

Supporting Information

Aqueous Biphasic Systems Composed of a Water Stable Ionic Liquid + Carbohydrates and their Applications

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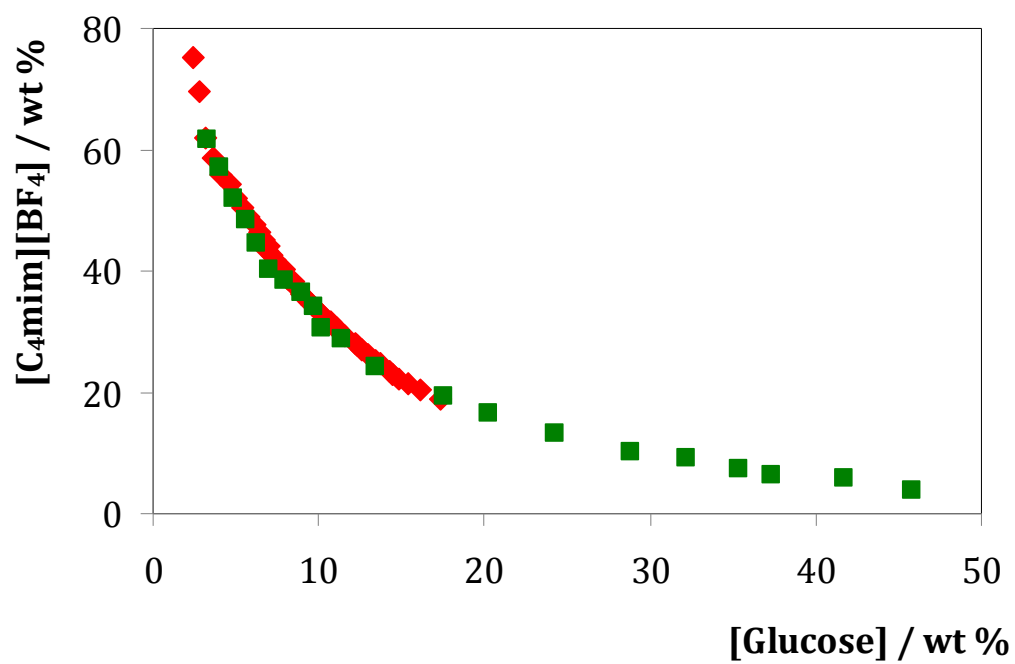


Fig. S1 Phase diagram for [C₄mim][BF₄] + D-glucose + water system at 298 K : (□) literature data³⁰; (♦) this work.

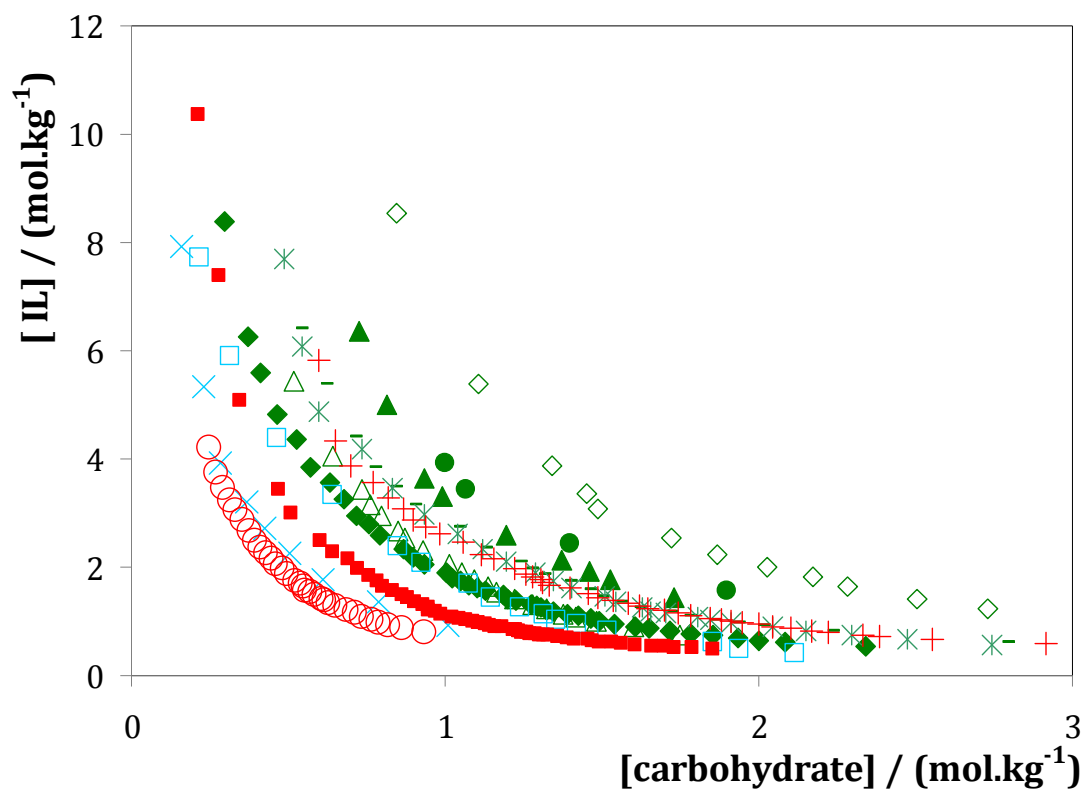


Fig. S2 Phase diagrams for the ternary systems composed by $[C_4mim][CF_3SO_3]$ + carbohydrate + H_2O at 298 K: (\blacklozenge) D-(+)-glucose; (\triangle) D-(+)-galactose; ($*$) D-(-)-fructose; (-) D-(+)-mannose; (\blacktriangle) D-(-)-arabinose; (\bullet) L-(+)-arabinose; (\diamond) D-(+)-xylose; (\times) D-(+)-maltose; (\square) sucrose; (\circ) D-maltitol; (\blacksquare) D-sorbitol; (+) xylitol.

Monosacharides: green; Dissacharides: blue; Polyols: red.

Table S1 Experimental binodal curve mass fraction data for the system [C₄mim][BF₄]
(1) + D-glucose (2) + H₂O (3) at 298 K

[C ₄ mim][BF ₄] + D-glucose					
100 w ₁	100 w ₂	100 w ₁	100 w ₂	100 w ₁	100 w ₂
75.2490	2.3881	42.6559	7.2106	29.3483	11.5547
69.5549	2.7588	41.7287	7.3923	28.1486	12.2326
61.9341	3.1640	40.1697	7.9731	27.6645	12.3563
58.6109	3.6582	38.8417	8.1598	26.9900	12.6071
55.7919	4.1364	38.1173	8.4512	26.1826	12.9443
54.3738	4.6568	37.0907	8.6863	25.2259	13.4309
51.8934	4.9979	36.2404	8.9089	24.6248	13.7502
50.3331	5.4134	34.9962	9.3866	23.4952	14.2296
48.7944	5.8286	34.2781	9.5627	22.9090	14.4825
47.5904	6.1589	33.1269	10.0651	22.2102	14.8670
46.4157	6.4488	32.5508	10.3047	21.3839	15.3856
45.1486	6.7504	31.5326	10.7079	20.2697	16.1556
43.9957	6.9891	30.6353	11.1175	18.7835	17.3431
43.3360	6.9321	30.0518	11.2224		

Table S2 Experimental binodal curve mass fraction data for the system
[C₄mim][CF₃SO₃] (1) + D-glucose/D-(+)-mannose (2) + H₂O (3) at 298 K

D-glucose		D-(+)-mannose			
100 w ₁	100 w ₂	100 w ₁	100 w ₂	100 w ₁	100 w ₂
70.7134	5.0360	28.3764	18.0857	64.8760	8.6316
64.3492	6.2705	27.5034	18.6608	60.8706	9.8346
61.7235	6.9267	27.0186	18.8968	56.0231	11.1787
58.1970	7.7439	26.4837	19.0622	52.5818	12.0626
55.7481	8.6443	25.9630	19.2585	50.0435	12.9785
52.6220	9.3564	25.3938	19.5034	47.7135	13.8156
50.6149	10.2228	24.5757	20.0296	44.1636	15.6639
48.4233	10.8946	23.9266	20.4443	40.5916	16.7527
45.9950	11.4381	23.1254	20.8964	37.6191	18.0734
44.5421	11.9688	22.3935	21.1928	36.2642	18.5303
42.6894	12.4911	21.4186	21.7287	35.0096	19.0113
40.2582	13.5371	20.7408	22.4421	33.5765	19.9550
38.6869	13.9254	20.0030	22.9040	31.4894	20.6602
37.2662	14.3704	19.1299	23.6147	29.8256	21.1205
35.3999	15.3018	18.3079	24.3028	28.1054	21.8247
34.2066	15.5314	17.4040	25.0572	26.6704	22.4546
33.3388	15.8956	16.6407	25.8189	25.4045	23.5145
32.5622	16.2527	15.7532	26.4985	24.0254	24.1517
31.7911	16.5735	15.0095	27.2795	22.9965	24.9679
31.0485	16.9157	13.3303	29.6538	22.0136	25.7172
30.0063	17.6089			21.1057	26.4960
28.9851	17.7711			18.9369	28.5630

Table S3 Experimental binodal curve mass fraction data for the system
 [C₄mim][CF₃SO₃] (1) + D-(-)-fructose/D-(+)-galactose/D-(+)-xylose (2) + H₂O (3) at
 298 K

D-(-)-fructose		D-(+)-galactose		D-(+)-xylose	
100 <i>w</i> ₁	100 <i>w</i> ₁	100 <i>w</i> ₁	100 <i>w</i> ₂	100 <i>w</i> ₁	100 <i>w</i> ₂
68.9467	8.0801	61.0577	8.5350	71.1398	11.2673
63.6435	8.9467	53.9164	10.3804	60.7959	14.2226
58.3851	9.7308	49.8546	11.6739	52.7070	16.7697
54.5921	11.6780	47.6505	12.0803	49.1522	17.9019
49.8797	13.0415	45.8982	12.5601	47.0747	18.2635
46.1916	14.4036	43.4384	13.3009	42.3666	20.5517
43.0229	15.7833	42.1389	13.5979	39.2347	21.9157
40.2790	16.7873	39.8369	14.3225	36.4560	23.3348
37.6280	17.7031	37.2042	15.4268	34.2809	24.5801
35.4204	18.8136	35.3321	15.9414	32.0368	25.5128
33.5158	19.4949	33.6419	16.4526	28.8826	27.3117
31.7617	20.1944	32.0630	16.9974	26.1274	29.0555
29.8094	21.3719	30.7531	17.3317	23.0186	31.3867
28.2085	21.7662	29.0297	18.0390		
26.5023	22.6867	27.4236	18.7043		
25.4550	22.9797	26.0478	19.2676		
24.8501	23.5064	24.7474	19.8680		
23.7681	24.5648	23.6037	20.3399		
22.8142	24.9480	22.2887	21.0732		
21.7663	25.6070	20.3385	22.3792		
20.4033	26.9138	17.6472	23.9326		
18.9587	27.9261				
17.4808	29.2785				
16.0741	30.8295				
14.2251	33.0768				
11.9355	36.5251				

Table S4 Experimental binodal curve mass fraction data for the system
[C₄mim][CF₃SO₃] (1) + D-(-)-arabinose/L-(+)-arabinose (2) + H₂O (3) at 298 K

D-(-)-arabinose		L-(+)-arabinose	
100 w ₁	100 w ₂	100 w ₁	100 w ₂
64.7475	9.8217	53.0112	13.0506
58.9833	10.8809	49.7286	13.7781
51.1611	12.3168	41.3169	17.3279
48.7887	12.9662	31.1939	22.1602
42.6944	15.2084		
38.0847	17.0765		
35.6884	17.9848		
33.7642	18.6584		
29.3007	20.6024		

Table S5 Experimental binodal curve mass fraction data for the system
[C₄mim][CF₃SO₃] (1) + D-(+)-maltose/sucrose (2) + H₂O (3) at 298 K

D-(+)-maltose		Sucrose	
100 w ₁	100 w ₂	100 w ₁	100 w ₂
69.5833	5.4159	69.0111	6.9727
60.5713	7.6414	62.9178	9.6922
53.1283	9.2487	55.8468	13.7444
47.9283	11.6266	49.0755	18.0295
43.8680	13.2972	40.6110	22.5122
39.3385	15.3948	37.3817	24.0722
33.9215	18.0742	32.6833	26.8783
28.0830	22.0657	29.2788	28.1849
21.0720	26.6296	26.7533	29.7459
		24.4932	30.9950
		22.8698	31.6668
		21.2735	32.6877
		19.2559	34.1996
		14.9677	38.7963
		12.4765	39.8776
		10.6171	41.9749

Table S6 Experimental binodal curve mass fraction data for the system
[C₄mim][CF₃SO₃] (1) + D-sorbitol (2) + H₂O (3) at 298 K

D-sorbitol					
100 w_1	100 w_2	100 w_1	100 w_2	100 w_1	100 w_2
74.9096	3.7490	23.6560	15.7227	18.7622	18.4855
68.0337	4.7991	23.1053	15.9685	18.5298	18.6713
59.4219	5.9384	22.6068	16.2423	18.3222	18.7914
49.7353	7.8828	22.2587	16.5272	18.0880	19.0002
46.3405	8.4806	21.7839	16.7670	17.8703	19.1659
41.8341	9.8748	21.4098	17.0359	17.6702	19.3176
39.7041	10.4579	25.8859	14.6851	17.4579	19.4900
38.2130	11.1464	25.1886	14.9844	17.0771	19.8455
36.2173	11.6004	24.4093	15.2615	16.6846	20.1980
34.7903	12.0948	23.6560	15.7227	16.3265	20.4439
33.2935	12.4954	23.1053	15.9685	16.0123	20.9377
32.0710	12.7241	22.6068	16.2423	15.6536	21.1152
31.0922	13.1690	22.2587	16.5272	15.3313	21.3402
30.1590	13.5795	21.7839	16.7670	14.9462	21.8136
29.1104	13.8461	21.4098	17.0359	14.5243	22.1686
28.0745	14.1190	21.0254	17.1890	14.0973	22.6234
27.2552	14.4588	20.7149	17.4249	13.6865	23.2004
26.4981	14.7233	20.4010	17.7108	13.3420	23.6259
25.8859	14.6851	19.8448	18.1507	12.9988	23.9657
25.1886	14.9844	19.4900	18.2379	12.6596	24.5508
24.4093	15.2615	19.1269	18.3398	12.2026	25.2312

Table S7 Experimental binodal curve mass fraction data for the system
[C₄mim][CF₃SO₃] (1) + xylitol (2) + H₂O (3) at 298 K

xylitol			
100 w ₁	100 w ₂	100 w ₁	100 w ₂
62.6714	8.3585	29.4471	18.4590
55.5502	9.0249	28.6101	18.9560
52.7933	9.6272	27.8868	19.4053
50.7670	10.4605	27.0447	19.7795
48.5804	11.0805	25.7138	20.5290
47.0210	11.6472	25.0842	20.9759
45.3914	12.0493	24.3019	21.3390
44.1771	12.5082	23.3643	21.9166
42.8884	13.0232	22.9169	22.2519
41.4088	13.8610	22.3911	22.5256
39.1433	14.4843	21.8361	22.8375
38.1662	14.9427	21.2886	23.3252
36.2432	15.6894	20.7119	23.7061
35.1609	16.0345	19.9608	24.2377
34.3984	16.2903	19.2521	24.8227
33.7361	16.5732	18.5856	25.2703
33.2149	16.6177	17.7810	26.1869
32.6062	16.8379	17.2505	26.6424
31.6116	17.5384	16.1613	27.9642
30.5188	18.1252	14.4099	30.7247

Table S8 Experimental binodal curve mass fraction data for the system
[C₄mim][CF₃SO₃] (1) + D-maltitol (2) + H₂O (3) at 298 K

D-maltitol			
100 w ₁	100 w ₂	100 w ₁	100 w ₂
54.8079	7.8548	31.0797	16.0088
51.9000	8.4511	30.6071	16.4065
49.9130	9.1633	30.0629	16.7562
48.2806	9.7058	29.0169	17.2683
46.8608	10.2044	28.4283	17.5061
45.2655	10.9138	27.8844	17.7498
43.4272	11.5069	27.1153	18.3293
41.6827	11.9421	25.9676	19.0724
40.5688	12.4437	24.8538	19.7420
39.4314	12.9004	23.7822	20.2202
38.4387	13.2785	22.7888	20.8741
37.2271	13.7001	21.9097	21.3121
36.2492	14.2311	21.0976	21.9887
35.0775	14.5263	19.9741	22.9473
33.5786	15.2078	18.5042	24.3256
32.7302	15.6428	17.5070	25.4455
32.0381	15.8854		

Table S9 Density of each aqueous rich phase at a ternary composition of 40 wt % of [C₄mim][CF₃SO₃] and 25 wt % of each carbohydrate (CH) in the temperature range between (298.15 and 318.15) K

T / K	sucrose ($\rho / \text{g}\cdot\text{cm}^{-3}$)		D-(+)-glucose ($\rho / \text{g}\cdot\text{cm}^{-3}$)		D-(-)-fructose ($\rho / \text{g}\cdot\text{cm}^{-3}$)		D-(+)-mannose ($\rho / \text{g}\cdot\text{cm}^{-3}$)		D-(+)-xylose ($\rho / \text{g}\cdot\text{cm}^{-3}$)		D-maltitol ($\rho / \text{g}\cdot\text{cm}^{-3}$)		D-sorbitol ($\rho / \text{g}\cdot\text{cm}^{-3}$)		xylitol ($\rho / \text{g}\cdot\text{cm}^{-3}$)	
	IL-rich phase	CH- rich phase	IL-rich phase	CH- rich phase	IL-rich phase	CH- rich phase	IL-rich phase	CH- rich phase	IL-rich phase	CH- rich phase	IL-rich phase	CH- rich phase	IL-rich phase	CH- rich phase	IL-rich phase	CH- rich phase
298.15	1.2234	1.2247	1.2363	1.2172	1.2335	1.2204	1.2348	1.1824	1.2333	1.2045	1.2261	1.2202	1.2333	1.1929	1.2348	1.1824
303.15	1.2204	1.2207	1.2323	1.2144	1.2294	1.2171	1.2306	1.1794	1.2291	1.2014	1.2220	1.2175	1.2291	1.1899	1.2306	1.1794
308.15	1.2175	1.2167	1.2282	1.2117	1.2254	1.2137	1.2265	1.1763	1.2251	1.1984	1.2180	1.2147	1.2251	1.1870	1.2265	1.1763
313.15	1.2146	1.2126	1.2242	1.2089	1.2214	1.2102	1.2224	1.1732	1.2209	1.1953	1.2140	1.2118	1.2209	1.1840	1.2224	1.1732
318.15	1.2115	1.2086	1.2201	1.2059	1.2173	1.2067	1.2182	1.1700	1.2168	1.1921	1.2099	1.2087	1.2168	1.1809	1.2182	1.1700

Table S10 Viscosity of each aqueous rich phase at a ternary composition of 40 wt % of [C₄mim][CF₃SO₃] and 25 wt % of each carbohydrate (CH) in the temperature range between (298.15 and 318.15) K

T / K	sucrose		D-(+)-glucose		D-(-)-fructose		D-(+)-mannose		D-(+)-xylose		D-maltitol		xylitol		D-sorbitol	
	$(\eta / \text{mPa}\cdot\text{s})$		$(\eta / \text{mPa}\cdot\text{s})$		$(\eta / \text{mPa}\cdot\text{s})$		$(\eta / \text{mPa}\cdot\text{s})$		$(\eta / \text{mPa}\cdot\text{s})$		$(\eta / \text{mPa}\cdot\text{s})$		$(\eta / \text{mPa}\cdot\text{s})$		$(\eta / \text{mPa}\cdot\text{s})$	
	IL-rich phase	CH-rich phase	IL-rich phase	CH-rich phase	IL-rich phase	CH-rich phase	IL-rich phase	CH-rich phase	IL-rich phase	CH-rich phase	IL-rich phase	CH-rich phase	IL-rich phase	CH-rich phase	IL-rich phase	CH-rich phase
298.15	8.3799	13.763	9.8116	9.0652	11.094	8.8939	9.7071	6.9634	9.1772	7.6858	8.5738	12.975	9.1772	8.2700	9.7071	6.9634
303.15	7.0285	11.186	8.2138	7.4783	9.1491	7.2665	8.0830	5.7907	7.7225	6.2694	7.2426	10.548	7.7225	6.8210	8.0830	5.7907
308.15	5.9913	9.1988	6.9806	6.2632	7.5672	5.9832	6.8891	4.8867	6.6157	5.2898	6.1953	8.7241	6.6157	5.7064	6.8891	4.8867
313.15	5.1862	7.6107	6.0107	5.314	6.2654	5.0344	5.9525	4.1773	5.7345	4.5219	5.3507	7.3058	5.7345	4.8368	5.9525	4.1773
318.15	4.5327	6.3207	5.2334	4.5414	5.2341	4.3142	5.1887	3.6099	5.0057	3.915	4.6529	6.1943	5.0057	4.1483	5.1887	3.6099

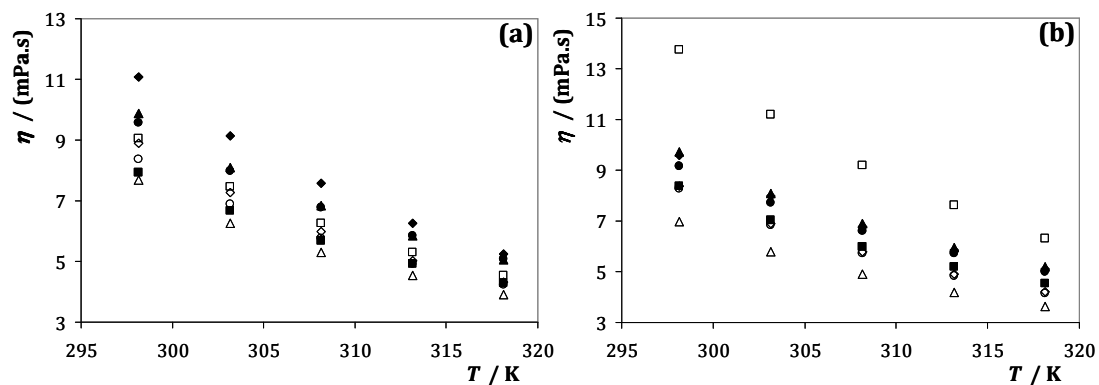


Fig. S3 Experimental viscosity (η) as a function of temperature for the IL-rich phase (full symbols) and carbohydrate-rich phase (empty symbols). **(a)**: (\square) D-(+)-glucose; (\diamond) D-(-)-fructose; (\circ) D-(+)-mannose; (\triangle) D-(+)-xylose; **(b)**: (\square) sucrose; (\diamond) D-maltitol; (\circ) D-sorbitol; (\triangle) xylitol.

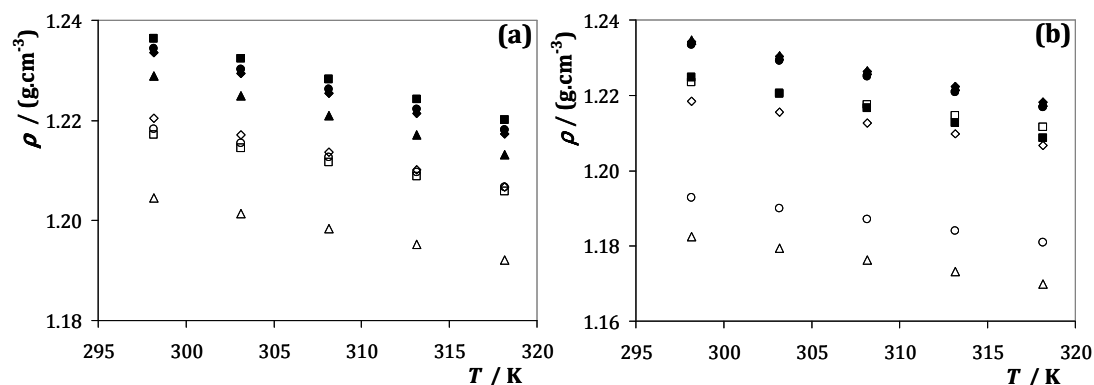


Fig. S4 Experimental density (ρ) as a function of temperature for the IL-rich phase (full symbols) and carbohydrate-rich phase (empty symbols). **(a)**: (\square) D-(+)-glucose; (\diamond) D-(-)-fructose; (\circ) D-(+)-mannose; (\triangle) D-(+)-xylose; **(b)**: (\square) sucrose; (\diamond) D-maltitol; (\circ) D-sorbitol; (\triangle) xylitol.

Table S11 Partition coefficients of L-tryptophan, caffeine and β -carotene (and respective standard deviations, σ) and mass fraction compositions of the ternary mixture at 298 K

Carbohydrate	Mass fraction composition / wt %		$K \pm \sigma$
	IL	CH	
L-tryptophan			
sucrose	39.93	25.04	1.13 ± 0.02
D-(+)-glucose	40.11	24.94	1.06 ± 0.04
D-(-)-fructose	39.98	24.97	1.08 ± 0.02
D-(+)-mannose	39.84	24.91	1.08 ± 0.04
D-(+)-xylose	40.08	24.93	1.19 ± 0.04
D-maltitol	40.00	24.99	1.06 ± 0.01
xylitol	39.82	24.89	1.06 ± 0.05
D-sorbitol	39.98	24.97	1.13 ± 0.06
caffeine			
sucrose	39.95	24.97	2.19 ± 0.06
D-(+)-glucose	40.01	25.02	2.57 ± 0.01
D-(-)-fructose	40.03	24.97	2.68 ± 0.09
D-(+)-mannose	40.01	24.93	2.15 ± 0.03
D-(+)-xylose	39.87	24.89	1.50 ± 0.07
D-maltitol	39.95	25.02	2.89 ± 0.09
xylitol	40.06	24.96	2.80 ± 0.02
D-sorbitol	39.97	25.01	3.37 ± 0.01
β -carotene			
sucrose	40.09	25.06	12.5 ± 0.6
D-(+)-glucose	40.05	24.89	10.0 ± 0.8
D-(-)-fructose	39.87	24.95	9.3 ± 0.4
D-(+)-mannose	39.97	24.87	7.9 ± 0.5
D-(+)-xylose	39.62	24.71	5.5 ± 0.2
D-maltitol	39.99	25.02	24.0 ± 0.4
xylitol	39.95	25.02	20.0 ± 0.7
D-sorbitol	40.01	24.97	20.5 ± 0.9



Fig. S5 Macroscopic evidence for the preferential partitioning of β -carotene for the bottom $[\text{C}_4\text{mim}][\text{CF}_3\text{SO}_3]$ -rich phase (40 wt % of $[\text{C}_4\text{mim}][\text{CF}_3\text{SO}_3]$ + 25 wt % of D-maltitol + 35 wt % of water).