

Composition of BmimFeCl₄

The elemental analyses are listed in Table S1. Wang⁴ proved that BmimFeCl₄ shows strong Brønsted acid characteristics. However, there are free chloride ions in the iron-based ionic liquid. Therefore, we believe that a certain amount of hydrogen chloride combines with BmimFeCl₄ to form an iron-based ionic liquid by hydrogen bonding. The chemical formula of iron-based ionic liquid can be assigned as [BmimFeCl₄][HCl]_{0.5}. FTIR of Fe-IL shows that C-H stretching vibration peak on [Bmim]⁺ appears at 3150-3000 cm⁻¹, C-H symmetric and antisymmetric stretching vibration peak on alkyl chain appears at 2960-2850 cm⁻¹, C=N stretching vibration peak on imidazole ring appears at 1590 cm⁻¹, and C=C stretching vibration peak appears at 1165 cm⁻¹. (Fig. S1) Referring to the previous work², Raman spectrum showed that [FeCl₄]⁻ peak appears only at 333 cm⁻¹ in Fe-IL, and ESI-MS also showed that Fe³⁺ exists only in the form of [FeCl₄]⁻, while cations exist in the form of [Bmim]⁺ in Fe-IL. In addition, iron-based ionic liquid shows significant hydrophobicity, and water content cannot be detected by the trace water analyser.

Table S1 Elemental contents of [Bmim][FeCl₄][HCl]_{0.5}

element	Fe(cal.)/%	C(cal.)/%	N(cal.)/%	H(cal.)/%
[BmimFeCl ₄][HCl] _{0.5}	14.4(15.7)	26.2(27.0)	8.6(7.9)	4.3(4.2)
relative error	0.08	0.03	0.09	0.02

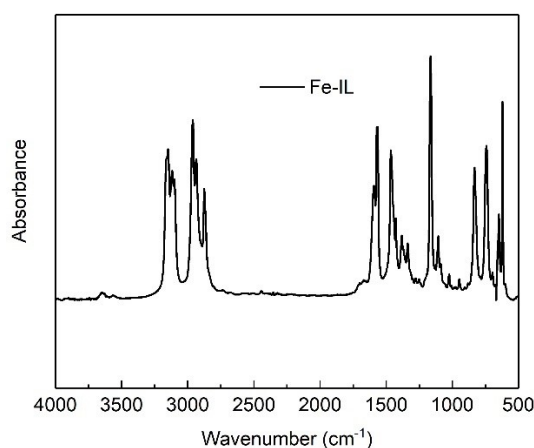


Fig. S1 FTIR of BmimFeCl₄

Table S2 The densities of BmimFeCl₄/DMAC and BmimFeCl₄/NHD

x	T(K)						
	293.2	298.2	303.2	308.2	313.2	318.2	323.2
Density (g·cm ⁻³) for BmimFeCl ₄ /DMAC							
1.0000	1.37564	1.37142	1.36719	1.36299	1.35891	1.35464	1.35037
0.7940	1.33842	1.33429	1.33003	1.32579	1.32172	1.31737	1.31317
0.5983	1.28866	1.28453	1.28025	1.27603	1.27198	1.26757	1.26342
0.4007	1.22132	1.21723	1.21289	1.20869	1.20465	1.20018	1.19605
0.2000	1.11636	1.11243	1.10791	1.10374	1.09969	1.09506	1.09095
0.0000	0.93930	0.93601	0.93082	0.92672	0.92266	0.91737	0.91386
Density (g·cm ⁻³) for BmimFeCl ₄ /NHD							
1.0000	1.37564	1.37142	1.36719	1.36299	1.35891	1.35464	1.35037
0.7946	1.30515	1.30078	1.29629	1.29192	1.28768	1.28331	1.27894
0.5917	1.24052	1.23636	1.23389	1.22973	1.22557	1.21974	1.21558
0.3928	1.17532	1.17113	1.16694	1.16273	1.15854	1.15436	1.15017
0.1790	1.10753	1.10321	1.09889	1.09456	1.09024	1.08593	1.08161
0.0000	1.03293	1.02837	1.02381	1.01927	1.0147	1.01014	1.00558

x is the mole fraction of BmimFeCl₄ in composites.

Table S3 The density fitting parameters of BmimFeCl₄/DMAC and BmimFeCl₄/NHD

x	A	B × 10 ⁻⁴	R ²	x	A	B × 10 ⁻⁴	R ²
BmimFeCl ₄ /DMAC				BmimFeCl ₄ /NHD			
1.0000	1.622	-8.403	1	1.0000	1.621	-8.403	0.999
0.7940	1.585	-8.421	1	0.7946	1.560	-8.727	0.999
0.5983	1.536	-8.422	0.999	0.5917	1.484	-8.312	0.989
0.4007	1.469	-8.439	0.999	0.3928	1.421	-8.385	1
0.2000	1.366	-8.513	0.999	0.1790	1.360	-8.640	1
0.0000	1.195	-8.697	0.997	0.0000	1.300	-9.115	1

x is the mole fraction of BmimFeCl₄ in composites.

Table S4 Fitted parameters of RK equation and standard deviation (σ) for two binary systems of BmimFeCl₄/DMAC and BmimFeCl₄/NHD

T(K)	293.2	298.2	303.2	308.2	313.2	318.2	323.2
BmimFeCl ₄ +DMAC							
V ^E (cm ³ /mol)							
A ₀	-1.49	-1.58	-1.80	-1.87	-1.94	-2.15	-2.21
A ₁	0.43	0.44	0.65	0.71	0.78	1.02	1.10
A ₂	0.08	0.08	0.10	0.05	0.10	0.09	0.02
σ	0.07	0.07	0.09	0.10	0.11	0.14	0.15
$\Delta\eta$ (mPa·s)							
A ₀	-19.42	-15.37	-11.67	-8.09	-5.73	-4.09	-2.93
A ₁	2.29	1.88	1.82	1.73	2.06	1.41	1.03
A ₂	-3.07	-1.37	-1.27	-3.19	-2.55	-2.44	-2.47
σ	0.07	0.04	0.02	0.02	0.01	0.01	0.02
BmimFeCl ₄ +NHD							
V ^E (cm ³ /mol)							
A ₀	-10.55	-11.03	-11.55	-12.05	-12.49	-12.93	-13.38
A ₁	13.33	13.45	13.56	13.76	13.97	14.14	14.38
A ₂	-17.13	-17.23	-17.20	-17.01	-17.25	-17.58	-17.77
σ	0.17	0.18	0.19	0.20	0.20	0.20	0.21
$\Delta\eta$ (mPa·s)							
A ₀	27.35	23.69	18.60	14.47	12.51	9.88	8.08
A ₁	2.38	5.98	6.01	5.04	5.23	4.99	3.86
A ₂	-32.62	-30.93	-24.13	-18.40	-15.51	-11.90	-10.11
σ	0.50	0.50	0.42	0.33	0.27	0.19	0.20

Table S5 The excess molar volume of BmimFeCl₄/DMAC composites

T(K)	x					
	1.0000	0.7940	0.5983	0.4007	0.2000	0.0000
293.2	0.000	-0.280	-0.345	-0.396	-0.353	0.000
298.2	0.000	-0.296	-0.367	-0.419	-0.371	0.000
303.2	0.000	-0.321	-0.408	-0.484	-0.435	0.000
308.2	0.000	-0.323	-0.427	-0.500	-0.451	0.000
313.2	0.000	-0.334	-0.438	-0.526	-0.473	0.000
318.2	0.000	-0.354	-0.479	-0.587	-0.538	0.000
323.2	0.000	-0.360	-0.495	-0.602	-0.565	0.000

x is the mole fraction of BmimFeCl₄ in composites.

Table S6 The excess molar volume of BmimFeCl₄/NHD composites

T(K)	x					
	1.0000	0.7946	0.5917	0.3928	0.1790	0.0000
293.2	0.000	-1.282	-2.358	-3.127	-3.977	0.000
298.2	0.000	-1.348	-2.483	-3.235	-4.071	0.000
303.2	0.000	-1.411	-2.624	-3.345	-4.167	0.000
308.2	0.000	-1.452	-2.757	-3.452	-4.259	0.000
313.2	0.000	-1.515	-2.859	-3.567	-4.360	0.000
318.2	0.000	-1.589	-2.963	-3.683	-4.462	0.000
323.2	0.000	-1.647	-3.065	-3.800	-4.564	0.000

x is the mole fraction of BmimFeCl₄ in composites.

Table S7 The viscosities of BmimFeCl₄/DMAC and BmimFeCl₄/NHD composites

ω	T(K)						
	293.2	298.2	303.2	308.2	313.2	318.2	323.2
Viscosity (mPa·s) for BmimFeCl ₄ /DMAC							
1.0	30.82	26.01	21.89	18.52	16.58	14.50	12.70
0.9002	18.21	15.43	13.40	11.70	10.22	8.93	7.71
0.6993	8.67	7.54	6.45	5.79	5.25	4.72	4.22
0.5012	3.73	3.47	3.22	2.98	2.77	2.56	2.37
0.3002	2.13	1.95	1.87	1.76	1.67	1.57	1.49
0.0996	1.47	1.39	1.32	1.26	1.2	1.18	1.16
0.0000	1.16	1.11	1.08	1.07	1.06	1.03	1.02
Viscosity (mPa·s) for BmimFeCl ₄ /NHD							
0.9021	29.32	25.10	21.11	17.80	16.02	13.95	12.20
0.7008	27.19	23.48	19.72	16.53	14.81	12.95	11.11
0.4996	24.50	21.12	17.61	14.63	12.90	11.01	9.63
0.3001	15.32	12.60	10.40	8.84	7.34	6.81	6.29
0.1000	8.58	7.36	6.49	5.71	5.04	4.54	4.10
0.0000	6.08	5.66	5.12	4.46	3.96	3.62	3.26

ω is the mass fraction of BmimFeCl₄ in composites.

Table S8 The viscosity fitting parameters of BmimFeCl₄/DMAC and BmimFeCl₄/NHD

ω	$\eta_{\infty}(\text{mPa}\cdot\text{s})$	$E_a(\text{KJ}\cdot\text{mol})$	R^2
BmimFeCl ₄ /DMAC			
1.0000	0.0019	23.619	0.997
0.9002	0.0021	22.136	0.999
0.6993	0.0035	18.991	0.996
0.5012	0.0297	11.799	0.998
0.3002	0.0497	9.137	0.998
0.0996	0.0992	6.542	0.994
0.0000	0.3117	3.168	0.944
BmimFeCl ₄ /NHD			
1.0000	0.0019	23.619	0.997
0.9021	0.0020	23.368	0.998
0.7008	0.0017	23.675	0.997
0.4996	0.0009	24.952	0.998
0.3001	0.0005	25.382	0.989
0.1000	0.0027	19.635	0.998
0.0000	0.0067	16.639	0.990

ω is the mass fraction of BmimFeCl₄ in composites.

Table S9 The viscosity deviation of BmimFeCl₄/DMAC composites

T(K)	x						
	1.0000	0.6995	0.3763	0.2055	0.0998	0.0279	0.0000
293.2	0.00	-3.99	-4.74	-3.52	-2.19	-0.52	0.00
298.2	0.00	-3.12	-3.74	-2.75	-1.64	-0.42	0.00
303.2	0.00	-2.34	-2.87	-2.14	-1.29	-0.34	0.00
308.2	0.00	-1.66	-2.04	-1.67	-1.05	-0.30	0.00
313.2	0.00	-1.12	-1.50	-1.28	-0.81	-0.26	0.00
318.2	0.00	-0.82	-1.08	-0.94	-0.60	-0.23	0.00
323.2	0.00	-0.61	-0.80	-0.69	-0.50	-0.19	0.00

x is the mole fraction of BmimFeCl₄ in composites.

Table S10 The viscosity deviation of BmimFeCl₄/NHD composites

T(K)	x						
	1.0000	0.8783	0.6516	0.4449	0.2557	0.0818	0.0000
293.2	0.00	1.51	5.01	7.42	2.90	0.48	0.00
298.2	0.00	1.41	4.59	6.39	1.84	0.24	0.00
303.2	0.00	1.25	3.65	5.03	1.30	0.12	0.00
308.2	0.00	1.01	2.89	3.89	0.99	0.10	0.00
313.2	0.00	0.94	2.60	3.32	0.79	0.08	0.00
318.2	0.00	0.78	2.19	2.55	0.56	0.06	0.00
323.2	0.00	0.65	1.69	2.17	0.42	0.05	0.00

x is the mole fraction of BmimFeCl₄ in composites.

Table S11 The redox peak potentials and conductivities of different systems

Systems	x	E _A (mV)	I _A (mA/cm ²)	E _C (mV)	I _C (mA/cm ²)	E _A -E _C (mV)	I _A /I _C	σ (μS/cm)
Fe-IL/DMAC	0.2	473.8	2.589	-259.8	2.785	733.6	0.930	1599
	0.4	593.9	2.259	-168.4	2.163	762.3	1.044	1126
	0.6	717.4	1.874	-201.1	1.697	918.5	1.104	866
	0.8	746.6	1.768	-210.3	1.580	956.9	1.119	803
Fe-IL/NHD	0.2	319.9	0.879	-534.2	0.822	854.1	1.069	337
	0.4	633.7	1.287	-225.6	1.106	859.3	1.164	407
	0.6	712.2	1.565	-203.3	1.303	915.5	1.201	443
	0.8	718.0	1.909	-181.1	1.604	899.1	1.190	573
Pure Fe-IL	1.0	644.6	1.885	-113.3	1.627	757.9	1.159	736

x is the mole fraction of BmimFeCl₄ in composites.