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APPENDICES

Appendix A Adsorption Isotherms of Surfactant Solution

Table A1 Adsorption isotherm on activated carbons of CPC

Initial concentration (μmol/L)	Equilibrium concentration (μmol/L)	Amounts of adsorbed surfactant per specific area of adsorbent (μmol/m^2)
322.58	103.46	2.46
476.19	208.50	3.00
566.04	295.51	3.03
833.33	410.06	4.75
1000	617.23	4.29
1111.11	770.96	3.81
1250	894.40	3.99
2000	1648.06	3.95
4000	3574.95	4.77
6000	5477.52	5.86
8000	7516.52	5.42
10000	9546.38	5.09

Table A2 Adsorption isotherm on MWCNTs of CPC

Initial concentration (μmol/L)	Equilibrium concentration (μmol/L)	Amounts of adsorbed surfactant per specific area of adsorbent (μmol/m^2)
66.23	50.56	0.46
103.39	75.28	0.82
135.17	105.27	0.87
217.40	149.44	1.99
219.70	161.91	1.69
356.42	247.89	3.18
584.40	411.14	5.07
1406.82	1141.66	7.76
1426.17	1194.88	6.77
1494.82	1316.34	5.22
2227.20	1985.25	7.08
4232.03	3988.95	7.11
6135.34	5898.47	6.93
8000	7795.65	5.98
10000	9714.10	8.37

Table A3 Adsorption isotherm on activated carbons of SDBS

Initial concentration (μmol/L)	Equilibrium concentration (μmol/L)	Amounts of adsorbed surfactant per specific area of adsorbent (μmol/m^2)
99.01	63.72	0.40
196.08	114.42	0.92
697.67	555.63	1.59
909.09	741.12	1.88
1250	1057.29	2.16
1428.57	1157.80	3.04
2000	1681.97	3.57
2500	2155.25	3.87
3000	2656.29	3.85
3333.33	3026.04	3.45
3636.36	3294.63	3.83
4000	3611.99	4.35
5000	4668.04	3.7
6000	5592.65	4.57
8000	7497.89	5.63

Table A4 Adsorption isotherm on MWCNTs of SDBS

Initial concentration (μmol/L)	Equilibrium concentration (μmol/L)	Amounts of adsorbed surfactant per specific area of adsorbent (μmol/m^2)
99.01	19.77	2.32
196.08	71.96	3.63
384.62	220.16	4.81
697.67	507.65	5.56
909.09	704.32	5.99
1250	1005.20	7.16
1428.57	1192.33	6.91
1666.67	1441.45	6.59
2000	1715.26	8.33
3000	2808.82	5.59
4000	3543.38	13.36
4444.44	4156.58	8.42
5000	4746.54	7.42
6000	5696.90	8.87
8000	7809.12	5.59

Table A5 Adsorption isotherm on activated carbons of $OP(EO)_{10}$

Initial concentration (μmol/L)	Equilibrium concentration (μmol/L)	Amounts of adsorbed surfactant per specific area of adsorbent (μmol/m^2)
49.50	16.79	0.37
75.76	34.40	0.46
98.04	53.20	0.50
138.89	92.20	0.52
161.29	101.53	0.67
192.31	124.98	0.75
212.77	147.49	0.73
238.10	174.89	0.71
283.02	212.40	0.79
312.50	242.41	0.79
454.55	353.74	1.13
625	523.18	1.14
1111.11	968.29	1.60
1428.57	1301.20	1.43
2142.86	2005.02	1.55
2857.14	2664.27	2.16
10000	9842.98	1.76

Table A6 Adsorption isotherm on MWCNTs of $OP(EO)_{10}$

Initial concentration (μmol/L)	Equilibrium concentration (μmol/L)	Amounts of adsorbed surfactant per specific area of adsorbent (μmol/m^2)
49.50	16.65	0.96
75.76	37.13	1.13
98.04	41.67	1.65
121.95	63.47	1.71
138.89	71.07	1.98
161.29	99.55	1.81
192.31	107.16	2.49
212.77	132.96	2.34
238.10	155.25	2.42
283.02	183.99	2.90
312.5	209.99	3.00
454.55	343.41	3.25
625	522.76	2.99
1111.11	945.53	4.84
1428.57	1280.21	4.34
2142.86	1943.86	5.82
2857.14	2652.75	5.98
10000	9812.34	5.49

Appendix B UV-Vis Spectra of Surfactant Solutions Dispersed MWCNTs without Any Dilution

Table B1 UV-Vis Spectra of MWCNTs dispersed in 0.1 times of critical micelle concentration of surfactants and without surfactant

Time (Sec)	0% Surfactant	CPC	SDBS	$OP(EO)_{10}$
0	0.2142	0.2928	0.4313	0.3026
500	0.0721	0.1349	0.1517	0.1547
1000	0.0464	0.1084	0.0743	0.0911
1500	0.0372	0.1067	0.0522	0.0854
2000	0.0221	0.0773	0.0479	0.0668
2500	0.0291	0.0598	0.0414	0.0502
3000	0.0375	0.0555	0.0459	0.0511
3500	0.0244	0.048	0.033	0.0431
4000	0.0233	0.0509	0.03	0.0373

Table B2 UV-Vis Spectra of MWCNTs dispersed in critical micelle concentration of surfactants and without surfactant

Time (sec)	0% surfactant	CPC	SDBS	$OP(EO)_{10}$
0	0.2142	0.3809	0.2792	0.5887
500	0.0721	0.1866	0.182	0.1575
1000	0.0464	0.1018	0.1519	0.1254
1500	0.0372	0.127	0.1255	0.1056
2000	0.0221	0.0913	0.118	0.0971
2500	0.0291	0.0842	0.1151	0.0991
3000	0.0375	0.0789	0.1168	0.0948
3500	0.0244	0.0798	0.1131	0.0925
4000	0.0233	0.0777	0.1118	0.0839

Table B3 UV-Vis Spectra of MWCNTs dispersed in 10 times of critical micelle concentration of surfactants and without surfactant

Time (sec)	0% surfactant	CPC	SDBS	$OP(EO)_{10}$
0	0.2142	0.4371	0.4614	0.7659
500	0.0721	0.2945	0.3819	0.511
1000	0.0464	0.2561	0.3362	0.4565
1500	0.0372	0.2405	0.3403	0.4502
2000	0.0221	0.2263	0.3456	0.4406
2500	0.0291	0.2214	0.34	0.4422
3000	0.0375	0.228	0.3366	0.4345
3500	0.0244	0.2211	0.3344	0.4403
4000	0.0233	0.2181	0.3331	0.4335

Table B4 UV-Vis Spectra of MWCNTs dispersed with different concentrations of CPC and without surfactant

Time (sec)	0% surfactant	0.1 CMC	CMC	10 CMC
0	0.2142	0.3129	0.3809	0.4371
500	0.0721	0.1105	0.1866	0.2945
1000	0.0464	0.0719	0.1018	0.2561
1500	0.0372	0.0678	0.127	0.2405
2000	0.0221	0.0589	0.0913	0.2263
2500	0.0291	0.0591	0.0842	0.2214
3000	0.0375	0.0514	0.0789	0.228
3500	0.0244	0.0425	0.0798	0.2211
4000	0.0233	0.0395	0.0777	0.2181

Table B5 UV-Vis Spectra of MWCNTs dispersed with different concentrations of SDBS and without surfactant

Time (sec)	0% surfactant	0.1 CMC	CMC	10 CMC
0	0.2142	0.2957	0.2792	0.4614
500	0.0721	0.083	0.182	0.3819
1000	0.0464	0.0514	0.1519	0.3362
1500	0.0372	0.0314	0.1255	0.3403
2000	0.0221	0.028	0.118	0.3456
2500	0.0291	0.036	0.1151	0.34
3000	0.0375	0.0239	0.1168	0.3366
3500	0.0244	0.0225	0.1131	0.3344
4000	0.0233	0.0165	0.1118	0.3331

Table B6 UV-Vis Spectra of MWCNTs dispersed with different concentrations of $OP(EO)_{10}$ and without surfactant

Time (sec)	0% surfactant	0.1 CMC	CMC	10 CMC
0	0.2142	0.364	0.5887	0.7659
500	0.0721	0.1284	0.1575	0.511
1000	0.0464	0.0848	0.1254	0.4565
1500	0.0372	0.0488	0.1056	0.4502
2000	0.0221	0.0598	0.0971	0.4406
2500	0.0291	0.0456	0.0991	0.4422
3000	0.0375	0.0415	0.0948	0.4345
3500	0.0244	0.0365	0.0925	0.4403
4000	0.0233	0.0333	0.0839	0.4335

Appendix C Zeta Potential Values of MWCNTs

Table C1 Zeta potential values of MWCNTs at natural pH of CPC solution

0.1 CPC	0.5 CPC	CPC	1.5 CPC	2 CPC
38.21	55.83	72.4	66.76	91.89
36.1	62.24	78.2	82.83	98.39
30.63	66.76	72.68	79.08	110
28.16	51.89	80.45	97.49	107.4
23.37	61.32	86.31	74.74	99.59
28.24	54.1	69.01	78.42	107.4
30.98	68.5	67.48	89.22	102.9
35.74	68.24	66.52	71	113.3
31.57	45.37	88.8	75.35	116.2
30.42	63.86	64.53	87.96	102.3
36.52	65.79	62.77	72.68	102.3
40.4	51.32	82.68	88.38	128.3
37.83	49.32	58.67	81.52	127
32.69	61.1	69.52	79.77	104.6
29.96	61.32	63.21	87.96	96.47
36.76	45.6	62.14	92.36	82.26
28.31	68	55.58	83.75	102.9
22.16	62.56	68.5	86.31	115.5
28.27	52.19	75.67	77.41	95.47
31.14	40.95	57.76	79.08	90.53
31.24	36.02	57.57	88.38	118.4

	0.1 CPC	0.5 CPC	CPC	1.5 CPC	2 CPC
	33.86	36.37	67.74	81.89	100.1
	30.47	53.95	66.52	71.84	94.49
	27.18	60.5	63.86	72.96	92.82
	37.67	41.49	64.3	81.89	100.1
	34.75	37.15	62.35	83.75	102.9
	21.93	41.77	63.86	88.8	94.99
	35.17	45.93	78.74	89.96	94.49
	48.67	56.1	63.86	85.1	96.46
	43.91	45.49	79.08	82.26	110.6
	39.66	62.35	77.74	93.36	111.2
	39.06	51.61	71	79.08	102.9
	38.06	41.68	61.71	72.5	91.43
	33.46	55.92	60.5	79.86	114.8
	41.12	62.98	59.63	80.07	120
	28.68	66.27	53.79	75.35	123.6
	31.33	51.75	56.86	79.08	87.11
	40.4	59.05	57.94	72.68	87.96
	41.12	56.86	64.53	81.89	102.9
	39.15	51.32	67.48	88.38	98.6
Av.	33.85875	54.2705	67.5485	81.52875	103.5138

Table C2 Zeta potential values of MWCNTs at natural pH of SDBS solution

0.1 SDBS	0.5 SDBS	SDBS	1.5 SDBS	2 SDBS
-95.4	-122	-130	-110	-134
-89.6	-128	-93.7	-150	-116
-66.5	-137	-100	-135	-135
-49.9	-146	-110	-115	-138
-102	-138	-104	-112	-116
-108	-87.1	-127	-131	-162
-70.7	-132	-138	-128	-116
-80.8	-142	-131	-116	-117
-48.5	-95.9	-124	-127	-139
-72.1	-142	-132	-112	-166
-56.5	-113	-177	-142	-175
-75.6	-189	-149	-143	-160
-75	-126	-104	-117	-147
-102	-116	-93.3	-120	-123
-56.2	-120	-123	-132	-132
-93.3	-75.6	-119	-144	-140
-101	-100	-149	-122	-175
-65.7	-112	-152	-130	-155
-73.5	-112	-107	126	-132
-80.8	-91.8	-98	-143	-145
-84.7	-90.9	-134	-137	-194
-80.4	-90.1	-148	-115	-183
-87.9	-114	-92.8	-128	-193

	0.1 SDBS	0.5 SDBS	SDBS	1.5 SDBS	2 SDBS
	-107	-146	-136	-122	-166
	-82.6	-101	-122	-113	-176
	-116	-114	-122	-117	-135
	-138	-85.1	-90.1	-154	-151
	-114	-132	-96.9	-160	-134
	-89.6	-98.5	-125	-154	-137
	-104	-79.7	-131	-160	-175
	-74.7	-99	-119	-152	-172
	-69.2	-102	-126	-113	-142
	-65.3	-94.4	-110	-125	-153
	-62.1	-100	-102	-114	-134
	-104	-108	-137	-132	-194
	-75.9	-97.4	-94.4	-125	-179
	-78	-95.6	-120	-126	-118
	-93.3	-87.5	-116	-135	-126
	-62.7	-95.4	-96.5	-148	-121
	-115	-102	-142	-135	-194
Av.	-84.19	-111.45	-120.5	-124.2	-150

Table C3 Zeta potential values of MWCNTs at natural pH of $OP(EO)_{10}$ solution

0.1 $OP(EO)_{10}$	0.5 $OP(EO)_{10}$	$OP(EO)_{10}$	1.5 $OP(EO)_{10}$	2 $OP(EO)_{10}$
-47.6	-43.6	-51.6	-75.3	-86.7
-55.4	-57.5	-65.5	-82.2	-75.9
-63.6	-48.1	-74.7	-74.4	-98.1
-72.6	-46.6	-55.5	-65.5	-84.7
-30.4	-56.1	-54.5	-64.3	-102
-56.1	-54.2	-58.3	-66.2	-96.4
-41.8	-50	-57.7	-61.3	-101
-33.3	-63.8	-67.7	-79	-76.6
-43.8	-59.43	-63.2	-80.1	-74.7
-38.5	-41.5	-63.6	-67.7	-90.5
-35.3	-51.8	-52.4	-74.1	-99.5
-34.7	-42.4	-73.5	-73.8	-92.3
-44.7	-52.2	-58.6	-68.7	-91.4
-59	-48.1	-60.1	-59.2	-95.2
-42.7	-52.6	-59.8	-67.5	-105
-22.7	-51.4	-68.5	-70.7	-83.9
-19.2	-50.7	-70.1	-75.4	-102
-22.3	-39.8	-64	-74.4	-86.7
-27.2	-50.7	-65.2	-77.5	-94.6
-25.4	-41.3	-67.4	-79.4	-87.7
-23.2	-50.6	-83	-61.3	-89.6

	0.1 $OP(EO)_{10}$	0.5 $OP(EO)_{10}$	$OP(EO)_{10}$	1.5 $OP(EO)_{10}$	2 $OP(EO)_{10}$
	-24	-42.7	-58.8	-73.1	-77.7
	-18.8	-40.4	-54.9	-68.5	-96.9
	-42.7	-52.3	-50.3	-73.8	-75.3
	-30.5	-57.3	-68	-74.7	-90.1
	-30.9	-41.3	-72.1	-69.3	-106
	-25.8	-42.6	-69.9	-62.3	-99
	-35.1	-50	-56.2	-63.2	-81.8
	-38	-43	-55.8	-68.8	-81
	-40.3	-39	-49.9	-72.4	-80.7
	-40	-35.1	-59.2	-67.9	-87.5
	-57	-40.5	-58.63	-74	-92.1
	-53.1	-47.6	-49.7	-57.9	-104
	-34.8	-49.3	-55.7	-64	-84.7
	-45.4	-45.2	-67.4	-74.9	-83.3
	-38.2	-45.2	-66.5	-79.4	-87.5
	-32.6	-60.2	-63.6	-65.4	-108
	-42.6	-55.7	-62.5	-70.7	-95.6
	-33.4	-45.1	-75.3	-72.9	-85.6
	-30.7	-50.4	-65.4	-69.1	-96.7
Av.	-38.34	-48.38	-62.37	-70.51	-90.7

Appendix D Calibration Curve of Surfactant Solution

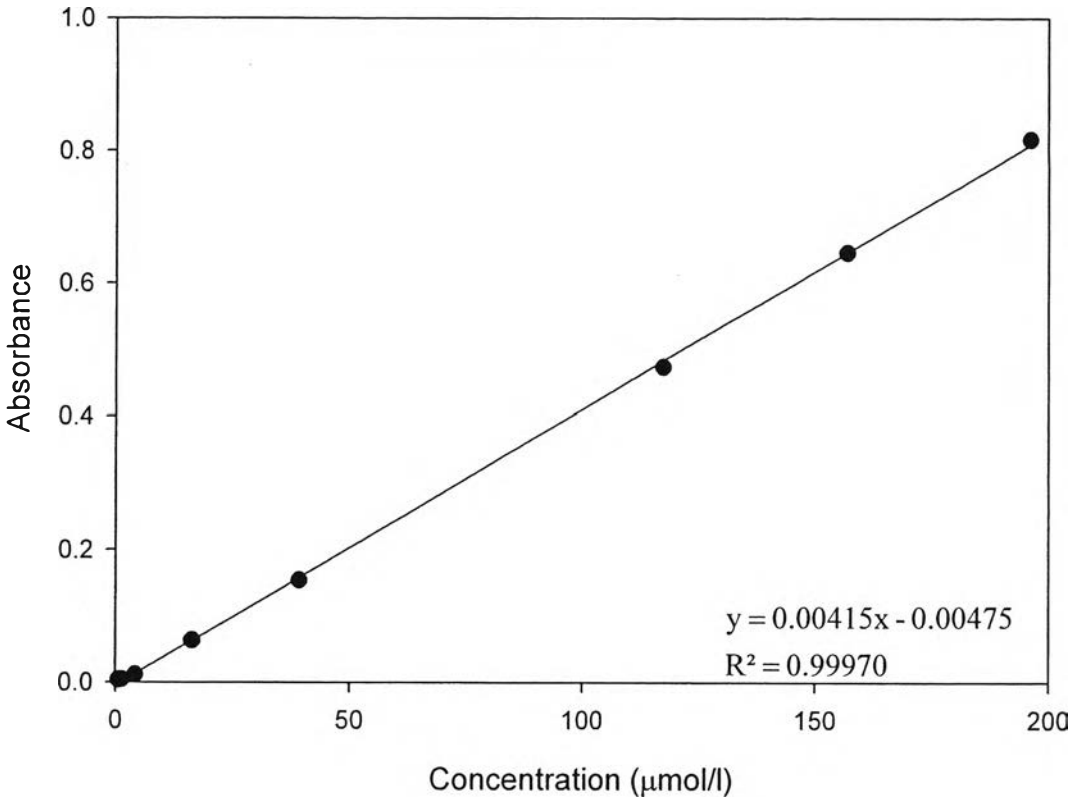

Figure D1 Calibration curve of CPC solution.

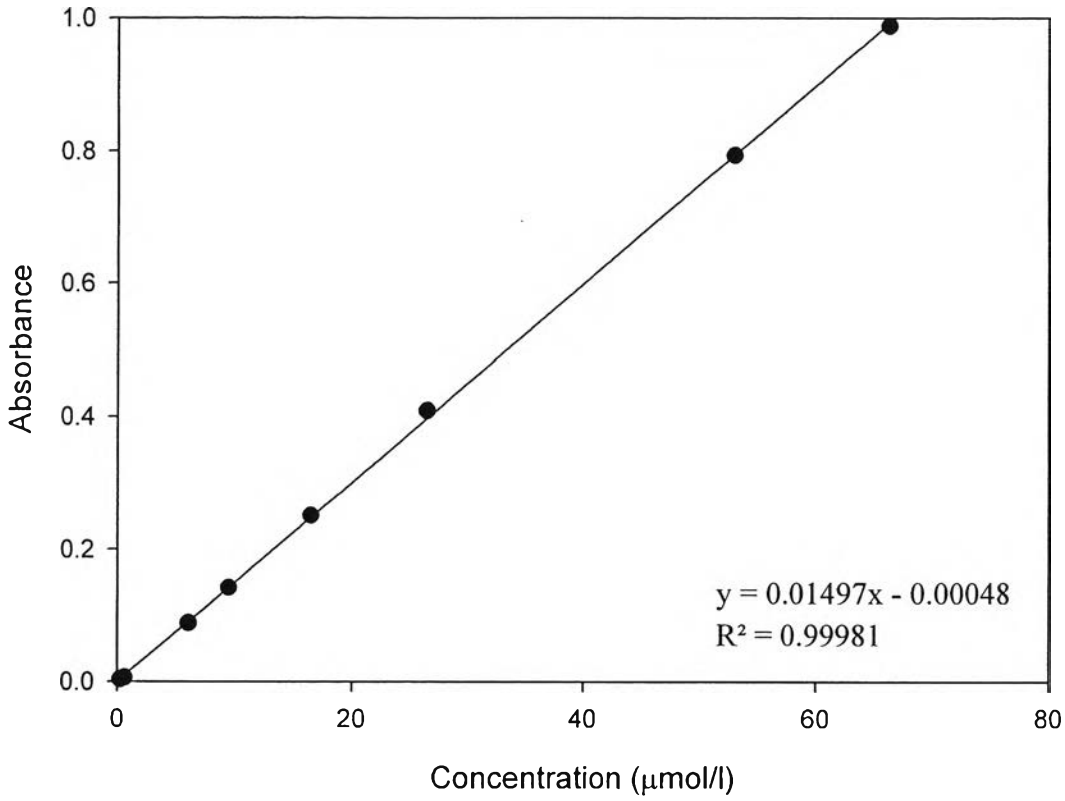

Figure D2 Calibration curve of SDBS solution.

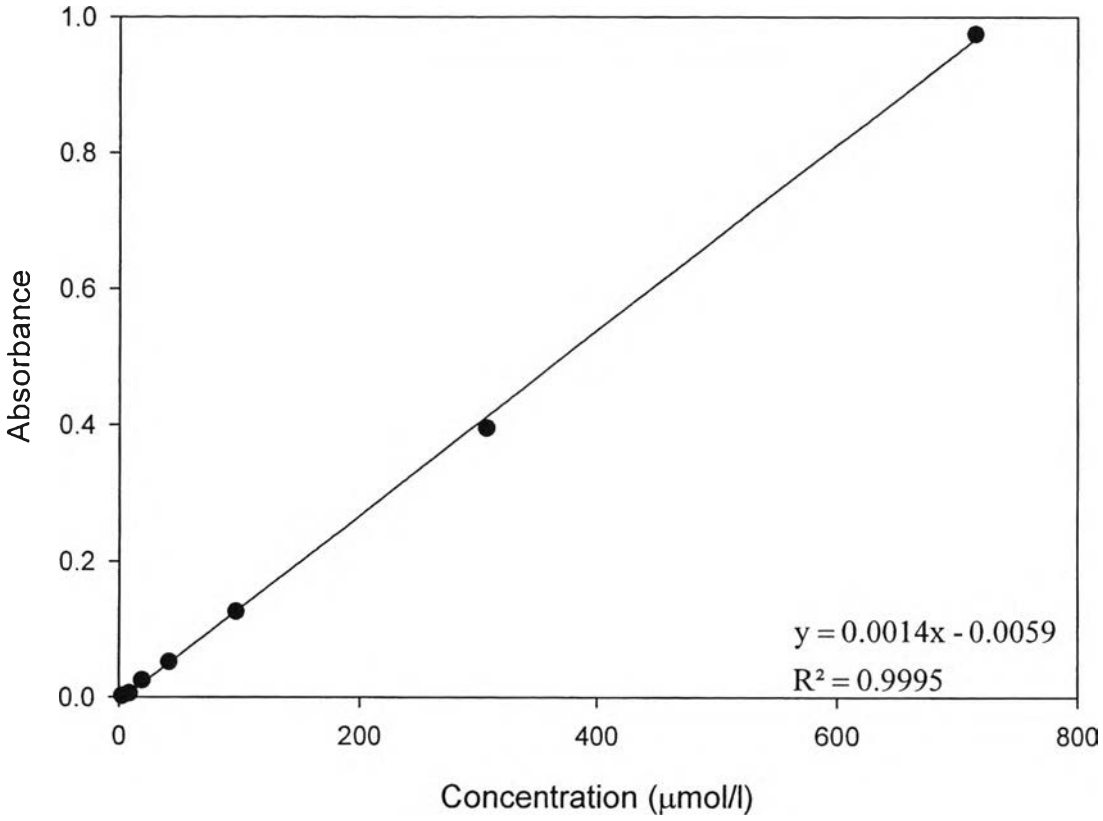

Figure D3 Calibration curve of $OP(EO)_{10}$ solution.

Appendix E Example of Calculation for Surfactant Adsorption Isotherms

Adsorption for solution of CPC on MWCNTs

$$\Gamma = \frac{(C_o - C_e) * V}{W * A_s}$$

Where

Γ= The amounts of adsorbed surfactant per specific area of adsorbent ($\mu mol/m^2$)

C_o = Initial surfactant solution concentration ($\mu mol/L$)

C_e = Equilibrium surfactant solution concentration ($\mu mol/L$)

V = The volume of a surfactant solution (mL)

W = The weight of carbonaceous adsorbents (mg)

A_s = The specific surface area of carbonaceous adsorbents (m^2/g).

The adsorption isotherm was a plot between adsorption of surfactant on MWCNTs ($\mu mol/m^2$) and concentration of surfactant solution ($\mu mol/L$).

C_o = 10,000 $\mu mol/L$

Equilibrium concentration of surfactant was converted from

UV-Vis spectrophotometer (wavelength) → $\mu mol/L$

The concentration of surfactant solution should be diluted about 51 times before using UV spectrophotometer in order to get the accurate absorbance.

Calibration equaition for CPC solution from UV-Vis spectrophotometer,

Y = 0.00415 X – 0.00475

Where X = $C_{e,}$ (μmol/L)

Y = Wavelength

Substituting into calibration equations,

X = (0.79584+0.00475)/0.00415

Diluted concentration X = 192.91325 μmol/L

Real concentration X = 192.91325 x 51 = 9838.58 μmol/L

Thus, surfactant adsorption for solution of CPC on MWCNTs at 10,000 μmol/L, initial concentration is

$$\Gamma = \frac{(10000 - 9838.57575\ )\ \mu mol/L * 20mL}{2.5\ mg * 273.4\ m^2/g} = 4.723\ \mu mol/m^2$$

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1. Mattavakul, W.; and Kitiyanan, B. (2012, April 24) Effect of Surfactant Adsorption on Multi-walled Carbon Nanotube Dispersion. Proceedings of the 3rd Research Symposium on Petrochemical and Materials Technology and the 18th PPC Symposium on Petroleum, Petrochemical, and Polymers, Bangkok, Thailand.