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APPENDICES

Appendix A Experiment Data of Equilibrium Solubility of Calcium Soap Scum

Table A1 Equilibrium solubility of soap scum in 0.1M DDAO at 25 °C and various solution pH

Solution pH	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)
4	1.75	700	17.5
5	0.96	384	9.6
6	0.45	180	4.5
7	0.32	128	3.2
8	0.25	100	2.5
9	0.18	72	1.8
10	0.14	56	1.4
11	0.13	52	1.3

Table A2 Equilibrium solubility of calcium soap scum in 0.1M DDAO with 0.1M Na₂EDTA at 25 °C and various solution pH

Solution pH	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)
4	1.13	452	11.3
5	1.31	524	13.1
6	1.69	676	16.9
7	1.83	732	18.3
8	1.86	744	18.6
9	1.87	748	18.7
10	1.93	772	19.3
11	2.05	820	20.5

Table A3 Equilibrium solubility of calcium soap scum in 0.1M DDAO with 0.0001M NaCl at 25 °C and various solution pH

Solution pH	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)
4	1.77	708	17.7
5	0.98	392	9.8
6	0.47	188	4.7
7	0.4	160	4.0
8	0.27	108	2.7
9	0.32	128	3.2
10	0.22	88	2.2
11	0.3	120	3.0

Table A4 Equilibrium solubility of calcium soap scum in 0.1M DDAO with 0.001M NaCl at 25 °C and various solution pH

Solution pH	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)
4	1.65	660	16.5
5	0.90	360	9.0
6	0.46	184	4.6
7	0.32	128	3.2
8	0.31	124	3.1
9	0.17	68	1.7
10	0.21	84	2.1
11	0.24	96	2.4

Table A5 Equilibrium solubility of calcium soap scum in 0.1M DDAO with 0.01M NaCl at 25 °C and various solution pH

Solution pH	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)
4	1.72	688	17.2
5	1.05	420	10.5
6	0.53	212	5.3
7	0.32	128	3.2
8	0.31	124	3.1
9	0.25	100	2.5
10	0.16	64	1.6
11	0.25	100	2.5

Table A6 Equilibrium solubility of calcium soap scum in 0.1M DDAO with 0.1M NaCl at 25 °C and various solution pH

Solution pH	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)
4	1.52	608	15.2
5	1.07	428	10.7
6	0.57	228	5.7
7	0.32	128	3.2
8	0.27	108	2.7
9	0.24	96	2.4
10	0.13	52	1.3
11	0.16	64	1.6

Table A6 Equilibrium solubility of calcium soap scum in 0.1M DDAO with 0.1M Na₂EDTA and 0.0001M NaCl at 25 °C and various solution pH

Solution pH	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)
4	1.21	484	12.1
5	1.19	476	11.9
6	1.22	488	12.2
7	1.14	456	11.4
8	1.20	480	12.0
9	1.24	496	12.4
10	1.18	472	11.8
11	1.25	500	12.5

Appendix B Experiment Data of Accumulative Dissolution of Calcium Soap Scum

Table B1 Accumulative dissolution of calcium soap scum in deionized water at pH 4 and 25 °C

time	$[\text{Ca}^{2+}]_{\text{dilute}}$ (ppm)	$[\text{Ca}^{2+}]$ (ppm)	$[\text{Ca}^{2+}]$ (mM)	Accumulative dissolution (mM)
0	0	0	0	0
5	0.72	3.60	0.0900	0.0900
10	0.60	3.00	0.0750	0.1650
15	0.45	2.25	0.0563	0.2213
20	0.40	2.00	0.0500	0.2713
25	0.32	1.60	0.0400	0.3113
30	0.25	1.25	0.0313	0.3425

Table B2 Accumulative dissolution of calcium soap scum in deionized water at pH 7 and 25 °C

time	$[\text{Ca}^{2+}]_{\text{dilute}}$ (ppm)	$[\text{Ca}^{2+}]$ (ppm)	$[\text{Ca}^{2+}]$ (mM)	Accumulative dissolution (mM)
0	0	0	0	0
5	0.55	2.75	0.0688	0.0688
10	0.28	1.40	0.0350	0.1038
15	0.21	1.05	0.0263	0.1300
20	0.20	1.00	0.0250	0.1550
25	0.21	1.05	0.0263	0.1813
30	0.16	0.80	0.0200	0.2013

Table B3 Accumulative dissolution of calcium soap scum in deionized water at pH 11 and 25 °C

time	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	Accumulative dissolution (mM)
0	0	0	0	0
5	0.37	1.85	0.0463	0.0463
10	0.19	0.95	0.0238	0.0700
15	0.20	1.00	0.0250	0.0950
20	0.17	0.85	0.0213	0.1163
25	0.21	1.05	0.0263	0.1425
30	0.29	1.45	0.0363	0.1788

Table B4 Accumulative dissolution of calcium soap scum in 0.1M DDAO at pH 4 and 25 °C

time	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	Accumulative dissolution (mM)
0	0	0	0	0
5	2.35	235.0	5.8750	5.8750
10	2.29	114.5	2.8625	8.7375
15	2.07	103.5	2.5875	11.3250
20	1.27	63.5	1.5875	12.9125
25	1.18	59.0	1.4750	14.3875
30	1.02	51.0	1.2750	15.6625

Table B5 Accumulative dissolution of calcium soap scum in 0.1M DDAO at pH 7 and 25 °C

time	$[\text{Ca}^{2+}]_{\text{dilute}}$ (ppm)	$[\text{Ca}^{2+}]$ (ppm)	$[\text{Ca}^{2+}]$ (mM)	Accumulative dissolution (mM)
0	0	0	0	0
5	1.32	66.0	1.6500	1.6500
10	0.96	48.0	1.2000	2.8500
15	0.87	43.5	1.0875	3.9375
20	0.75	37.5	0.9375	4.8750
25	0.73	36.5	0.9125	5.7875
30	0.72	36.0	0.9000	6.6875

Table B6 Accumulative dissolution of calcium soap scum in 0.1M DDAO at pH 11 and 25 °C

time	$[\text{Ca}^{2+}]_{\text{dilute}}$ (ppm)	$[\text{Ca}^{2+}]$ (ppm)	$[\text{Ca}^{2+}]$ (mM)	Accumulative dissolution (mM)
0	0	0	0	0
5	0.28	14.0	0.3500	0.3500
10	0.25	12.5	0.3125	0.6625
15	0.24	12.0	0.3000	0.9625
20	0.24	12.0	0.3000	1.2625
25	0.23	11.5	0.2875	1.5500
30	0.23	11.5	0.2875	1.8375

Table B7 Accumulative dissolution of calcium soap scum in 0.1M DDAO with 0.1M Na₂EDTA at pH 4 and 25 °C

time	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	Accumulative dissolution (mM)
0	0	0	0	0
5	2.35	235	5.875	5.875
10	1.53	153	3.825	9.700
15	1.26	126	3.150	12.850
20	1.07	107	2.675	15.525
25	0.69	69	1.725	17.250
30	0.68	68	1.700	18.950

Table B8 Accumulative dissolution of calcium soap scum in 0.1M DDAO with 0.1M Na₂EDTA at pH 7 and 25 °C

time	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	Accumulative dissolution (mM)
0	0	0	0	0
5	2.99	299	7.475	7.475
10	2.00	200	5.000	12.475
15	1.39	139	3.475	15.950
20	0.93	93	2.325	18.275
25	0.60	60	1.500	19.775
30	0.54	54	1.350	21.125

Table B9 Accumulative dissolution of calcium soap scum in 0.1M DDAO with 0.1M Na₂EDTA at pH 11 and 25 °C

time	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	Accumulative dissolution (mM)
0	0	0	0	0
5	1.29	516	12.900	12.900
10	1.89	189	4.725	17.625
15	0.77	77	1.925	19.550
20	0.53	53	1.325	20.875
25	0.49	49	1.225	22.100
30	0.48	48	1.200	23.300

Table B10 Accumulative dissolution of calcium soap scum in 0.1M DDAO with 0.0001M NaCl at pH 4 and 25 °C

time	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	Accumulative dissolution (mM)
0	0	0	0	0
5	0.24	96	2.4	2.4
10	0.35	140	3.5	5.9
15	0.26	104	2.6	8.5
20	0.20	80	2.0	10.5
25	0.23	92	2.3	12.8
30	0.21	84	2.1	14.9

Table B11 Accumulative dissolution of calcium soap scum in 0.1M DDAO with 0.0001M NaCl at pH 7 and 25 °C

time	$[\text{Ca}^{2+}]_{\text{dilute}}$ (ppm)	$[\text{Ca}^{2+}]$ (ppm)	$[\text{Ca}^{2+}]$ (mM)	Accumulative dissolution (mM)
0	0	0	0	0
5	0.24	96	2.4	2.4
10	0.17	68	1.7	4.1
15	0.19	76	1.9	6.0
20	0.22	88	2.2	8.2
25	0.14	56	1.4	9.6
30	0.16	64	1.6	11.2

Table B12 Accumulative dissolution of calcium soap scum in 0.1M DDAO with 0.0001M NaCl at pH 11 and 25 °C

time	$[\text{Ca}^{2+}]_{\text{dilute}}$ (ppm)	$[\text{Ca}^{2+}]$ (ppm)	$[\text{Ca}^{2+}]$ (mM)	Accumulative dissolution (mM)
0	0	0	0	0
5	0.24	96	2.4	2.4
10	0.13	52	1.3	3.7
15	0.18	72	1.8	5.5
20	0.12	48	1.2	6.7
25	0.15	60	1.5	8.2
30	0.19	76	1.9	10.1

Table B13 Accumulative dissolution of calcium soap scum in 0.1M DDAO with 0.001M NaCl at pH 4 and 25 °C

time	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	Accumulative dissolution (mM)
0	0	0	0	0
5	0.41	164	4.1	4.1
10	0.30	120	3.0	7.1
15	0.27	108	2.7	9.8
20	0.22	88	2.2	12.0
25	0.19	76	1.9	13.9
30	0.18	72	1.8	15.7

Table B14 Accumulative dissolution of calcium soap scum in 0.1M DDAO with 0.001M NaCl at pH 7 and 25 °C

time	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	Accumulative dissolution (mM)
0	0	0	0	0
5	0.23	92	2.3	2.3
10	0.20	80	2.0	4.3
15	0.23	92	2.3	6.6
20	0.21	84	2.1	8.7
25	0.21	84	2.1	10.8
30	0.17	68	1.7	12.5

Table B15 Accumulative dissolution of calcium soap scum in 0.1M DDAO with 0.001M NaCl at pH 11 and 25 °C

time	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	Accumulative dissolution (mM)
0	0	0	0	0
5	0.21	84	2.1	2.1
10	0.16	64	1.6	3.7
15	0.12	48	1.2	4.9
20	0.11	44	1.1	6.0
25	0.10	40	1.0	7.0
30	0.13	52	1.3	8.3

Table B16 Accumulative dissolution of calcium soap scum in 0.1M DDAO with 0.01M NaCl at pH 4 and 25 °C

time	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	Accumulative dissolution (mM)
0	0	0	0	0
5	0.63	252	6.3	6.3
10	0.31	124	3.1	9.4
15	0.25	100	2.5	11.9
20	0.23	92	2.3	14.2
25	0.19	76	1.9	16.1
30	0.23	92	2.3	18.4

Table B17 Accumulative dissolution of calcium soap scum in 0.1M DDAO with 0.01M NaCl at pH 7 and 25 °C

time	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	Accumulative dissolution (mM)
0	0	0	0	0
5	0.25	100	2.5	2.5
10	0.27	108	2.7	5.2
15	0.22	88	2.2	7.4
20	0.15	60	1.5	8.9
25	0.20	80	2.0	10.9
30	0.18	72	1.8	12.7

Table B18 Accumulative dissolution of calcium soap scum in 0.1M DDAO with 0.01M NaCl at pH 11 and 25 °C

time	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	Accumulative dissolution (mM)
0	0	0	0	0
5	0.23	92	2.3	2.3
10	0.17	68	1.7	4.0
15	0.16	64	1.6	5.6
20	0.15	60	1.5	7.1
25	0.17	68	1.7	8.8
30	0.13	52	1.3	10.1

Table B19 Accumulative dissolution of calcium soap scum in 0.1M DDAO with 0.1M NaCl at pH 4 and 25 °C

time	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	Accumulative dissolution (mM)
0	0	0	0	0
5	0.31	124	3.1	3.1
10	0.22	88	2.2	5.3
15	0.15	60	1.5	6.8
20	0.18	72	1.8	8.6
25	0.18	72	1.8	10.4
30	0.18	72	1.8	12.2

Table B20 Accumulative dissolution of calcium soap scum in 0.1M DDAO with 0.1M NaCl at pH 7 and 25 °C

time	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	Accumulative dissolution (mM)
0	0	0	0	0
5	0.14	56	1.4	1.4
10	0.24	96	2.4	3.8
15	0.15	60	1.5	5.3
20	0.12	48	1.2	6.5
25	0.19	76	1.9	8.4
30	0.14	56	1.4	9.8

Table B21 Accumulative dissolution of calcium soap scum in 0.1M DDAO with 0.1M NaCl at pH 11 and 25 °C

time	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	Accumulative dissolution (mM)
0	0	0	0	0
5	0.19	76	1.9	1.9
10	0.20	80	2.0	3.9
15	0.18	72	1.8	5.7
20	0.14	56	1.4	7.1
25	0.12	48	1.2	8.3
30	0.16	64	1.6	9.9

Table B22 Accumulative dissolution of calcium soap scum in 0.1M DDAO with 0.1M Na₂EDTA and 0.0001M NaCl at pH 4 and 25 °C

time	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	Accumulative dissolution (mM)
0	0	0	0	0
5	0.56	224	5.6	5.6
10	0.44	176	4.4	10.0
15	0.42	168	4.2	14.2
20	0.36	144	3.6	17.8
25	0.36	144	3.6	21.4
30	0.30	120	3.0	24.4

Table B23 Accumulative dissolution of calcium soap scum in 0.1M DDAO with 0.1M Na₂EDTA and 0.0001M NaCl at pH 7 and 25 °C

time	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	Accumulative dissolution (mM)
0	0	0	0	0
5	0.68	272	6.8	6.8
10	0.47	188	4.7	11.5
15	0.42	168	4.2	15.7
20	0.30	120	3.0	18.7
25	0.54	216	5.4	24.1
30	0.15	60	1.5	25.6

Table B24 Accumulative dissolution of calcium soap scum in 0.1M DDAO with 0.1M Na₂EDTA and 0.0001M NaCl at pH 11 and 25 °C

time	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	Accumulative dissolution (mM)
0	0	0	0	0
5	0.84	336	8.4	8.4
10	0.49	196	4.9	13.3
15	0.24	96	2.4	15.7
20	0.18	72	1.8	17.5
25	0.32	128	3.2	20.7
30	0.13	52	1.3	22.0

Appendix C Dissolution Rate of Calcium Soap Scum

Table C1 Initial rate constant of calcium soap scum

Solution	pH	Initial rate constant (min^{-1})
H ₂ O	4	0.00007
	7	0.00004
	11	0.00003
0.1M DDAO	4	0.00380
	7	0.00120
	11	0.00030
0.1M DDAO + 0.1M Na ₂ EDTA	4	0.00410
	7	0.00530
	11	0.00800
0.1M DDAO + 0.0001M NaCl	4	0.00230
	7	0.00170
	11	0.00160
0.1M DDAO + 0.001M NaCl	4	0.00300
	7	0.00180
	11	0.00150
0.1M DDAO + 0.01M NaCl	4	0.00410
	7	0.00210
	11	0.00170
0.1M DDAO + 0.1M NaCl	4	0.00220
	7	0.00140
	11	0.00160
0.1M DDAO + 0.1M Na ₂ EDTA + 0.0001M NaCl	4	0.00420
	7	0.00490
	11	0.00570

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1. Ratanaalert, D., Itsadanont, S., Chavadej, S., and Scamehorn, J.F. (2012, April 24). Effect of Solution pH and Salinity on Equilibrium Solubility and Dissolution Rate of Calcium Soap Scum in Amphoteric Surfactant Solutions with Na₂EDTA Chelant. Proceedings of the 3rd Research Symposium on Petrochemical and Materials Technology and 18th PPC Symposium on Petroleum, Petrochemical, and Polymers, Bangkok, Thailand.

