559	0.4081	245	240	2.04
		450	5.2379		278	277	0.36
		500	5.8199		312	314	-0.64
		550	6.4019		349	353	-1.15
35	677	400	5.1058	0.4104	240	245	-2.08
		450	5.7440		262	283	-8.02
		500	6.3822		320	321	-0.31
		550	7.0204		402	361	11.36
40	533	400	5.5656	0.4130	247	238	3.64
		450	6.2613		257	274	-6.61
		500	6.9570		329	312	5.17
		550	7.6527		343	350	-2.04
45	411	225	3.8545	0.4159	140	134	4.29
		300	4.5347		165	163	1.21
		350	5.2905		195	196	-0.51
		400	6.0462		226	230	-1.77
		500	7.5578		305	302	0.98

Table 0.7 Prediction Accuracy of Data from Table 5.7 by the Correlation $Sh_p = 3.00 \times 10^{-5} Re_p^{1.21} Sc^{0.50}$

T (°C)	Sc	Rotation speed (rpm)	$Re_p \times 10^{-4}$	Mv	Sh_p Experiment	Sh_p Calculation	$\% \Delta Sh_p / Sh_p = [(Sh_{exp} - Sh_{cal}) / Sh_{exp}] \times 100$
30	1,516	350	3.0883	0.3395	348	345	0.86
		400	3.5295		386	406	-5.18
		450	3.9707		489	468	4.29
		500	4.4118		530	531	-0.19
35	1,210	350	3.4525	0.3420	299	314	-5.02
		400	3.9458		373	369	1.07
		450	4.4390		432	426	1.39
		500	4.9322		498	484	2.81

Table 0.8 Prediction Accuracy of Data from Table 5.8 by the Correlation $Sh_p = 3.57\times10^{-5} Re_p^{1.21} Sc^{0.50}$

T (°C)	Sc	Rotation speed (rpm)	$Re_p \times 10^{-4}$	Mv	Sh_p		$\%\Delta Sh_p/Sh_p = [(Sh_{exp}-Sh_{cal})/Sh_{exp}]\times100$
					Experiment	Calculation	
25	3,043	350	2.2192	0.3004	361	358	0.83
		400	2.5362		406	421	-3.69
		450	2.8533		533	485	9.00
		500	3.1703		515	551	-6.99
30	2,355	350	2.5194	0.3009	373	366	1.87
		400	2.8794		438	430	1.83
		450	3.2393		534	496	7.12
		500	3.5992		591	564	4.57
35	1,868	350	2.8319	0.3016	380	371	2.36
		400	3.2365		451	436	3.33
		450	3.6411		471	503	-6.79
		500	4.0457		576	571	0.88
40	1,539	350	3.1604	0.3055	389	385	1.29
		400	3.6119		451	452	-0.22
		450	4.0634		525	520	0.95
		500	4.5149		578	590	-2.08

Table 0.9 Prediction Accuracy of Data from Table 5.9 by the Correlation $Sh_p = 6.48x10^{-5}Re_p^{1.21}Sc^{0.50}$

T (°C)	Sc	Rotation speed (rpm)	$Re_p x10^{-4}$	Mv	Sh_p		$\% \Delta Sh_p/Sh_p = [(Sh_{exp}-Sh_{cal})/Sh_{exp}]x100$
					Experiment	Calculated	
25	14,318	350	1.0488	0.2166	541	551	-1.85
		400	1.1987		686	647	1.37
		450	1.3485		725	746	-2.89
		500	1.4983		880	848	3.64
30	10,764	400	1.3671	0.2181	636	660	-3.77
		450	1.5380		780	762	2.31
		500	1.7089		880	864	1.82
		550	1.8798		967	970	-0.31
35	8,469	400	1.5050	0.2201	690	689	0.14
		450	1.6931		828	795	3.99
		500	1.8812		894	903	-1.01
		550	2.0693		980	1,013	-3.25
40	7,072	400	1.5750	0.2227	714	671	6.02
		450	1.7718		790	775	1.89
		500	1.9687		827	881	-6.53
		550	2.1650		972	988	-1.65

VITA

Miss Anchaleeporn Waritswat was born on January 25, 1961. She received her Bachelor of Science in Chemical Engineering from The Department of Chemical Technology, Faculty of Science, Chulalongkorn University in 1983. She is at present a tutor at The Department of Applied Chemistry, Faculty of Industrial Education and Science, King Mongkut's Institute of Technology Ladkrabang.