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Appendix A

Equilibrium Isothermal Adsorption

Temp. 30°C

Table A-1

Equilibrium Adsorption of Formaldehyde

Exp. No.	m_c (gm)	Total adsorption time					
		24 hrs.			48 hrs.		
		C_o (gm/litre)	C^* (gm/litre)	m (gm/gm)	C_o (gm/litre)	C^* (gm/litre)	m (gm/gm)
1	2.0011	20.10	10.5	0.48	20.1	7.0	0.66
2	2.3532	44.50	20.4	1.02	44.5	23.0	0.91
3	2.0983	69.70	44.8	1.19	69.7	45.0	1.18
4	1.9685	250.30	213.2	1.89	250.3	212.0	1.91
5	2.0105	195.7	160.2	1.78	195.7	162.0	1.69
6	2.1311	131.2	101.1	1.51	131.2	102.0	1.46
7	2.0899	185.1	150.3	1.67	185.1	152.5	1.56

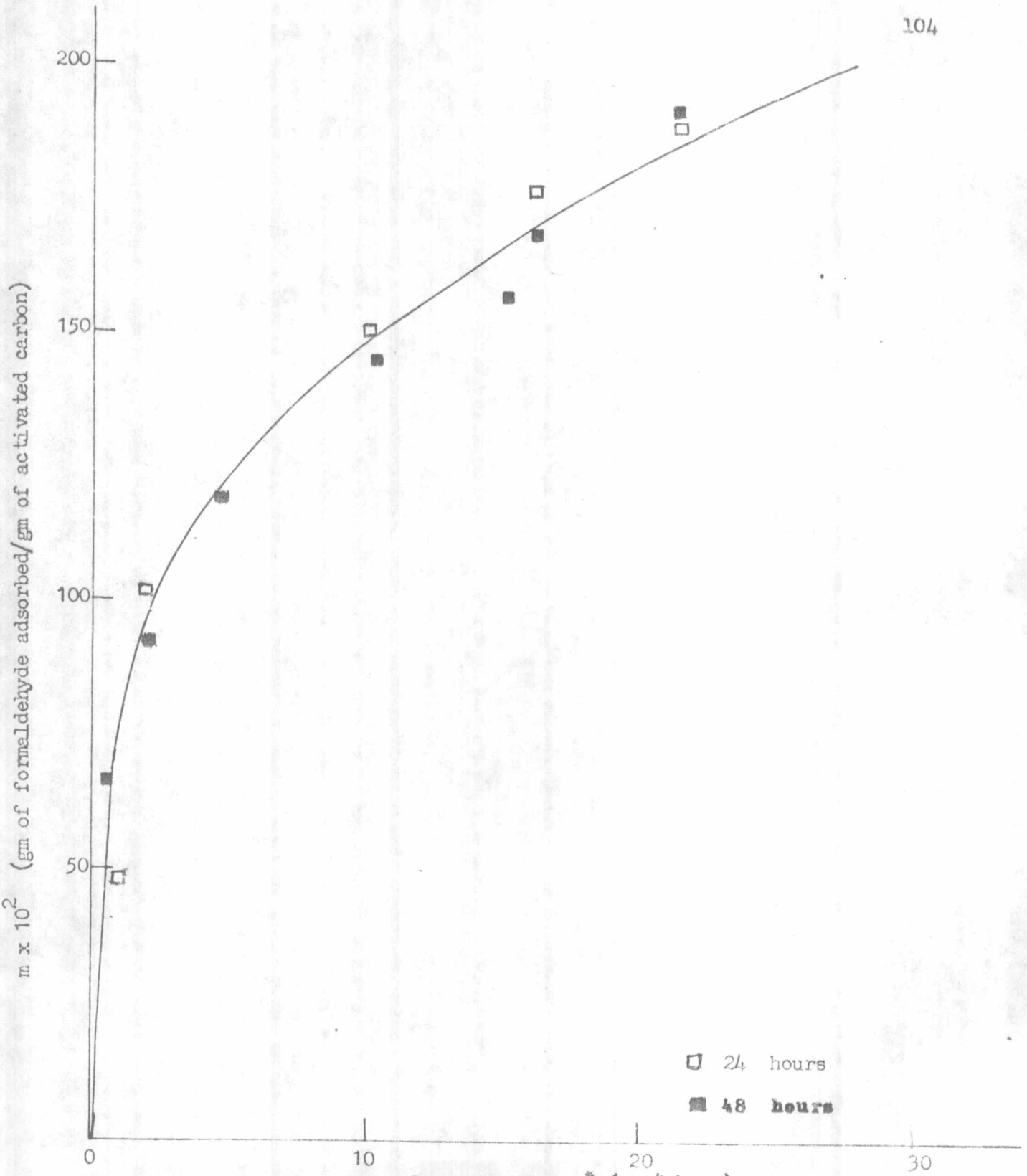

Fig.A-1 Equilibrium Adsorption of Formaldehyde at 30°C

Table A-2

Equilibrium Adsorption of Sodium Hydroxide

Exp.No.	m_c (gm)	C_o (Molar)	C^* (Molar)	C^* (gm/litre)	m X 10^2 (gm/gm)
1	20.0351	0.1073	0.0153	0.6132	0.9180
2	19.9196	0.0307	0.0043	0.1720	0.2650
3	20.1270	0.0077	0.0029	0.1148	0.0476
4	20.0562	0.0230	0.0038	0.1532	0.1911
5	20.1162	0.0155	0.0038	0.1532	0.1163
6	19.9634	0.0155	0.0038	0.1532	0.1172
7	20.0607	0.0115	0.0029	0.1148	0.0860
8	19.9659	0.0058	0.0019	0.0768	0.0384
9	20.0032	0.1724	0.0268	1.0728	1.4560
10	19.9953	0.5594	0.0498	1.9923	5.0970
11	19.8763	0.9303	0.0843	3.3716	8.5200
12	20.0351	1.4598	0.1226	4.9042	13.3480
13	19.9821	1.7663	0.1686	6.7433	15.9913
14	20.8956	2.0613	0.2165	8.6588	17.6570

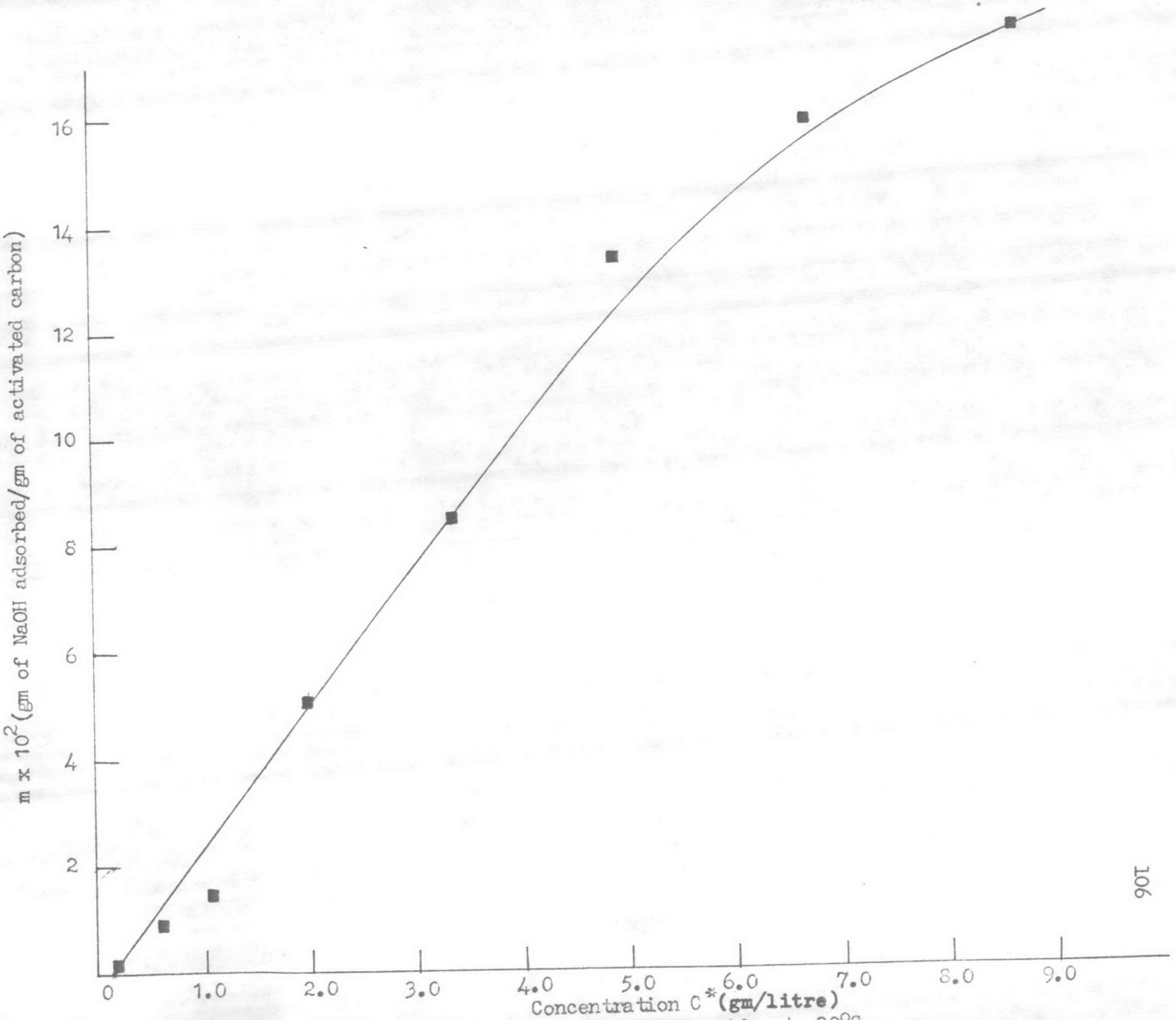

Fig.A-2 Equilibrium Adsorption of Sodium Hydroxide at 30°C

Table A-3

Equilibrium Adsorption of Sodium Carbonate

Exp.No.	m_c (gm)	C_o (Molar)	C^* (Molar)	C^* (gm/litre)	m X 10^2 (gm/gm)
1	20.0557	0.1073	0.0675	7.1580	1.0510
2	19.9225	0.0287	0.0115	1.2184	0.4587
3	19.9424	0.0163	0.0062	0.6600	0.2673
4	20.0486	0.0153	0.0038	0.4062	0.3038
5	19.9389	0.0048	0.0029	0.3046	0.0509
6	19.9467	0.0105	0.0038	0.4062	0.1781
7	20.0357	0.0115	0.0053	0.5584	0.1647
8	20.0896	0.0058	0.0019	0.2035	0.1009
9	20.0134	0.8889	0.0190	2.0151	1.8500
10	19.9963	0.3276	0.0579	6.1332	7.1500
111	20.0034	0.5651	0.0989	10.4813	12.3500
12	19.8952	0.7548	0.1351	14.3227	16.5100
13	19.9755	1.0204	0.1852	19.6312	22.1400
14	19.9832	1.1475	0.2576	27.3056	24.8500
15	19.9845	0.4540	0.0756	8.0104	10.0400

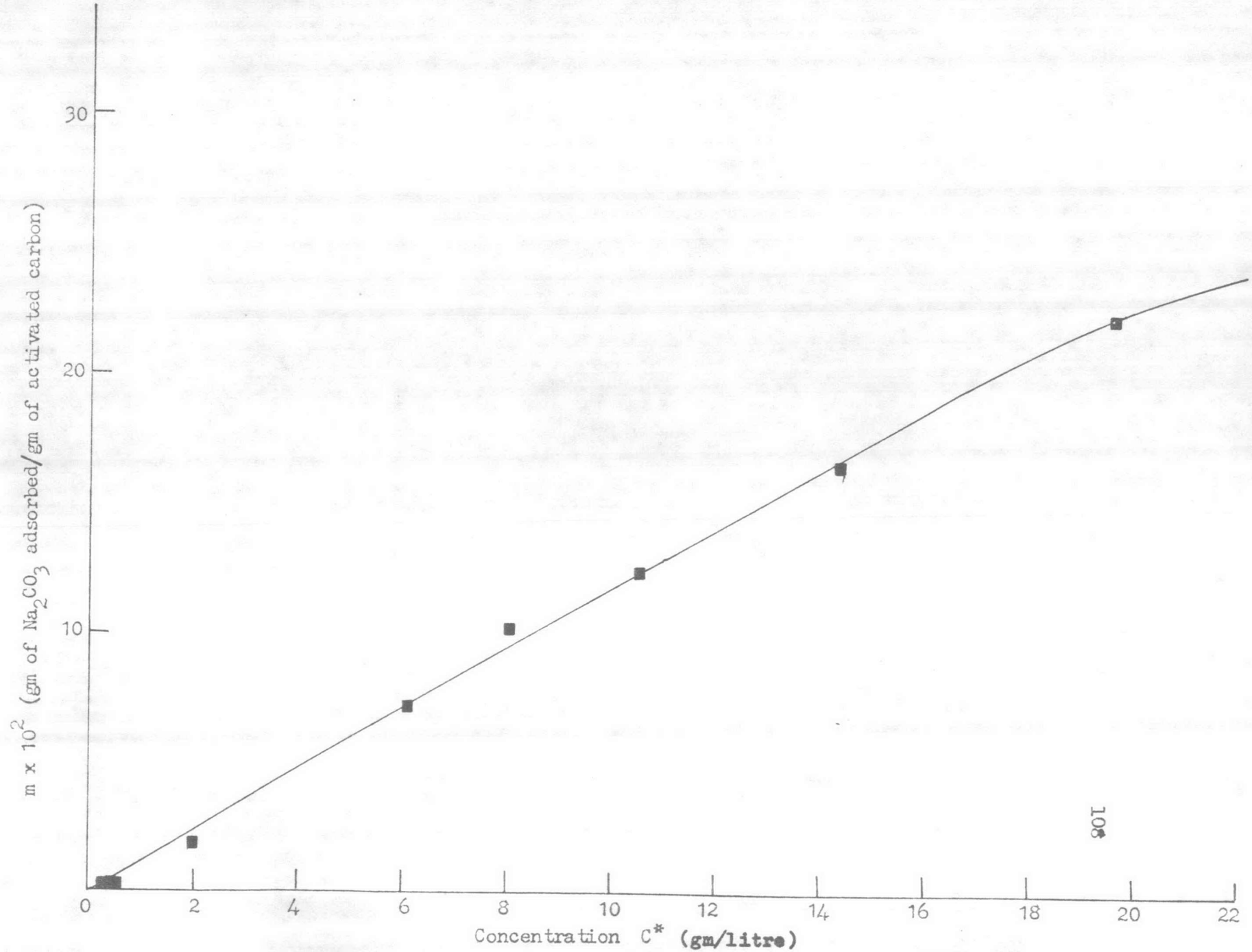

Fig.A-3 Equilibrium Adsorption of Sodium Carbonate at 30°C

Table A-4

Equilibrium Adsorption of Mixture of NaOH and Na_2CO_3

Exp. No.	m_c (gm)	NaOH				Na_2CO_3			
		C_o (Molar)	c^* (Molar)	c^* (gm/litre)	m x 10^2 (gm/gm)	C_o (Molar)	c^* (Molar)	c^* (gm/litre)	m x 10^2 (gm/gm)
1	20.0942	0.2048	0.1207	4.8048	0.8428	0.2043	0.1737	18.4122	0.8071
2	20.0838	0.1843	0.0971	3.8840	0.8684	0.1838	0.1530	16.748	0.6808
3	20.0423	0.1639	0.0935	3.7400	0.7025	0.1634	0.1377	14.5962	0.6796
4	20.0528	0.1434	0.0953	3.8120	0.4797	0.1430	0.1094	11.5964	0.8881
5	20.0401	0.1024	0.0459	1.8360	0.5639	0.1021	0.0830	8.7980	0.5062
6	19.9992	0.0819	0.0256	1.0240	0.5630	0.0817	0.0715	7.5790	0.2703
7	20.0053	0.0614	0.0124	0.4960	0.4899	0.0613	0.0494	5.2364	0.3153
8	20.0564	0.1229	0.0830	3.3200	0.3979	0.1226	0.0953	10.1018	0.7214
9	20.0431	0.2234	0.1375	5.5000	0.8567	0.2234	0.1700	18.0200	1.4107
10	20.0221	0.2776	0.1653	6.6120	1.1220	0.2776	0.2342	24.8252	1.1496
11	19.9963	0.3335	0.1806	7.2240	1.5291	0.3335	0.2897	30.7082	1.1605
12	20.0552	0.3568	0.2125	8.5000	1.4389	0.3568	0.2981	31.5986	1.5509
13	20.0611	0.3877	0.2523	10.0921	1.3502	0.3877	0.3260	34.5560	1.6309
14	20.0531	0.4201	0.2789	11.1560	1.4081	0.4201	0.3565	37.7890	1.6803

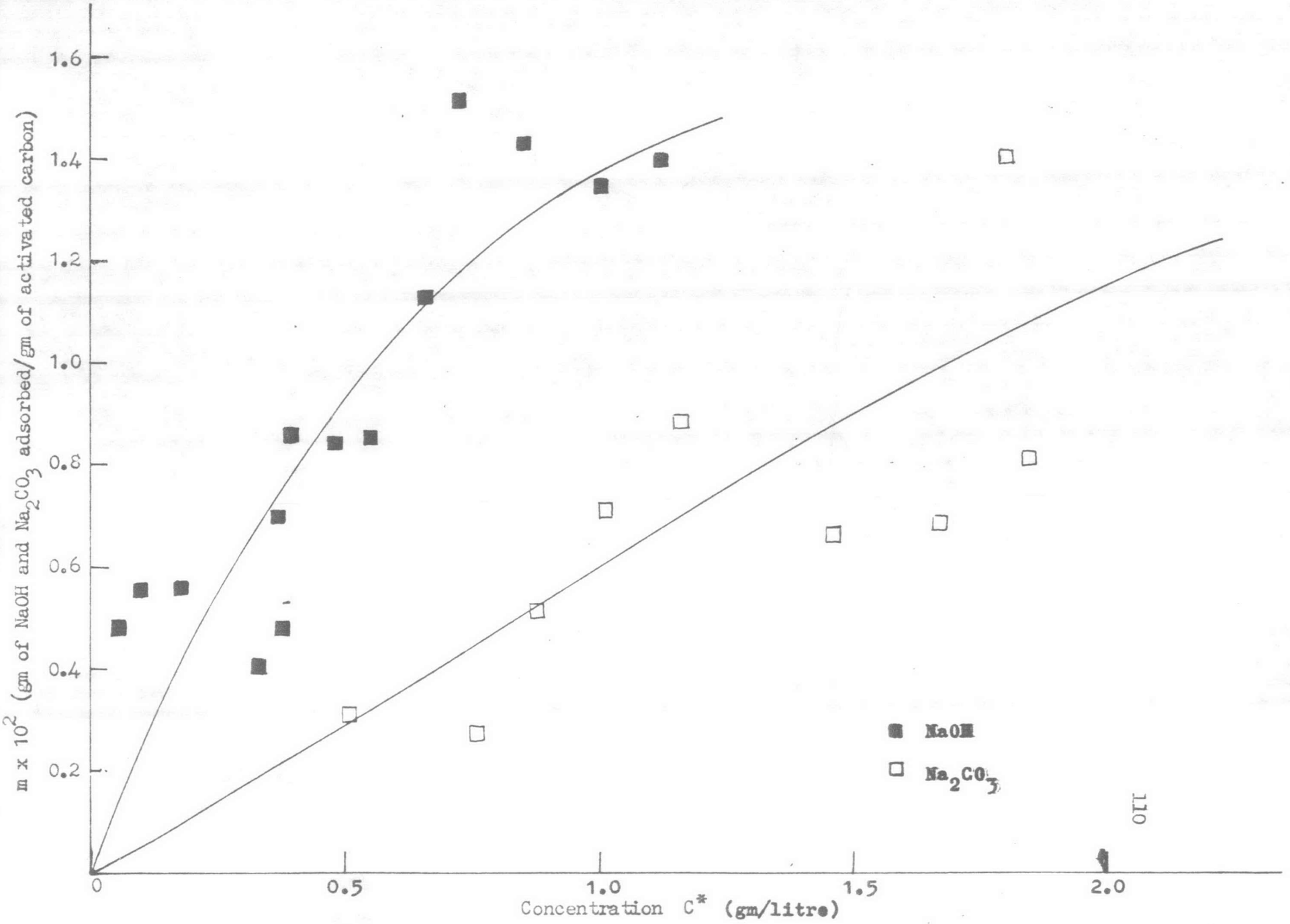

Fig.A-4 Equilibrium Adsorption of Mixture of Sodium Hydroxide and Sodium Carbonate at 30°C

Table A-5

Calibration of Rotameter

Rotameter Reading (mm)	Flow rate (cm^3/min)
10	320
15	530
20	710
30	1040
35	1260
40	1440
45	1600
50	1780
55	1960
60	2160
65	2340
70	2530
75	2745
80	2960
85	3180
90	3400

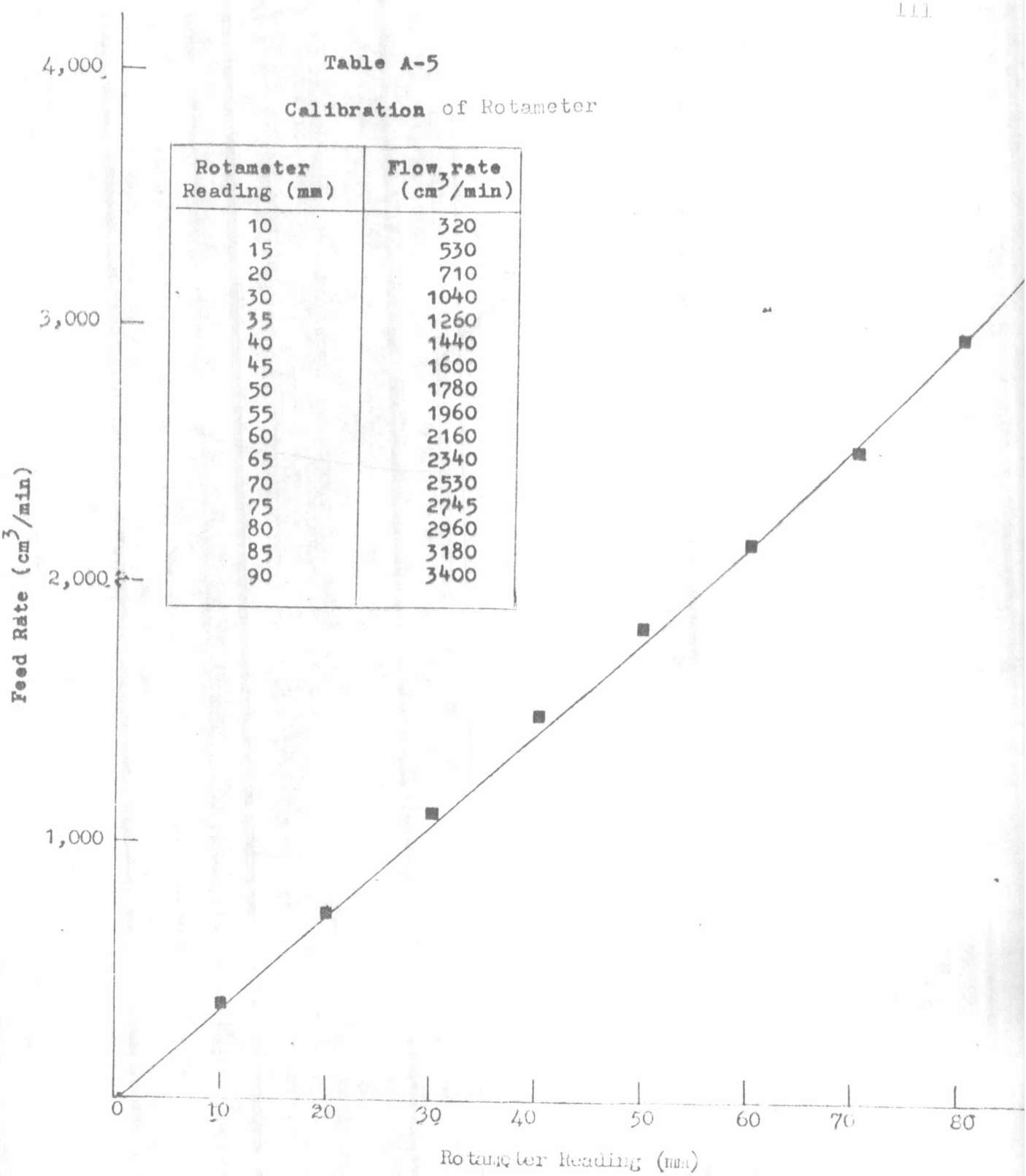

Fig. A-5 Calibration Curve of Rotameter

Table A-6

d_p (cm)	0.119	0.100	0.076
u	ΔP	ΔP	ΔP
0.15	80	70	30
0.26	115.5	110.5	67.5
0.44	117	113	88
0.58	115	109	85
0.75	115	108	83.5
0.86	116.75	108.75	83.5
1.04	116.75	108.5	83
1.19	117	108.5	83
1.32	117	108.5	83
1.47	117.5	107.25	83
1.61	117	107	83
1.78	117	109	83

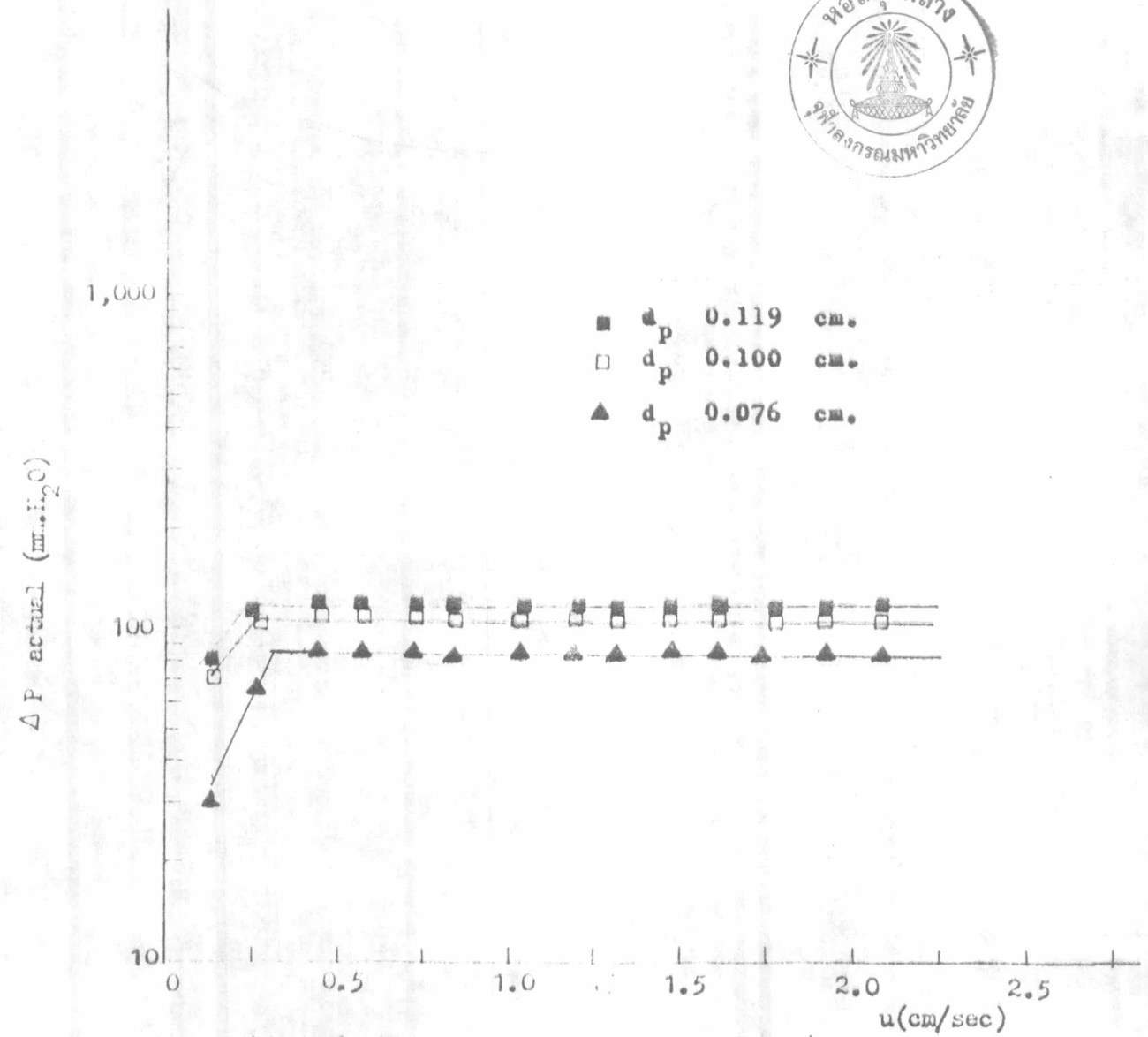

Fig.A-6 Variation of Pressure drop (ΔP) with Velocity (u) for Various Sizes of Activated Carbon

Appendix B

EXPERIMENTAL DATA FOR ADSORPTION

1 Experimental Data For Adsorption of Formaldehyde

Table B -1

$q = 1{,}260\ cm^3/min$ $d_p = 0.100\ cm$

Time (min)	C_o(Molar) 0.328		0.267		0.177		0.113	
	C	$mX10^2$	C	$mX10^2$	C	$mX10^2$	C	$mX10^2$
0	0.328	0.00	0.267	0.00	0.177	0.00	0.113	0.00
5	0.315	2.52	0.243	4.41	-	-	0.080	6.30
10	0.310	5.99	0.252	7.25	0.177	0	0.110	6.93
15	0.290	13.23	0.238	12.60	-	-	0.110	7.56
20	0.293	19.85	0.242	17.26	0.170	2.52	0.120	6.30
25	0.297	25.83	0.243	21.67	-	-	0.117	5.67
30	0.273	36.23	0.238	27.09	0.163	7.56	0.120	4.41
35	0.303	40.95	0.252	29.93	-	-	0.157	3.78
40	0.307	45.05	0.245	34.02	0.157	15.12	0.097	6.30
45	0.323	45.99	0.246	37.99	-	-	0.080	5.67
50	0.303	50.72	0.242	42.71	0.143	27.72	0.080	11.97
55	0.310	54.18	0.252	45.55	-	-	0.070	20.16
60	0.300	59.54	0.252	48.38	0.150	37.80	0.100	20.68
65	0.313	62.37	0.246	52.29	-	-	0.103	22.57
70	0.317	64.58	0.250	55.44	0.160	44.10	0.103	24.46
75	0.327	64.89	0.262	56.39	-	-	0.127	21.94
80	0.328	64.89	0.258	57.96	0.160	50.40	0.113	21.94
85	0.328	64.89	0.261	59.03	-	-	0.113	21.94
90	0.327	64.89	-	-	0.177	50.40	0.113	21.94

Table B -2

$q = 1{,}600\ cm^3/min$ $d_p = 0.076\ cm$

Time (min)	C_o(Molar) 0.220		0.330		0.195		0.113	
	C	$mX10^2$	C	$mX10^2$	C	$mX10^2$	C	$mX10^2$
0	0.220	0.00	0.330	0.00	0.195	0.00	0.113	0.00
5	0.203	4.00	0.303	6.40	0.172	5.20	0.100	3.20
10	0.199	9.00	0.298	14.00	0.178	8.80	0.105	5.20
15	0.203	13.00	0.305	20.00	0.178	12.40	0.097	9.20
20	0.203	19.00	0.307	25.60	0.172	17.60	0.083	13.60
25	0.203	23.00	0.307	31.20	0.168	23.60	0.110	14.40
30	0.203	27.00	0.307	36.80	0.163	30.80	0.098	18.00
35	0.195	33.00	0.307	42.40	0.198	29.60	0.105	20.00
40	0.203	37.00	0.310	47.20	0.195	29.60	0.095	24.40
45	0.199	42.00	0.310	52.00	0.168	35.10	0.107	26.00
50	0.201	46.50	0.310	56.80	0.162	43.20	0.097	30.00
55	0.208	49.30	0.313	60.80	0.168	49.20	0.098	33.60
60	0.205	53.00	0.313	64.80	0.182	52.00	0.103	36.00
65	0.217	55.00	0.317	68.00	0.195	52.00	0.103	38.40
70	0.210	57.50	0.323	69.60	0.195	52.00	0.107	40.40
75	0.214	59.00	-	-	-	-	0.107	41.60
80	0.217	61.00	-	-	-	-	-	-

C = Molar

m = gm CH_2O adsorbed / gm activated carbon

Table B-3

$q = 1{,}780\ cm^3/min$

$d_p = 0.076\ cm$

Time (min)	C_o (Molar) 0.220		0.215	
	C	$mX10^2$	C	$mX10^2$
0	0.220	0.00	0.215	0.00
5	0.207	3.56	0.185	8.01
10	0.205	7.57	0.205	10.68
15	0.185	16.91	0.203	13.80
20	0.190	24.92	0.192	20.03
25	0.193	32.04	0.208	21.81
30	0.210	34.71	-	21.81
35	0.187	43.61	0.203	24.92
40	0.200	48.95	0.192	31.15
45	0.187	57.85	0.182	40.05
50	0.183	67.64	0.175	50.73
55	0.217	68.53	0.175	61.41
60	0.220	68.53	0.205	64.08
65	0.220	68.53	0.215	64.08
70	-	-	0.215	64.08

Table B-4

$q = 1{,}260\ cm^3/min$

$d_p = 0.076\ cm$

Time (min)	C_o (Molar) 0.220		0.217	
	C	$mX10^2$	C	$mX10^2$
0	0.220	0.00	0.217	0.00
5	0.215	1.01	0.213	0.63
10	0.215	1.95	0.210	1.89
15	0.205	4.85	0.203	4.31
20	0.200	8.63	0.200	7.56
25	0.203	11.78	0.190	12.60
30	0.183	18.71	0.187	18.27
35	0.167	28.79	0.190	23.31
40	0.182	36.09	0.197	27.09
45	0.192	41.55	0.193	31.50
50	0.193	46.49	0.197	35.28
55	0.200	50.27	0.200	38.43
60	0.178	51.91	0.203	40.95
65	0.200	55.69	0.207	42.84
70	0.210	55.58	0.200	45.99
75	0.215	58.52	0.213	46.62
80	0.218	58.84	0.200	49.77
85	0.200	58.84	0.213	50.40
90	-	- -	0.215	50.72

Table B-5

$q = 1{,}440\ cm^3/min$

$d_p = 0.076\ cm$

Time (min)	C_o (Molar) 0.223		0.220	
	C	$mX10^2$	C	$mX10^2$
0	0.223	0.00	0.220	0.00
5	0.218	1.08	0.215	1.08
10	0.198	6.47	0.210	3.24
15	0.215	8.28	0.207	6.14
20	0.212	10.80	0.200	10.46
25	0.185	19.08	0.193	16.22
30	0.195	25.20	0.197	21.26
35	0.217	26.64	0.197	26.30
40	0.197	32.40	0.200	30.62
45	0.212	34.92	0.200	34.94
50	0.190	42.12	0.203	38.54
55	0.195	48.24	0.193	44.30
60	0.205	52.20	0.197	49.34
65	0.212	54.70	0.200	53.66
70	0.205	58.68	0.200	57.98
75	0.205	62.64	0.210	60.14
80	0.222	63.00	0.215	61.22
85			0.220	61.22

C = Molar

m = CH_2O adsorbed / gm activated carbon

Table B -6

$q = 1{,}600\ cm^3/min$

$C_o = 0.220$ Molar

Time (min)	d_p (cm) 0.119		0.100		0.059	
	C	$mX10^2$	C	$mX10^2$	C	$mX10^2$
0	0.220	0.00	0.220	0.00	0.220	0.00
5	0.207	3.00	0.212	2.00	0.220	4.80
10	0.203	7.00	0.198	7.20	0.203	8.80
15	0.208	9.80	0.205	10.80	0.198	14.00
20	0.207	13.00	0.202	15.20	0.198	19.20
25	0.205	16.60	0.205	18.80	0.200	24.00
30	0.208	19.60	0.198	24.00	0.197	29.36
35	0.205	23.00	0.203	28.00	0.200	34.40
40	0.207	26.00	0.205	31.60	0.197	40.00
45	0.207	29.20	0.208	34.40	0.197	45.60
50	0.208	32.00	0.207	37.60	0.197	51.20
55	0.207	35.20	0.208	40.40	0.200	56.00
60	0.208	38.00	0.205	44.40	0.200	60.80
65	0.207	41.00	0.212	46.00	0.207	64.00
70	0.207	44.00	0.208	48.80	0.213	67.20
75	0.207	47.00	0.210	51.20	0.213	68.80
80	-	-	0.215	53.40	-	70.40

C = Molar

m = gm CH_2O adsorbed / gm activated carbon

2 Experimental Data for Adsorption of Sodium Hydroxide

Table B -7

$q = 1{,}600\ cm^3/min$ $d_p = 0.100cm$

Time (min)	C_o(Molar) 0.2322		0.1849		0.1706		0.1449	
	C	$mX10^2$	C	$mX10^2$	C	$mX10^2$	C	$mX10^2$
0	0.2322	0.00	0.1849	0.00	0.1706	0.00	0.1449	0.00
4	0.2274	0.96	0.1801	0.97	0.1685	0.41	0.1438	0.41
8	0.2288	1.66	0.1815	1.66	0.1685	0.83	0.1438	0.62
12	0.2301	2.06	0.1822	2.21	0.1682	1.31	0.1432	0.97
16	0.2288	2.75	0.1836	2.49	0.1685	1.73	0.1445	1.04
20	0.2260	3.99	0.1836	2.76	0.1685	2.14	0.1445	1.11
24	0.2288	4.68	0.1829	3.18	0.1685	2.28	0.1438	1.31
28	0.2308	4.95	0.1839	3.45	0.1685	2.42	0.1438	1.52
32	0.2308	5,23	0.1840	3.65	0.1703	2.47	0.1438	1.73
36	0.2301	5.63	0.1843	3.79	0.1706	2.47	0.1445	1.79
40	0.2315	5.87	0.1843	3.92	0.1692	2.47	0.1438	2.00
44	0.2308	6.15	0.1843	4.06	0.1699	2.75	0.1445	2.07
48	0.2322	6.15	0.1843	4.20	0.1699	3.03	o.1445	2.14
52	0.2315	6.28	0.1836	4.47	0.1706	3.17	o.1445	2.21
56	0.2322	6.28	0.1849	4.47	0.1699	3.30	0.1445	2.28
60	0.2315	6.42	0.1849	4.47	0.1699	3.44	0.1445	2.35
64	0.2315	6.56	0.1849	4.47	0.1699	3.58	0.1449	2.35
68	0.2322	6.56	-	-	-	-	-	-
72	0.2315	6.69	-	-	-	-	-	-
76	0.2315	6.83	-	-	-	-	-	-

C = Molar

m = gm NaOH adsorbed / gm activated carbon

Table B -8

$q = 1{,}600\ cm^3/min$ $C_o = 0.1800$(Molar)

Time (min)	d_p(cm) 0.119		0.100		0.076		0.059	
	C	$mX10^2$	C	$mX10^2$	C	$mX10^2$	C	mX10
0	0.1800	0.00	0.1800	0.00	0.1800	0.00	0.1800	0.00
4	0.1790	0.26	0.1790	0.26	0.1783	0.43	0.1781	0.48
8	0.1791	0.49	0.1786	0.63	0.1789	0.72	0.1781	0.98
12	0.1799	0.76	0.1788	0.94	0.1782	1.20	0.1787	1.33
16	0.1785	1.15	0.1785	1.33	0.1787	1.54	0.1785	1.72
20	0.1794	1.30	0.1789	1.62	0.1784	1.96	0.1784	2.14
24	0.1785	1.70	0.1787	1.96	0.1786	2.33	0.1788	2.45
28	0.1722	1.90	0.1783	2.40	0.1790	2.60	0.1781	2.93
32	0.1786	2.26	0.1795	2.53	0.1784	3.01	0.1781	3.43
36	0.1790	2.53	0.1781	3.01	0.1787	3.34	0.1788	3,74
40	0.1794	2.70	0.1788	3.33	0.1786	3.70	0.1787	4,08
44	0.1783	3.15	0.1789	3.63	0.1787	4.05	0.1785	4,45
48	0.1794	3.30	0.1788	3,95	0.1784	4.46	0.1790	4.70
52	0.1788	3.61	0.1790	4.20	0.1792	4.68	0.1789	5.00
56	0.1788	3.92	0.1788	4.51	0.1784	5.09	0.1783	5.45
60	0.1789	4.20	0.1784	4.92	0.1788	5.40	0.1787	5.80
64	0.1790	4.45	0.1793	5.10	0.1799	5.56	0.1781	6.28
68	0.1796	4.55	0.1789	5.43	0.1787	5.90	0.1796	6.40
72	0.1787	4.90	0.1791	5.66	0.1789	6.20	0.1865	6.75
76	0.1795	5.03	0.1792	5.86	0.1794	6.35	0.1790	7.02
80	0.1795	5.16	0.1793	6.04	0.1795	6.48	-	-

Table B -9

d_p = 0.100 cm C_o = 0.1914 Molar

Time (min)	q(cm^3/min) 1,260		1,440		1,600		1,960	
	C	$mX10^2$	C	$mX10^2$	C	$mX10^2$	C	$mX10^2$
0	0.1914	0.00	0.1914	0.00	0.1914	0.00	0.1914	0.00
4	0.1902	0.26	0.1900	0.34	0.1890	0.48	0.1884	0.62
8	0.1900	0.55	0.1900	0.68	0.1895	0.88	0.1890	1.06
12	0.1900	0.84	0.1903	0.95	0.1904	1.09	0.1884	1.68
16	0.1901	1.12	0.1901	1.27	0.1897	1.44	0.1895	2.08
20	0.1902	1.38	0.1900	1.60	0.1890	1.92	0.1897	2.42
24	0.1890	1.69	0.1902	1.89	0.1884	2.54	0.1904	2.63
28	0.1902	1.94	0.1901	2.21	0.1890	3.02	0.1904	2.84
32	0.1903	2.18	0.1902	2.50	0.1890	3.51	0.1911	2.91
36	0.1904	2.39	0.1901	2.80	0.1895	3.91	0.1904	3.11
40	0.1906	2.56	0.1900	3.13	0.1897	4.25	0.1890	3.60
44	0.1903	2.80	0.1905	3.35	0.1911	4.32	0.1904	3.81
48	0.1904	3.01	0.1904	3.59	0.1911	4.39	0.1904	4.01
52	0.1905	3.19	0.1907	3.77	0.1904	4.60	0.1911	4.08
56	0.1907	3.33	0.1908	3.92	0.1911	4.66	0.1911	4.15
60	0.1905	3.52	-	-	0.1911	4.73	0.1914	4.15
64	0.1907	3.66	-	-	0.1914	4.73	-	-

C = Molar

m = gm NaOH adsorbed / gm activated carbon

3. Experimental Data for Adsorption of Sodium Carbonate

Table B -10

$q = 1{,}600\ cm^3/min$ $\quad d_p = 0.119\ cm$

Time (min)	C_o (Molar) 0.0631		0.0691		0.0714		0.1754	
	C	$mX10^2$	C	$mX10^2$	C	$mX10^2$	C	$mX10^2$
0	0.0631	0.00	0.0691	0.00	0.0741	0.00	0.1754	0.00
4	0.0622	0.69	0.0685	0.43	0.0728	0.89	0.1721	2.23
8	0.0618	1.51	0.0676	1.42	0.0733	1.48	0.1741	3.12
12	0.0627	1.81	0.0689	1.56	0.0737	1.77	0.1741	4.01
16	0.0627	2.10	0.0685	1.99	0.0737	2.07	0.1747	4.46
20	0.0627	2.40	0.0685	2.42	0.0737	2.36	0.1741	5.35
24	0.0631	2.40	0.0689	2.56	0.0737	2.65	0.1741	6.24
28	0.0618	3.30	0.0676	3.55	0.0733	3.24	0.1747	6.68
32	0.0627	3.60	0.0685	3.98	0.0733	3.83	0.1734	8.02
36	0.0627	3.90	0.0685	4.41	0.0739	3.98	0.1754	8.02
40	0.0631	3.90	0.0691	4.41	0.0724	4.16	0.1754	8.02
44	0.0631	4.20	0.0689	4.55	0.0733	4.75	0.1751	8.25
48	0.0627	4.20	0.0689	4.70	0.0737	5.04	0.1751	8.47
52	0.0631	4.50	0.0689	4.84	0.0739	5.18	0.1751	8.69
56	0.0627	-	0.0689	4.98	0.0737	5.48	0.1754	8.69
60	-		-	-	0.0741	5.48	-	

Table B -11

$q = 1{,}600\ cm^3/min$ $\quad d_p = 0.100\ cm$

Time (min)	C_o (Molar) 0.1898		0.1909		0.1901		0.050	
	C	$mX10^2$	C	$mX10^2$	C	$mX10^2$	C	mX1
0	0.1898	0.00	0.1909	0.00	0.1901	0.00	0.0500	0.00
4	0.1884	0.96	0.1886	1.53	0.1886	0.96	0.0489	0.71
8	0.1872	2.69	0.1886	3.07	0.1886	1.91	0.0492	1.25
12	0.1875	4.24	0.1886	4.06	0.1886	2.87	0.0489	1.96
16	0.1880	5.43	0.1886	6.14	0.1856	5.92	0.0489	2.67
20	0.1889	6.01	0.1886	7.67	0.1881	7.26	0.0490	3.32
24	0.1878	7.35	0.1881	9.59	0.1881	8.60	0.0490	3.96
28	0.1878	8.69	0.1891	10.82	0.1884	9.75	0.0486	4.93
32	0.1878	10.04	0.1903	11.20	0.1884	10.90	0.0489	5.64
36	0.1884	11.00	0.1875	11.47	0.1881	12.24	0.0492	6.00
40	0.1884	11.97	0.1898	12.24	0.1886	13.21	0.0494	6.36
44	0.1884	12.93	0.1886	13.77	0.1889	13.97	0.0494	6.72
48	0.1889	13.51	0.1909	13.77	0.1892	14.55	-	-
52	0.1889	14.08	0.1886	15.31	0.1886	15.51	-	-
56	-	-	0.1897	16.09	0.1892	16.09	-	-
60	-	-	-	-	0.1892	16.66		

C = Molar

m = gm Na_2CO_3 adsorbed / gm activated carbon

Table B -12

$q = 1{,}600\ cm^3/min$ $C_o = 0.1761$ Molar

Time (min)	d_p (cm) 0.119		0.100		0.076		0.059	
	C	mX10	C	$mX10^2$	C	$mX10^2$	C	$mX10^2$
0	0.1761	0.00	0.1761	0.00	0.1761	0.00	0.1761	0.00
4	0.1747	0.90	0.1747	0.90	0.1747	0.90	0.1739	1.23
8	0.1747	1.79	0.1747	1.79	0.1721	3.59	0.1734	3.34
12	0.1734	3.59	0.1734	3.59	0.1721	6.28	0.1734	5.46
16	0.1747	4.48	0.1734	5.30	0.1734	8.08	0.1739	6.69
20	0.1758	5.47	0.1755	5.74	0.1758	8.25	0.1731	8.37
24	0.1721	7.35	0.1734	7.54	0.1755	8.61	0.1792	9.43
28	0.1747	8.24	0.1747	8.43	0.1747	9.51	0.1747	10.20
32	0.1758	8.43	0.1747	9.33	0.1747	10.41	0.1750	10.82
36	0.1747	9.32	0.1747	10.23	0.1744	10.85	0.1752	11.29
40	0.1758	9.50	0.1747	11.12	0.1755	11.21	0.1752	11.76
44	0.1755	9.86	0.1758	11.30	0.1758	11.39	0.1755	12.06
48	0.1761	9.86	0.1761	11.30	0.1761	11.39	0.1755	12.37
52	0.1758	10.03	-	-	-	-	0.1758	12.52
56	0.1758	10.21	-	-	-	-	-	-

Table B -13

$d_p = 0.100$ cm $C_o = 0.1898$ Molar

Time (min)	$q(cm^3/min)$ 1,260		1,440		1,600		1,960	
	C	$mX10^2$	C	$mX10^2$	C	$mX10^2$	C	mX1
0	0.1898	0.00	0.1898	0.00	0.1898	0.00	0.1898	0.00
4	0.1884	0.77	0.1878	1.21	0.1884	0.96	0.1878	1.6
8	0.1884	1.53	0.1882	2.14	0.1872	2.69	0.1878	1.7
12	0.1889	1.99	0.1882	3.08	0.1875	4.24	0.1878	1.8
16	0.1889	2.45	0.1882	4.01	0.1880	5.43	0.1881	1.9
20	0.1889	2.91	0.1884	4.88	0.1889	6.01	0.1882	1.9
24	0.1889	3.37	0.1884	5.74	0.1878	7.35	0.1882	2.0
28	0.1889	3.82	0.1884	6.61	0.1878	8.69	0.1881	2.2
32	0.1889	4.28	0.1889	7.13	0.1878	10.04	0.1884	2.3
36	0.1892	4.59	0.1889	7.56	0.1884	11.00	0.1889	2.3
40	0.1889	5.05	0.1889	8.17	0.1884	11.97	0.1889	2.4
44	0.1895	5.20	0.1889	8.68	0.1834	12.93	0.1889	2.5
48	0.1892	5.51	0.1889	9.20	0.1889	13.51	0.1892	2.6
52	0.1895	5.67	0.1886	9.93	0.1889	14.08	0.1890	2.7
56	0.1895	5.82	0.1893	10.24	-	-	0.1890	2.8
60	0.1898	5.82	0.1889	10.76	-	-	0.1895	2.8
64	-	-	0.1892	11.14	-		-	-

C = Molar

m = gm Na_2CO_3 adsorbed / gm activated carbon

4. Experimental Data for Adsorption of Mixture of Sodium Hydroxide amd Sodium Carbonate

Table B -14

$q = 1{,}600\ cm^3/min$ $\qquad d_p = 0.119\ cm$

Time (min)	C_o (Molar) 0.10725				0.09503				0.07213			
	NaOH		Na_2CO_3		NaOH		Na_2CO_3		NaOH		Na_2CO_3	
	C	$mX10^2$	C	$mX10^2$	C	$mX10^2$	C	$mX10^2$	C	$mX10^2$	C	$mX10^2$
0	0.10725	0.00	0.10725	0.00	0.09503	0.00	0.09503	0.00	0.07213	0.00	0.07213	0.00
4	0.10702	0.06	0.10712	0.09	0.09480	0.06	0.09498	0.03	0.07213	0.02	0.07211	0.01
8	0.10704	0.11	0.10720	0.12	0.09485	0.10	0.09498	0.07	0.07205	0.04	0.07211	0.03
12	0.10705	0.16	0.10720	0.16	0.09485	0.15	0.09499	0.09	0.07207	0.05	0.07211	0.04
16	0.10705	0.21	0.10721	0.18	0.09487	0.19	0.09498	0.13	0.07207	0.07	0.07211	0.05
20	0.10706	0.26	0.10721	0.21	0.09489	0.23	0.09499	0.16	0.07207	0.08	0.07212	0.06
24	0.10707	0.31	0.10722	0.23	0.09489	0.26	0.09499	0.18	0.07206	0.10	0.07212	0.07
28	0.10709	0.35	0.10721	0.26	0.09491	0.29	0.09499	0.21	0.07206	0.12	0.07212	0.08
32	0.10711	0.39	0.10725	0.26	0.09493	0.32	0.09499	0.24	0.07207	0.13	0.07212	0.09
36	0.10709	0.43	0.10720	0.29	0.09495	0.34	0.09499	0.26	0.07207	0.15	0.07212	0.10
40	0.10713	0.46	0.10716	0.35	0.09493	0.36	0.09499	0.29	0.07207	0.16	0.07211	0.10
44	0.10715	0.48	0.10717	0.41	0.09485	0.38	0.09499	0.32	0.07207	0.18	0.07212	0.11
48	0.10713	0.51	0.10720	0.44	0.09495	0.41	0.09499	0.34	0.07207	0.20	0.07212	0.12
52	0.10714	0.54	0.10723	0.45	0.09495	0.43	0.09500	0.36	0.07207	0.21	0.07211	0.13
56	0.10718	0.56	0.10721	0.48	0.09499	0.44	0.09500	0.39	0.07209	0.22	0.07212	0.14
60	0.10714	0.57	0.10721	0.51	0.09497	0.45	0.09501	0.40	0.07209	0.23	0.07212	0.14
64	0.10718	0.61	0.10725	0.51	0.09497	0.47	0.09501	0.41	0.07207	0.25	0.07212	0.15
68	0.10719	0.62	0.10725	0.51	0.09497	0.48	0.09502	0.42	0.07207	0.26	0.07212	0.16

C = Molar

m = gm NaOH, Na_2CO_3 adsorbed /gm activated carbon

Table B -15

$q = 1{,}600\ cm^3/min$ $C_o = 0.09503$ Molar

Time (min)	d_p (cm) 0.100				0.076			
	NaOH		Na_2CO_3		NaOH		Na_2CO_3	
	C	$mX10^2$	C	$mX10^2$	C	$mX10^2$	C	$mX10^2$
0	0.09503	0.00	0.09503	0.00	0.09503	0.00	0.09503	0.00
4	0.09480	0.06	0.09497	0.04	0.09476	0.07	0.09496	0.05
8	0.09485	0.11	0.09498	0.07	0.09482	0.12	0.09498	0.08
12	0.09482	0.16	0.09498	0.11	0.09485	0.17	0.09498	0.12
16	0.09485	0.20	0.09498	0.14	0.09483	0.22	0.09498	0.15
20	0.09492	0.23	0.09500	0.16	0.09485	0.27	0.09499	0.18
24	0.09486	0.28	0.09498	0.20	0.09484	0.32	0.09498	0.21
28	0.09493	0.31	0.09498	0.23	0.09487	0.36	0.09499	0.24
32	0.09484	0.35	0.09499	0.26	0.09483	0.38	0.09499	0.26
36	0.09494	0.37	0.09499	0.28	0.09498	0.42	0.09500	0.29
40	0.09495	0.39	0.09499	0.31	0.09483	0.47	0.09501	0.30
44	0.09498	0.41	0.09500	0.33	0.09498	0.48	0.09499	0.33
48	0.09491	0.44	0.09501	0.35	0.09489	0.52	0.09500	0.35
52	0.09502	0.44	0.09500	0.37	0.09493	0.55	0.09501	0.36
56	0.09502	0.44	0.09501	0.38	0.09491	0.58	0.09501	0.37
60	0.09501	0.45	0.09501	0.39	0.09501	0.58	0.09500	0.39
64	0.09503	0.45	0.09502	0.40	0.09501	0.59	0.09501	0.41
68	-	-	-	-	0.09503	0.59	0.09502	0.41

C = Molar

m = gm NaOH, Na_2CO_3 adsorbed / gm activated carbon

Table B -16

d_p = 0.119 cm C_o = 0.09503 Molar

Time (min)	q(cm^3/min) 1,440				1,780			
	NaOH		Na_2CO_3		NaOH		Na_2CO_3	
	C	mX10^2	C	mX10^2	C	mX10^2	C	mX10^2
0	0.09503	0.00	0.09503	0.00	0.09503	0.00	0.09503	0.00
4	0.09487	0.07	0.09498	0.03	0.09471	0.08	0.09496	0.05
8	0.09491	0.09	0.09499	0.06	0.09496	0.10	0.09496	0.11
12	0.09488	0.13	0.09500	0.07	0.09484	0.15	0.09501	0.12
16	0.09490	0.16	0.09499	0.10	0.09484	0.21	0.09501	0.14
20	0.09486	0.20	0.09499	0.12	0.09489	0.24	0.09495	0.20
24	0.09497	0.21	0.09498	0.15	0.09491	0.28	0.09499	0.23
28	0.09488	0.25	0.09498	0.18	0.09489	0.32	0.09500	0.25
32	0.09492	0.27	0.09498	0.21	0.09496	0.34	0.09498	0.29
36	0.09488	0.30	0.09499	0.24	0.09491	0.37	0.09500	0.31
40	0.09490	0.33	0.09499	0.26	0.09469	0.39	0.09500	0.33
44	0.09492	0.36	0.09500	0.28	0.09493	0.42	0.09500	0.35
48	0.09492	0.38	0.09500	0.30	0.09494	0.45	0.09500	0.38
52	0.09501	0.39	0.09501	0.31	0.09500	0.46	0.09500	0.40
56	0.09497	0.40	0.09503	0.31	0.09500	0.46	0.09501	0.41
60	0.09499	0.41	0.09501	0.32	0.09499	0.48	0.09500	0.44
64	0.09501	0.42	0.09502	0.33	0.09494	0.51	0.09501	0.45
68	-	-	-	-	0.09503	0.51	0.09502	0.46
72	-	-	-	-	0.09498	0.52	0.09502	0.47

C = Molar

m = gm NaOH, Na_2CO_3 adsorbed / gm activated carbon

Appendix C

NUMERICAL RESULTS

Table C-1

Systemic Properties of Experimental Fluidized Carbon Columns for Adsorption of Formaldehyde

Exp. No.	C_o (Molar)	C_o (gm/litre)	d_p (cm)	q (cm^3/min)	u (cm/sec)	M x 10^2 (gm/gm-min)	S x 10^{-4} (cm^2/gm)	k_p x 10^6 (cm/hr)	$\frac{1}{S}$ x 10^8 (gm/cm^2)	Rep
1	0.328	985	0.100	1,260	1.04	0.9655	1,600	3.67	6.25	10.87
2	0.177	530	0.100	1,260	1.04	0.5195	1,600	3,68	6.25	10.87
3	0.113	340	0.100	1,260	1,04	0.3332	1,600	3,68	6.25	10.87
4	0.220	660	0.076	1,600	1.32	0.8200	2,000	3.72	5.00	10.49
5	0.195	585	0.076	1,600	1.32	0.7300	2,000	3.74	5.00	10.49
6	0.220	660	0.076	1,780	1.46	1.1600	2,000	5.27	5.00	11.67
7	0.215	645	0.076	1,780	1.46	1.0769	2,000	5,01	5.00	11.67
8	0.223	670	0.076	1,440	1.18	0.8750	2,000	3.92	5.00	9.44
9	0.220	660	0.076	1,440	1.18	0.8750	2,000	3.64	5.00	9.44
10	0.220	660	0.076	1,260	1.04	0.8000	2,000	2.36	5.00	8.26
11	0.217	650	0.076	1,260	1.04	0.5200	2,000	2.41	5.00	8.26
12	0.220	660	0.100	1,600	1.32	0.7600	1,600	4.32	6.25	13.80
13	0.220	660	0.119	1,600	1.32	0.7100	1,300	4.97	7.69	16.43
14	0.220	660	0.059	1,600	1.32	0.9600	2,630	3.32	3.80	8.14
15	0.330	990	0.076	1,600	1,32	1.2000	2,000	3.64	5.00	10.49
16	0.113	340	0.076	1,600	1,32	0.4121	2,000	3.64	5.00	10.49
17	0.267	800	0.100	1,260	1.04	0.7841	1,600	3.68	6.25	10.87

Table C-2

Systemic Properties of Experimental Fluidized Carbon Column for Adsorption of Sodium Hydroxide

Exp. No.	C_o (Molar)	C_o (gm/litre)	d_p (cm)	q (cm^3/min)	u (cm/sec)	M x 10^2 (gm/gm-min)	S x 10^4 (cm /gm)	k_f x 10^7 (cm/hr)	$\frac{1}{S}$ x 10^8 (gm/cm)	Rep
1	0.1800	7.20	0.119	1,600	1.32	0.0679	1,300	4.35	7.69	16.49
2	0.1800	7.20	0.100	1,600	1.32	0.0813	1,600	4.22	6.25	13.85
3	0.1800	7.20	0.076	1,600	1.32	0.0948	2,000	3.95	5.00	10.53
4	0.1800	7.20	0.059	1,600	1.32	0.0978	2,630	3.10	3.80	6.17
5	0.2322	9.30	0.100	1,600	1.32	0.200	1,600	8.06	6.25	10.85
6	0.1849	7.40	0.100	1,600	1.32	0.1091	1,600	5.53	6.25	13.85
7	0.1706	6.80	0.100	1,600	1.32	0.0840	1,600	4.63	6.25	13.85
8	0.1449	5.80	0.100	1,600	1.32	0.0727	1,600	4.70	6.25	13.85
9	0.1914	7.80	0.100	1,260	1.04	0.0724	1,600	3.48	6.25	10.92
10	0.1914	7.80	0.100	1,440	1.18	0.0811	1,600	3.90	6.25	12.36
11	0.1914	7.80	0.100	1,600	1.32	0.1000	1,600	4.81	6.25	13.85
12	0.1914	7.80	0.100	1,960	1.61	0.1100	1,600	5.29	6.25	16.90

Table C-3

Systemic Properties of Experimental Fluidized Carbon Column

for Adsorption of Sodium Carbonate

Exp. No.	C_o		d_p	q	u	M x 10^2	S x 10^{-4}	k_f x 10^6	$\frac{1}{S}$ x 10^8	Rep
	(Molar)	(gm/litre)	(cm)	(cm^3/min)	(cm/sec)	(gm/gm-min)	(cm^2/gm)	(cm/hr)	(gm/cm^2)	
1	0.1761	18.66	0.119	1,600	1.32	0.2750	1,300	0.680	7.69	16.49
2	0.1761	18.66	0.100	1,600	1.32	0.3056	1,600	0.610	6.25	13.85
3	0.1761	18.66	0.076	1,600	1.32	0.3810	2,000	0.603	5.00	10.53
4	0.1761	18.66	0.059	1,600	1.32	0.5021	2,630	0.497	3.80	8.17
5	0.0631	6.69	0.119	1,600	1.32	0.1023	1,300	0.710	7.69	16.49
6	0.0691	7.32	0.119	1,600	1.32	0.1200	1,300	0.760	7.69	16.49
7	0.0741	7.86	0.119	1,600	1.32	0.1290	1,300	0.758	7.69	16.49
8	0.175	18.59	0.119	1,600	1.32	0.2739	1,300	0.660	7.69	16.49
9	0.1898	20.12	0.100	1,600	1.32	0.3320	1,600	0.620	6.25	13.85
10	0.1909	20.24	0.100	1,600	1.32	0.3741	1,600	0.690	6.25	13.85
11	0.1901	20.15	0.100	1,600	1.32	0.3534	1,600	0.660	6.25	13.85
12	0.0500	5.30	0.100	1,600	1.32	0.1600	1,600	0.113	6.25	13.85
13	0.1898	20.12	0.100	1,260	1.04	0.2563	1,600	0.290	6.25	10.91
14	0.1898	20.12	0.100	1,440	1.18	0.2625	1,600	0.490	6.25	12.38
15	0.1898	20.12	0.100	1,600	1.32	0.3333	1,600	0.620	6.25	13.85
16	0.1898	20.12	0.100	1,960	1.61	0.4250	1,600	0.790	6.25	16.90

Table C-4

Systemic Properties of Experimental Fluidized Carbon Column of Mixture of Sodium Hydroxide and Sodium Carbonate

Exp. No.	C_o (Molar)	d_p (cm)	q (cm^3/min)	u (cm/sec)	M x 10^4 (gm/gm-min)		S x 10^{-4} (cm^2/gm)	k_f x 10^7 (cm/hr)		$\frac{1}{S}$x10^8 (gm/cm^2)	Rep
					NaOH	Na_2CO_3		NaOH	Na_2CO_3		
1	0.10725	0.119	1,600	1.32	1.33	1.03	1,300	1,43	0.42	7.69	16.49
2	0.09503	0.119	1,600	1.32	1.17	0.76	1,300	1,43	0.35	7.69	16.49
3	0.07213	0.119	1,600	1.32	0.467	0.33	1,300	0.45	0.20	7.69	16.49
4	0.09503	0.119	1,440	1.18	1.03	0.635	1,300	1.24	0.29	7.69	14.78
5	0.09503	0.119	1,780	1.46	1.28	0.975	1,300	1.49	0.44	7.69	18.27
6	0.09503	0.100	1,600	1,32	1.20	0.80	1,600	1.18	0.30	6.25	13.80
7	0.09503	0.076	1,600	1.32	1.32	0.88	2,000	1.04	0.26	5.00	10.49

Appendix D

SAMPLE OF CALCULATION

1. Gram Adsorbate Adsorbed/Gram Adsorbent for Equilibrium Isothermal Adsorption.

For NaOH, Experiment No.1

m_c = 20.0351 gm

C_o = 0.1073 Molar

C^* = 0.0153 Molar

v = 50 ml

From the equation

$$m = \frac{(C_o - C^*)(v)(MW_{NaOH})}{(m_c)(1000)}$$

$$m = \frac{(0.1073-0.0153)(50)(40)}{(20.0351)(1000)}$$

$$= 0.00981 \text{ gm/gm}$$

2. Gram Adsorbate Adsorbed/Gram Adsorbent for Adsorption at Any Time, m .

For NaOH, Experiment No.1

m_c = 100.03 gm

C_o = 0.1800 Molar

d_p = 0.119 cm

q = 1,600 ml/min

At $t = 4$ min, $C = 0.1790$ Molar

From the equation

$$\text{gm diff} = \frac{(C_o - C)(q)(\Delta t)(MW)}{(1000)(m_c)}$$

Where gm diff = gm differential adsorbed which equals to amount of adsorbate adsorbed for a range of time Δt per unit mass of adsorbent

So $$\text{gm diff} = \frac{(0.1800-0.1790)(1600)(4)(40)}{(1000)(100.03)}$$

$$= 0.26 \times 10^{-2} \quad \text{gm/gm}$$

At $t = 8$ min, $C = 0.1791$ Molar

So $$\text{gm diff} = \frac{(0.1800-0.1791)(1600)(4)(40)}{(1000)(100.03)}$$

$$= 0.23 \times 10^{-2} \quad \text{gm/gm}$$

From $$m = \sum_{t=0}^{t} \text{gm diff}$$

where m = mass adsorbate adsorbed/mass adsorbent at any time

so at $t = 8$ min

$$m = \sum_{t=0}^{t=8 \text{ min}} (\text{gm diff})$$

$$= 0+(0.26\times10^{-2})+(0.23\times10^{-2}) \quad \text{gm/gm}$$

$$= 0.49\times10^{-2} \quad \text{gm/gm}$$

3.Mass Transfer Coefficient

From $k = \frac{M}{C_o S}$

where k = mass transfer coefficient, cm/hr

M = mass transfer rate, gm/gm – hr

C_o = influent concentration, gm/cm^3

S = surface area/mass adsorbent, cm^2/gm

then $k = \frac{(0.000679)(1000)(60)}{(0.1800)(40)(1300X10^4)}$

$= 4.35X10^{-7}$ cm/hr

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