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APPENDICES

Appendix A Characteristic of Natural Hard Water

Table A1 Characteristics of natural hard water

Parameter	Unit	Value
Calcium	ppm	142
Magnesium	ppm	42
Sodium	ppm	8.6
Potassium	ppm	138.5
Iron	ppm	0.26
Aluminium	ppm	0.3
Zinc	ppm	0.001
Manganese	ppm	0.002
Strontium	ppm	0.65
Nitrate	ppm	2.1
Sulfate	ppm	26.3
Chloride	ppm	30
Conductivity	μs	579.9
Total hardness	ppm as CaCO_3	190
Total dissolved solid	ppm	433.9

Appendix B Experiment Data of Characteristic of Soap Scum

Table B1 Calcium soap scum in each mixed soap scums

Types of mixed soap scum	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	[Ca ²⁺] (M)
4:1 Ca/Mg-S	0.215	86	2.1458	0.002145
4:1 Ca/Mg-CS	0.455	98.2	2.4022	0.002450
NHW-S	0.951	380.5	9.4936	0.009493
NHW-CS	0.520	208.1	5.1931	0.005193

Table B2 Magnesium soap scum in each mixed soap scums

Types of mixed soap scum	[Mg ²⁺] _{dilute} (ppm)	[Mg ²⁺] (ppm)	[Mg ²⁺] (mM)	[Mg ²⁺] (M)
4:1 Ca/Mg-S	0.064	12.7	0.5225	0.000523
4:1 Ca/Mg-CS	0.063	12.6	0.5184	0.000518
NHW-S	0.412	380.5	3.3964	0.003396
NHW-CS	0.664	132.9	5.4835	0.005468

Table B3 Weight ratio and Molar ratio of calcium to magnesium soap sum in each mixed soap scums

Types of mixed soap scum	Weight ratio of Ca:Mg	Molar ratio of Ca:Mg
4:1 Ca/Mg-S	6.771653543	4.106618079
4:1 Ca/Mg-CS	7.793650794	4.726400582
NHW-S	4.609191073	2.795209068
NHW-CS	1.565966739	0.949668686

Appendix C Experiment Data of Equilibrium Solubility of Calcium and Magnesium Soap Scum

Table C1 Equilibrium of calcium soap scum synthesized from stearic acid and commercial soap with different sources of Ca and Mg in pure water at 25°C and solution pH 4

Types of soap scum	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	[Ca ²⁺] (M)
Ca-S	0.380	75.93	1.8946	0.001895
4:1 Ca/Mg-S	0.173	34.52	0.8613	0.000861
NHW-S	0.584	116.8	2.9143	0.002914
Ca-CS	0.274	54.8	1.3673	0.001367
4:1 Ca/Mg-CS	0.297	59.4	1.4821	0.001482
NHW-CS	0.216	43.2	1.0779	0.001078

Table C2 Equilibrium of calcium soap scum synthesized from stearic acid and commercial soap with different sources of Ca and Mg in 0.1 M DDAO with 0.1 M Na₂EDTA at 25°C and solution pH 11

Types of soap scum	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	[Ca ²⁺] (M)
Ca-S	2.513	502.6	12.5405	0.012541
4:1 Ca/Mg-S	0.542	108.4	2.7047	0.002705
NHW-S	1.601	320.2	7.9894	0.007989
Ca-CS	1.319	263.8	6.5822	0.006582
4:1 Ca/Mg-CS	1.811	362.2	9.0374	0.009037
NHW-CS	1.593	318.6	7.9495	0.007949

Table C3 Equilibrium of calcium soap scum synthesized from stearic acid and commercial soap with different sources of Ca and Mg in 0.1 M DDAO with 0.1 M Na₄GLDA at 25°C and solution pH 11

Types of soap scum	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	[Ca ²⁺] (M)
Ca-S	1.833	366.6	9.147163	0.009147
4:1 Ca/Mg-S	0.446	89.2	2.225660	0.002226
NHW-S	1.341	268.2	6.691951	0.006692
Ca-CS	1.966	393.2	9.810869	0.009811
4:1 Ca/Mg-CS	1.940	388	9.681122	0.009681
NHW-CS	1.548	309.6	7.724936	0.007725

Table C4 Equilibrium of magnesium soap scum synthesized from stearic acid and commercial soap with different sources of Ca and Mg in pure water at 25°C and solution pH 4

Types of soap scum	[Mg ²⁺] _{dilute} (ppm)	[Mg ²⁺] (ppm)	[Mg ²⁺] (mM)	[Mg ²⁺] (M)
Mg-S	0.142	28.35	1.1664	0.001166
4:1 Ca/Mg-S	0.122	24.4	1.0039	0.001004
NHW-S	0.298	59.6	2.4522	0.002452
Mg-CS	0.098	19.6	0.8064	0.000806
4:1 Ca/Mg-CS	0.087	17.4	0.7159	0.000716
NHW-CS	0.130	26	1.0697	0.001070

Table C5 Equilibrium of magnesium soap scum synthesized from stearic acid and commercial soap with different sources of Ca and Mg in 0.1 M DDAO with 0.1 M Na₂EDTA at 25°C and solution pH 11

Types of soap scum	[Mg ²⁺] _{dilute} (ppm)	[Mg ²⁺] (ppm)	[Mg ²⁺] (mM)	[Mg ²⁺] (M)
Mg-S	0.202	40.4	1.6622	0.001662
4:1 Ca/Mg-S	0.182	36.4	1.4976	0.001498
NHW-S	0.281	56.2	2.3123	0.002312
Mg-CS	0.641	128.2	5.2746	0.005275
4:1 Ca/Mg-CS	0.235	47	1.9338	0.001934
NHW-CS	0.124	24.8	1.0204	0.001020

Table C6 Equilibrium of magnesium soap scum synthesized from stearic acid and commercial soap with different sources of Ca and Mg in 0.1 M DDAO with 0.1 M Na₄GLDA at 25°C and solution pH 11

Types of soap scum	[Mg ²⁺] _{dilute} (ppm)	[Mg ²⁺] (ppm)	[Mg ²⁺] (mM)	[Mg ²⁺] (M)
Mg-S	0.235	47	1.9338	0.001934
4:1 Ca/Mg-S	0.107	21.4	0.8805	0.000880
NHW-S	0.109	21.8	0.8969	0.000897
Mg-CS	0.617	123.4	5.0771	0.005077
4:1 Ca/Mg-CS	0.049	9.8	0.4032	0.000403
NHW-CS	0.088	17.6	0.7241	0.000724

Appendix D Experiment Data of Dissolution Rate of Mixed Soap Scum

Table D1 Dissolution rate of calcium stearate synthesized from natural hard water in 0.1 DDAO mixed with 0.1 Na₂EDTA at pH 11 and a constant temperature of 25 °C.

Time	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	% dissolved
0	0	0	0	0
5	0.285	57	1.42	19.58
10	0.505	101	2.52	54.28
15	0.335	67	1.67	77.30
20	0.17	34	0.85	88.98
25	0.065	13	0.32	93.45
30	0.02	4	0.1	94.82

Table D2 Dissolution rate of magnesium stearate synthesized from natural hard water in 0.1 DDAO mixed with 0.1 Na₂EDTA at pH 11 and a constant temperature of 25 °C.

Time	[Mg ²⁺] _{dilute} (ppm)	[Mg ²⁺] (ppm)	[Mg ²⁺] (mM)	% dissolved
0	0	0	0	0
5	0.039	7.9	0.32	12.42
10	0.070	14.1	0.58	34.61
15	0.05	10	0.41	50.34
20	0.04	8	0.33	62.92
25	0.035	7	0.29	73.94
30	0.025	5	0.20	81.80

Table D3 Dissolution rate of calcium stearate synthesized from natural hard water in 0.1 DDAO mixed with 0.1 Na₄GLTA at pH 11 and a constant temperature of 25 °C.

Time	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	% dissolved
0	0	0	0	0
5	0.21	42	1.05	14.43
10	0.45	90	2.25	45.35
15	0.35	70	1.75	69.40
20	0.16	32	0.8	80.39
25	0.1	20	0.5	87.26
30	0.1	20	0.5	94.14

Table D4 Dissolution rate of magnesium stearate synthesized from natural hard water in 0.1 DDAO mixed with 0.1 Na₄GLTA at pH 11 and a constant temperature of 25 °C.

Time	[Mg ²⁺] _{dilute} (ppm)	[Mg ²⁺] (ppm)	[Mg ²⁺] (mM)	% dissolved
0	0	0	0	0
5	0.015	6	0.25	9.275303394
10	0.0325	13	0.541666667	29.37179408
15	0.04	16	0.666666667	54.10593647
20	0.015	6	0.25	63.38123986
25	0.01	4	0.166666667	69.56477546
30	0.01	4	0.166666667	75.74831105

Table D5 Dissolution rate of calcium mixed commercial soap scum synthesized from natural hard water in 0.1 DDAO mixed with 0.1 Na₂EDTA at pH 11 and a constant temperature of 25 °C.

Time	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	% dissolved
0	0	0	0	0
5	0.35	70	1.75	34.57
10	0.3	60	1.5	64.21
15	0.25	50	1.25	88.91
20	0.05	10	0.25	93.85
25	0.02	4	0.1	95.83
30	0.01	2	0.05	96.82

Table D6 Dissolution rate of magnesium mixed commercial soap scum synthesized from natural hard water in 0.1 DDAO mixed with 0.1 Na₂EDTA at pH 11 and a constant temperature of 25 °C.

Time	[Mg ²⁺] _{dilute} (ppm)	[Mg ²⁺] (ppm)	[Mg ²⁺] (mM)	% dissolved
0	0	0	0	0
5	0.07	14	0.58	11.21
10	0.13	26	1.08	32.04
15	0.1	20	0.83	48.06
20	0.05	10	0.41	56.08
25	0.06	12	0.5	65.69
30	0.015	3	0.12	68.09

Table D7 Dissolution rate of calcium mixed commercial soap scum synthesized from natural hard water in 0.1 DDAO mixed with 0.1 Na₄GLTA at pH 11 and a constant temperature of 25 °C.

Time	[Ca ²⁺] _{dilute} (ppm)	[Ca ²⁺] (ppm)	[Ca ²⁺] (mM)	% dissolved
0	0	0	0	0
5	0.25	50	1.25	24.69
10	0.35	70	1.75	59.27
15	0.1	20	0.5	69.15
20	0.1	20	0.5	79.03
25	0.02	4	0.1	81.01
30	0.01	2	0.05	82.00

Table D8 Dissolution rate of magnesium mixed commercial soap synthesized from natural hard water in 0.1 DDAO mixed with 0.1 Na₄GLTA at pH 11 and a constant temperature of 25 °C.

Time	[Mg ²⁺] _{dilute} (ppm)	[Mg ²⁺] (ppm)	[Mg ²⁺] (mM)	% dissolved
0	0	0	0	0
5	0.05	10	0.41	8.01
10	0.125	25	1.04	28.04
15	0.047	9.4	0.39	35.57
20	0.039	7.8	0.32	41.82
25	0.09	18	0.75	56.24
30	0.029	5.8	0.24	60.88

Table D9 Initial rate constant of mixed soap scum

Solution	Initial rate constant (min ⁻¹) of NHW-S		Initial rate constant (min ⁻¹) of NHW-CS	
	Calcium	Magnesium	Calcium	Magnesium
0.1 M DDAO + 0.1 M Na ₂ EDTA	0.071	0.039	0.099	0.035
0.1 M DDAO + 0.1 M Na ₄ GLDA	0.054	0.031	0.083	0.029

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