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APPENDICES

Appendix A Experimental Data of Microemulsion Formation.

1. Interfacial Tension (IFT)

The interfacial tension of each phase of microemulsion is interpreted by the following formulation:

$$IFT = e(Vd)^3 n^2 \Delta\rho \qquad (A1)$$

where

σ = interfacial tension or IFT (mN/m, dyne/cm)

e = unity factor ($3.427*10^{-7}$ mN cm^3 min^2 /m g mm^3)

V = enlargement factor (0.31 mm/sdv)

d = measured drop diameter (sdv)

n = number of revolution (1/min)

$\Delta\rho$ = density difference of two liquids (g/cm^3)

2. Experimental Data of Interfacial Tension (IFT)

Table A1 Interfacial tension of each phase in microemulsion formation with 0.05 wt% of Alfoterra at different NaCl concentrations and an initial oil to water ratio = 1:1

Alfoterra conc. (wt%)	NaCl conc. (wt%)	No.	Upper density (g/mL)	Lower density (g/mL)	Upper level	Lower level	Speed (rpm)	IFT (mN/m)
0.05	2	1	0.8160	0.9880	4.5900	2.6700	3834	3.87970
		2	0.8130	0.9870	4.6400	2.5500	3744	4.77201
		3			4.6900	2.5700	3665	4.77250
		ave	0.8145	0.9875	4.6400	2.5967		4.47474
	3	1	0.8/13	0.9990	4.5200	2.5700	3910	4.07400
		2	0.8090	0.9940	4.4700	2.6000	3878	3.53430
		3			4.5600	2.5800	3500	3.41739
		ave	0.8090	0.9965	4.5167	2.5833		3.80415
	4	1	0.8080	1.0060	4.5400	2.9900	3708	1.85098
		2	0.8040	1.0020	4.5500	2.8000	3566	2.46379
		3			4.4300	2.8500	3939	2.21243
		ave	0.8060	1.0040	4.5450	2.8800		2.17573
	5	1	0.8090	1.0020	4.7100	2.6100	2855	2.87050
			0.8140		4.7500	2.6300	2923	3.09566
					4.7200	2.7100	2906	2.60776
		ave	0.8115	1.0020	4.7267	2.6500		2.85797
	6	1	0.8180	1.0170	4.5300	2.9100	4116	2.56307
		2	0.8140	1.0120	4.4700	2.8900	4282	2.57353
		3			4.4000	2.9900	5100	2.59456
		ave	0.8160	1.0145	4.5000	2.9300		2.57705

Table A2 Interfacial tension of each phase in microemulsion formation with 0.1 wt% of Alfoterra at different NaCl concentrations and an initial oil to water ratio= 1:1

Alfoterra conc. (wt%)	NaCl conc. (wt%)	No.	Upper density (g/mL)	Lower density (g/mL)	Upper level	Lower level	Speed (rpm)	IFT (mN/m)
0.1	2	1	0.8000	0.9900	5.0400	2.2000	2223	0.2126
		2	0.8040	0.9820	4.9300	2.3200	2398	0.1921
		3			4.8700	2.4300	2724	0.2025
		ave	0.8020	0.9860	4.9467	2.3167		0.2024
	3	1	0.8320	1.0130	4.9000	2.2400	2085	0.1495
		2	0.8200	0.9970	4.8900	2.2600	2351	0.1837
		3			4.8300	2.2300	2367	0.1800
		ave	0.8260	1.0050	4.8733	2.2433		0.1666
	4	1	0.8110	1.0160	4.7000	2.5100	1784	0.0684
		2	0.8140	1.0100	4.6300	2.4800	2173	0.0961
		3			4.6100	2.5100	1988	0.0749
		ave	0.8125	1.0130	4.6650	2.5000		0.0798
	5	1	0.8030	1.0170	4.4600	2.6800	1710	0.0358
		2	0.8010	1.0120	4.3200	2.7800	1852	0.0272
		3			4.3100	2.7000	1752	0.0278
		ave	0.8020	1.0145	4.3633	2.7200		0.0302
	6	1	0.8000	1.0080	4.6800	2.9800	3742	0.1440
		2	0.8080	1.0100	4.6200	2.8100	3406	0.1440
		3			4.5000	2.9400	3841	0.1172
		ave	0.8040	1.0090	4.6500	2.9100		0.1351

Table A3 Interfacial tension of each phase in microemulsion formation with 0.1 wt% at different NaCl concentrations and an initial oil to water ratio = 1:1

Alfoterra conc. (wt%)	NaCl conc. (wt%)	No.	Upper density (g/mL)	Lower densi ty (g/mL)	Upper level	Lower level	Speed (rpm)	IFT (mN/m)
0.15	2	1	0.8020	0.9840	4.8300	2.5900	3643	0.2711
		2	0.8100	0.9840	4.6900	2.6800	4208	0.2613
		3			4.7900	2.6500	3454	0.2125
		ave	0.8060	0.9840	4.7700	2.6400		0.2483
	3	1	0.8110	0.9930	5.0600	2.3500	2181	0.1803
		2	0.8080	0.9990	5.0600	2.3500	2181	0.1803
		3			4.9000	2.5200	3371	0.2917
		ave	0.8095	0.9960	5.0067	2.4067		0.2174
	4	1	0.8010	0.9970	4.6600	2.8100	3650	0.1688
		2	0.8020	0.9980	4.6900	2.7900	4093	0.2299
		3			4.6000	2.8200	3641	0.1496
		ave	0.8015	0.9975	4.6500	2.8067		0.1828
	5	1	0.8070	1.0040	4.5700	2.8800	2024	0.0400
		2	0.7990	0.9980	4.6100	2.8200	2609	0.0789
		3			4.5900	2.8700	2134	0.0468
		ave	0.8030	1.0010	4.5900	2.8567		0.0594
	6	1	0.7870	1.0020	4.5800	2.7800	2580	0.0836
		2	0.7970	1.0040	4.3900	2.9100	2819	0.0555
		3			4.3600	2.8900	2856	0.0558
		ave	0.7920	1.0030	4.4433	2.8600		0.0696

Table A4 Interfacial tension of each phase in microemulsion formation with 0.5 wt% at different NaCl concentrations and initial oil to water ratio = 1:1

Alfoterra conc. (wt%)	NaCl conc. (wt%)	No.	Upper density (g/mL)	Lower densi ty (g/mL)	Upper level	Lower level	Speed (rpm)	IFT (mN/m)
0.5	2	1	0.8160	0.9940	4.9100	2.3200	1787	0.0994
		2	0.8150	0.9880	4.9300	2.3100	1831	0.1080
		3			4.8000	2.4200	2182	0.1150
		ave	0.8155	0.9910	4.8800	2.3500		0.1075
	3	1	0.8060	0.9890	4.7100	2.6400	1704	0.0490
		2	0.8080	0.9980	4.6700	2.6900	1770	0.0463
		3			4.7000	2.6300	1703	
		ave	0.8070	0.9935	4.6933	2.6533		0.0477
	4	1	0.8240	1.0030	4.3400	3.0000	2811	0.0348
		2	0.8220	1.0020	4.3100	3.1000	3078	0.0308
		3			4.3200	3.0000	2944	0.0365
		ave	0.8230	1.0025	4.3233	3.0333		0.0340
	5	1	0.8230	1.0160	4.7500	2.6800	1911	0.0643
		2	0.8240	1.0200	4.6600	2.7200	2502	0.0908
		3			4.6500	2.8200	2478	0.0747
		ave	0.8235	1.0180	4.6867	2.7400		0.0775
	6	1	0.8260	1.0170				0.0000
		2	0.8110	1.0220	4.8100	2.5600	1857	0.0806
		3			4.8000	2.5900	1906	0.0805
		ave	0.8185	1.0195	4.8100	2.5750		0.0805

Appendix B Experimental Data of Colloidal Gas Aphron Studies.

1. CGA stability

The CGA stability was defined as the time that was required for the half volume of the initial liquid to drain

2. Gas hold up

The gas hold up was defined as the ratio of gas volume to the dispersion volume which was calculated by the following equations:

$$\text{Gas hold up} = \frac{V_g}{V_i} = \frac{V_i - V_l}{V_i} \qquad \text{(B1)}$$

where V_g = Gas volume

V_l = Initial liquid volume

V_i = Dispersion volume

3. Separation ratio

The separation ratio was defined as the ratio of oil concentration in aphron phase to the liquid phase which was calculated by the following equations:

$$\text{Separation ratio} = \frac{C_a}{C_l} \qquad \text{(B2)}$$

where C_a = concentration of oil in the aphron phase

C_l = concentration of oil in the liquid phase

4. Enrichment Ratio

The enrichment was defined as the ratio of oil concentration in aphron phase to the initial solution which was calculated by the following equations:

$$\text{Enrichment ratio} = \frac{C_a}{C_i} \quad \text{(B3)}$$

where C_a = concentration of oil in the aphron phase

C_i = concentration of oil in the initial solution

5. Oil removal

The oil removal was calculated by the following equations:

$$\text{Oil removal (\%)} = \frac{C_i - C_l}{C_i} \quad \text{(B4)}$$

where C_l = concentration of oil in the liquid phase

C_i = concentration of oil in the initial solution

6. **Effective parameter in colloidal gas aphron studies**

6.1 Effect of stirring speed

Table B-1 Summary results for the effect of stirring speed in colloidal gas aphron studies at the system containing Alfoterra concentration = 0.1 wt%, NaCl concentration = 3 wt%, oil to water ratio = 1:19 at stirring time = 5 minute

System	Stirring speed (rpm)	CGA stability (sec)	Gas hold up	Separation ratio	Enrichment ratio	Oil removal (%)
1:19 Alf 0.1 N 3	4000	4.00	0.576	7.39	7.38	88.59
	5000	6.00	0.648	11.14	8.16	92.14
	6000	8.12	0.657	10.82	7.64	91.91
	7000	9.00	0.663	9.48	6.40	90.93
	8000	9.47	0.663	7.32	7.40	88.57

6.2 Effect of stirring time

Table B-2 Summary results for the effect of stirring time in colloidal gas aphron studies at the system containing Alfoterra concentration = 0.1 wt%, NaCl concentration = 3 wt%, oil to water ratio = 1:19 at stirring speed = 5000 rpm

System	Stirring time (min)	CGA stability (sec)	Gas hold up	Separation ratio	Enrichment ratio	Oil removal (%)
1:19 Alf 0.1 N 3	2	5.21	0.642	4.77	11.17	83.54
	5	6.00	0.648	11.14	8.16	92.14
	10	10.30	0.689	7.52	6.77	88.91
	15	17.04	0.694	5.38	6.69	84.98

6.3 Effect of surfactant concentration

Table B-3 Summary results for the effect of surfactant concentration in colloidal gas aphron studies at the system containing NaCl concentration = 3 wt%, oil to water ratio = 1:19 at stirring speed = 5000 rpm, stirring time = 5 minute

System	Surfactant conc. (wt%)	CGA stability (sec)	Gas hold up	Separation ratio	Enrichment ratio	Oil removal (%)
1:19 Alf 0.1 N 3	0.05	6.00	0.635	8.40	10.16	89.62
	0.1	6.00	0.648	11.14	8.16	92.14
	0.15	8.15	0.670	5.47	7.41	85.06
	0.5	16.27	0.703	4.83	9.43	83.25

6.4 Effect of NaCl concentration

Table B-4 Summary results for the effect of NaCl concentration in colloidal gas aphron studies at the system containing Alfoterra concentration = 0.1 wt%, oil to water ratio = 1:19 at stirring speed = 5000 rpm, stirring time = 5 minute

System	NaCl conc. (wt%)	CGA stability (sec)	Gas hold up	Separation ratio	Enrichment ratio	Oil removal (%)
1:19 Alf 0.1 N 3	2	10.25	0.689	11.27	5.57	91.57
	3	6.00	0.648	11.35	8.16	92.15
	4	4.46	0.635	6.99	10.3	87.51
	5	3.15	0.630	6.15	11.57	85.86
	6	2.48	0.612	4.88	12.85	82.67

Appendix C Experimental Data of Froth Flotation Experiment.

1. **Dynamic oil removal**

The oil removal was calculated by the following formulation:

$$\text{Oil removal (\%)} = \frac{(C_i - C_t)}{C_i} * 100 \qquad \text{(C1)}$$

where C_t = concentration of oil in a solution at time t

C_i = concentration of oil in a solution at time zero

2. **Surfactant removal**

The surfactant removal was calculated by the following formulation:

$$\text{Surfactant removal (\%)} = \frac{(C_{s,i} - C_{s,t})}{C_{s,i}} * 100 \qquad \text{(C2)}$$

where $C_{s,t}$ = concentration of surfactant in a solution at time t

$C_{s,i}$ = concentration of surfactant in a solution at time zero

3. **Enrichment Ratio**

The enrichment ratio was calculated by the following formulation:

$$\text{Enrichment ratio} = \frac{C_f}{C_i} \qquad \text{(C3)}$$

where C_f = concentration of oil in the collapsed foam solution

C_i = concentration of oil in the feed solution

4. Effective Parameter on froth flotation performance

4.1 Effect of air flow rate

Table C-1 Summary results for the effect of air flow rate on froth flotation performance at the system containing Alfoterra concentration = 0.1 wt%, NaCl concentration = 3 wt% at oil to water ratio = 1:19

System	Air flow rate (l/min)	Oil removal (%)	Surfactant Removal (%)	Enrichment ratio	Foam flow rate (ml/min)	Foam wetness (g/ml)
1:19 Alf 0.1 N3	0.20	92.80	74.26	7.84	0.5	1.01
	0.25	91.52	70.54	7.11	0.52	1.02
	0.30	95.14	79.64	5.59	0.56	1.05
	0.35	91.50	79.41	4.92	0.55	1.00

4.2 Effect of colloidal gas aphron

Table C-2 Summary results for the effect of colloidal gas aphron on froth flotation performance at the system containing Alfoterra concentration = 0.1 wt%, NaCl concentration = 3 wt%, stirring speed = 5000 rpm, stirring time = 5 minute at oil to water ratio = 1:19

System	Air flow rate (l/min)	Oil removal (%)	Surfactant Removal (%)	Enrichment ratio	Foam flow rate (ml/min)	Foam wetness (g/ml)
1:19 Alf 0.1 N3	0.20	96.29	86.69	7.36	0.6	1.01
Speed 5000	0.25	96.11	86.91	6.46	0.75	1.06
Time 5	0.30	97.07	86.37	5.53	0.84	1.10
	0.35	95.51	83.41	4.58	0.76	1.06

4.3 Effect of equilibration time

Table C-3 Summary results for the effect of equilibration time on froth flotation performance at the system containing Alfoterra concentration = 0.1 wt%, NaCl concentration = 3 wt%, oil to water ratio = 1:19 at equilibration time of 1 month

System	Air flow rate (l/min)	Oil removal (%)	Surfactant Removal (%)	Enrichment ratio	Foam flow rate (ml/min)	Foam wetness (g/ml)
1:19 Alf 0.1 N3 Equilibrated	0.20	83.06	49.08	7.59	0.35	0.95
	0.25	83.08	52.59	5.26	0.35	0.98
	0.30	85.77	53.31	5.12	0.48	0.99
	0.35	83.63	57.07	4.61	0.41	0.96

Appendix D Experimental Data of Foam Ability and Foam Stability Experiment.

1. Foam ability

The foam ability was defined as the ratio of maximum foam height to initial solution height

$$\text{Foam ability} = \frac{H_{max}}{H_i} \qquad (D1)$$

where $H_{max.}$ = Maximum foam height

H_i = Initial solution height

2. Foam Stability ($t_{1/2}$)

The foam stability was defined as the time that was required for the foam volume to collapse by half.

3. Effective parameter on foam ability and foam stability

3.1 Effect of air flow rate

Table D-1 Summary results for the effect of air flow rate on foam ability and foam stability at the system containing Alfoterra concentration = 0.1 wt%, NaCl concentration = 3 wt% at oil to water ratio = 1:19

System	Air flow rate (l/min)	Foam ability	Foam stability (min)
1:19 Alf 0.1 N3	0.20	9.09	2.17
	0.25	13.91	2.31
	0.30	20.27	3.25
	0.35	12.73	2.00

3.2 Effect of colloidal gas aphron

Table D-2 Summary results for the effect of colloidal gas aphron on foam ability and foam stability at the system containing Alfoterra concentration = 0.1 wt%, NaCl concentration = 3 wt% stirring speed = 5000 rpm, stirring time = 5 minute at oil to water ratio = 1:19

System	Air flow rate (l/min)	Foam ability	Foam stability (min)
1:19 Alf 0.1 N3	0.20	12.27	4.57
Speed 5000	0.25	17.45	4.20
Time 5	0.30	20.27	5.58
	0.35	20.27	5.04

3.3 Effect of equilibration time

Table D-3 Summary results for the effect of equilibration time on foam ability and foam stability at the system containing Alfoterra concentration = 0.1 wt%, NaCl = 3 wt%, oil to water ratio = 1:19 at equilibration time of 1 month

System	Air flow rate (l/min)	Foam ability	Foam stability (min)
1:19 Alf 0.1 N3 Equilibrated	0.20	1.18	0.51
	0.25	1.64	0.57
	0.30	2.45	1.05
	0.35	2.27	0.35

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