Supporting information

An insight into the structure of Acebutolol tetraphenylborate: Crystal structure and quantum chemical calculations

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Table S1 Experimental and calculated bond lengths and bond angles of the ion-pair complex

Bond length (Å)	Exp[#]	Calculated	Bond angles (°)	Exp	Calculated*
C1_1−C2_1	1.415(2)	1.42176	C2_1−C1_1− C6_1	119.9(1)	118.8
C1_1−C6_1	1.393(2)	1.40137	C2_1−C1_1−O7_1	117.9(1)	118.8
C1_1−O7_1	1.360(1)	1.35975	C6_1−C1_1−O7_1	122.3(1)	122.2
C2_1−C3_1	1.402(2)	1.40623	C1_1−C2_1−C3_1	117.9(1)	118.9
C2_1−C16_1	1.484(2)	1.48849	C1_1−C2_1−C16_1	123.0(1)	123.0
C3_1−C4_1	1.381(2)	1.39682	C3_1−C2_1−C16_1	119.1(1)	118.1
C4_1−C5_1	1.388(2)	1.40028	C2_1−C3_1−C4_1	121.6(1)	121.9
C4_1−N19_2	1.431(2)	1.40988	C3_1−C4_1−C5_1	119.8(1)	118.2
C5_1−C6_1	1.383(2)	1.38940	C3_1−C4_1−N19_2	120.9(1)	123.4
O7_1−C8_1	1.442(1)	1.43133	C5_1−C4_1−N19_2	119.3(1)	118.4
C8_1−C9_1	1.511(2)	1.52551	C4_1−C5_1−C6_1	120.0(1)	121.1
C9_1−O10_1	1.423(1)	1.41942	C1_1−C6_1−C5_1	120.8(1)	120.9
C9_1−C11_1	1.525(2)	1.54216	C1_1−O7_1−C8_1	117.49(9)	119.0
C11_1−N12_1	1.488(2)	1.49975	O7_1−C8_1−C9_1	107.77(9)	109.4
N12_1−C13_1	1.510(2)	1.52324	C8_1−C9_1−O10_1	113.3(1)	109.4
C13_1−C14_1	1.514(2)	1.52703	C8_1−C9_1−C11_1	112.9(1)	114.4
C13_1−C15_1	1.515(2)	1.52814	O10_1−C9_1−C11_1	106.61(9)	109.5
C16_1−O17_1	1.226(1)	1.23143	C9_1−O10_1−H10_1	109.4(9)	
C16_1−C18_1	1.507(2)	1.51988	C9_1−C11_1−N12_1	109.64(9)	109.4
N19_2−C20_2	1.343(4)	1.38048	C11_1−N12_1−C13_1	114.83(9)	116.3
C20_2−O21_2	1.232(7)	1.22442	N12_1−C13_1−C14_1	109.4(1)	108.3
C20_2−C22_2	1.518(9)	1.52825	N12_1−C13_1−C15_1	108.8(1)	110.3
C22_2−C23_2	1.53(1)	1.53493	C14_1−C13_1−C15_1	112.4(1)	112.6
C23_2−C24_2	1.53(1)	1.53154	C2_1−C16_1−O17_1	123.2(1)	123.0
B1−C1_3	1.650(2)	1.66541	C2_1−C16_1−C18_1	118.5(1)	118.9
B1−C1_4	1.654(2)	1.66130	O17_1−C16_1−C18_1	118.3(1)	118.1
B1−C1_5	1.649(2)	1.66217	C4_1−N19_2−C20_2	117.3(3)	128.6

B1–C1_6	1.650(2)	1.66303	N19_2–C20_2–O21_2	125.0(5)	123.3
C1_3–C2_3	1.401(2)	1.41088	N19_2–C20_2–C22_2	115.1(5)	114.3
C1_3–C6_3	1.411(2)	1.39611	O21_2–C20_2–C22_2	119.8(6)	122.3
C2_3–C3_3	1.399(2)	1.39676	C20_2–C22_2–C23_2	109.8(6)	112.4
C3_3–C4_3	1.389(2)	1.39401	C22_2–C23_2–C24_2	112.3(7)	113.4
C4_3–C5_3	1.396(2)	1.40380	C1_3–B1–C1_4	110.87(9)	109.0
C5_3–C6_3	1.392(2)	1.41172	C1_3–B1–C1_5	107.51(9)	109.2
C1_4–C2_4	1.403(2)	1.40830	C1_3–B1–C1_6	109.97(9)	110.9
C1_4–C6_4	1.401(2)	1.39731	C1_4–B1–C1_5	109.68(9)	107.8
C2_4–C3_4	1.395(2)	1.39514	C1_4–B1–C1_6	108.13(9)	108.5
C3_4–C4_4	1.380(2)	1.39523	C1_5–B1–C1_6	110.70(9)	111.3
C4_4–C5_4	1.382(2)	1.39720	B1–C1_3–C2_3	124.2(1)	120.9
C5_4–C6_4	1.389(2)	1.41155	B1–C1_3–C6_3	120.5(1)	124.2
C1_5–C2_5	1.404(2)	1.41127	C2_3–C1_3–C6_3	115.2(1)	123.0
C1_5–C6_5	1.408(2)	1.40056	C1_3–C2_3–C3_3	122.7(1)	120.6
C2_5–C3_5	1.397(2)	1.39494	C2_3–C3_3–C4_3	120.2(1)	118.5
C3_5–C4_5	1.385(2)	1.39626	C3_3–C4_3–C5_3	119.1(1)	120.0
C4_5–C5_5	1.392(2)	1.39739	C4_3–C5_3–C6_3	119.7(1)	123.2
C5_5–C6_5	1.387(2)	1.41462	C1_3–C6_3–C5_3	123.1(1)	114.7
C1_6–C2_6	1.410(2)	1.41410	B1–C1_4–C2_4	125.1(1)	123.1
C1_6–C6_6	1.401(2)	1.39733	B1–C1_4–C6_4	120.1(1)	121.5
C2_6–C3_6	1.390(2)	1.39763	C2_4–C1_4–C6_4	114.8(1)	122.6
C3_6–C4_6	1.388(2)	1.39600	C1_4–C2_4–C3_4	122.5(1)	120.4
C4_6–C5_6	1.385(2)	1.40146	C2_4–C3_4–C4_4	120.7(1)	118.7
C5_6–C6_6	1.398(2)	1.41038	C3_4–C4_4–C5_4	118.6(1)	120.2
			C4_4–C5_4–C6_4	120.2(1)	122.8
			C1_4–C6_4–C5_4	123.2(1)	115.3
			B1–C1_5–C2_5	125.8(1)	123.8
			B1–C1_5–C6_5	119.3(1)	121.4
			C2_5–C1_5–C6_5	114.9(1)	123.1
			C1_5–C2_5–C3_5	122.4(1)	120.3

			C2_5–C3_5–C4_5	120.6(1)	118.5
			C3_5–C4_5–C5_5	118.8(1)	120.3
			C4_5–C5_5–C6_5	119.7(1)	123.1
			C1_5–C6_5–C5_5	123.6(1)	114.6
			B1–C1_6–C2_6	120.5(1)	121.1
			B1–C1_6–C6_6	124.6(1)	123.9
			C2_6–C1_6–C6_6	114.9(1)	122.9
			C1_6–C2_6–C3_6	122.8(1)	120.2
			C2_6–C3_6–C4_6	120.4(1)	118.7
			C3_6–C4_6–C5_6	118.8(1)	120.2
			C4_6–C5_6–C6_6	120.1(1)	122.9
			C1_6–C6_6–C5_6	123.0(1)	115.0

#*The atoms are numbered according to the molecular structure shown in the main text, Fig. 1.

* B3LYP/6-31G(d) method.

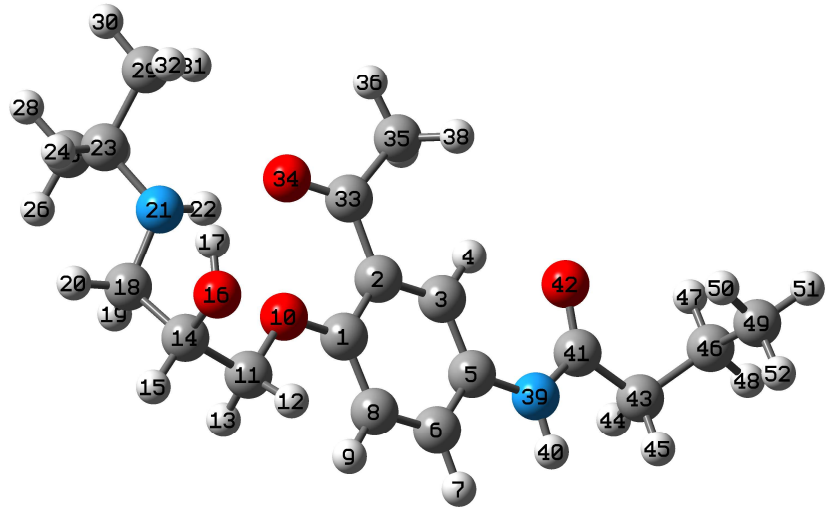
Table S2 Single-crystal X-ray diffraction data of the ion-pair complex

Data	Complex
Empirical formula	$C_{41}H_{48}BN_3O_4$
Formula weight ($g \cdot mol^{-1}$)	657.63
Temperature (K)	100(2)
Radiation, *l* (Å)	Cu_{Ka}, 1.54184
Crystal system	monoclinic
Space group	$P2_1/c$
Unit cell dimensions	
a (Å)	12.45670(10)
b (Å)	23.0603(3)
c (Å)	12.78140(10)
a (°)	90
b (°)	91.2060(10)
g (°)	90
Volume ($Å^3$)	3670.71(6)
Z	4
Calculated density ($Mg \cdot m^{-3}$)	1.190
Absorption coefficient (mm^{-1})	0.599
F(000)	1408
Theta range for collection	3.834 to 74.868°
Reflections collected	34099
Unique reflections	7220
Minimum/maximum transmission	0.792/1.000
Refinement method	Full-matrix least-squares on F^2
Data / parameters / restraints	7220 / 496 / 292
Goodness-of-fit on F^2	1.050
Final *R* indices [$I>2s(I)$]	R_1 = 0.0393, wR_2 = 0.1022
R indices (all data)	R_1 = 0.0429, wR_2 = 0.1044
Maximum/minimum residual electron density ($e \cdot Å^{-3}$)	0.313 / –0.222

Table S3 Atomic coordinates of the optimized structure of Acebutolol

Center number*	Atomic number	Atomic type	Coordinates (Å)		
			X	Y	Z
1	6	0	-0.371388	-1.059699	-0.064648
2	6	0	0.29263	0.198156	-0.005444
3	6	0	1.691455	0.236284	-0.130828
4	1	0	2.216862	1.177419	-0.084837
5	6	0	2.447861	-0.921055	-0.331089
6	6	0	1.778369	-2.147733	-0.39792
7	1	0	2.339482	-3.067283	-0.554085
8	6	0	0.397406	-2.217274	-0.264227
9	1	0	-0.07939	-3.187342	-0.316022
10	8	0	-1.71495	-1.099014	0.09091
11	6	0	-2.393415	-2.359226	0.01689
12	1	0	-1.987053	-3.049982	0.765866
13	1	0	-2.250364	-2.790478	-0.985314
14	6	0	-3.885822	-2.163018	0.301006
15	1	0	-4.357128	-3.117549	0.020444
16	8	0	-4.123708	-1.941427	1.672313
17	1	0	-4.257928	-0.965375	1.715318
18	6	0	-4.532821	-1.025949	-0.531647
19	1	0	-4.136034	-1.037796	-1.560614
20	1	0	-5.610622	-1.219244	-0.595755
21	7	0	-4.350266	0.236046	0.178056
22	1	0	-3.379878	0.544995	0.097871
23	6	0	-5.254131	1.334245	-0.193217
24	1	0	-6.277944	0.944225	-0.093472
25	6	0	-5.062519	1.828806	-1.638577
26	1	0	-5.218112	1.022328	-2.364347
27	1	0	-4.046054	2.217762	-1.775282
28	1	0	-5.769781	2.632395	-1.877695
29	6	0	-5.068755	2.476937	0.810992
30	1	0	-5.750922	3.306737	0.59285
31	1	0	-4.041521	2.857512	0.767715
32	1	0	-5.258952	2.126777	1.830855
33	6	0	-0.43388	1.495568	0.160309
34	8	0	-1.650716	1.595444	0.061138
35	6	0	0.379769	2.751802	0.44793
36	1	0	-0.320536	3.566098	0.640864
37	1	0	1.010403	3.022596	-0.406882
38	1	0	1.040548	2.621084	1.311431
39	7	0	3.854634	-0.920776	-0.46773
40	1	0	4.271043	-1.8334	-0.593455
41	6	0	4.722503	0.147849	-0.480536
42	8	0	4.369399	1.311956	-0.33376

43	6	0	6.183235	-0.232711	-0.731374
44	1	0	6.346093	-0.175239	-1.817085
45	1	0	6.368727	-1.276393	-0.442064
46	6	0	7.163514	0.704697	-0.013666
47	1	0	6.920143	1.733941	-0.297573
48	1	0	8.175051	0.497658	-0.384518
49	6	0	7.131043	0.568483	1.511567
50	1	0	6.14185	0.822391	1.907704
51	1	0	7.858088	1.240933	1.979938
52	1	0	7.372832	-0.454317	1.827926



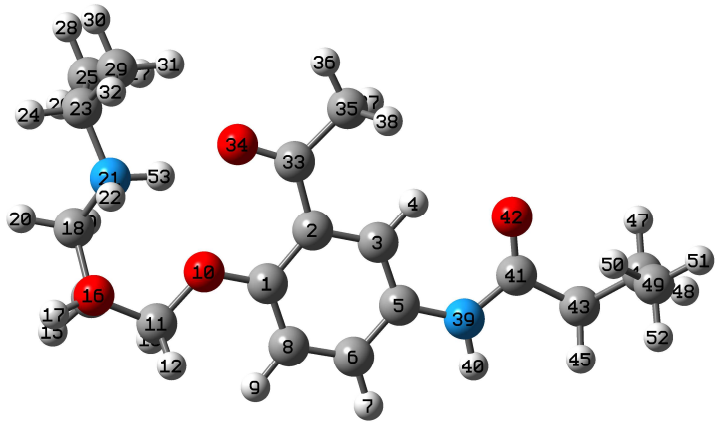
Local minimum structure of Acebutolol

*The atoms are numbered in an entirely different manner than what is seen in the case of the ion-pair (either crystal or optimized structures). Here, the numbers are presented based on the results of the Gaussian program of the shown local minimum structure.

Table S4 Atomic coordinates of the optimized structure of mono-protonated Acebutolol ion.

Center number*	Atomic number	Atomic type	Coordinates (Å)		
			X	Y	Z
1	6	0	-0.392224	-1.122229	-0.075589
2	6	0	0.261447	0.138996	-0.059732
3	6	0	1.663868	0.173332	-0.164317
4	1	0	2.19196	1.113777	-0.153585
5	6	0	2.427646	-0.991107	-0.295461
6	6	0	1.756114	-2.220434	-0.319959
7	1	0	2.317137	-3.146234	-0.423482
8	6	0	0.371037	-2.284961	-0.210335
9	1	0	-0.099868	-3.259726	-0.22776
10	8	0	-1.756503	-1.156997	0.054126
11	6	0	-2.434377	-2.400923	-0.086954
12	1	0	-2.097545	-3.125462	0.663116
13	1	0	-2.258235	-2.81351	-1.090294
14	6	0	-3.92786	-2.155691	0.117876
15	1	0	-4.454946	-3.031019	-0.279818
16	8	0	-4.194835	-1.993435	1.514512
17	1	0	-4.96228	-2.52821	1.767861
18	6	0	-4.451508	-0.903993	-0.621539
19	1	0	-4.010221	-0.799488	-1.614009
20	1	0	-5.539555	-0.954384	-0.719757
21	7	0	-4.135415	0.314172	0.188055
22	1	0	-4.25646	0.020611	1.168841
23	6	0	-4.986907	1.546573	-0.080504
24	1	0	-6.024024	1.197716	-0.013653
25	6	0	-4.700954	2.084889	-1.480433
26	1	0	-4.940668	1.359421	-2.264578
27	1	0	-3.650831	2.37892	-1.574267
28	1	0	-5.319432	2.969873	-1.655844
29	6	0	-4.709665	2.567146	1.022522
30	1	0	-5.34655	3.443542	0.872097
31	1	0	-3.664675	2.889472	0.999345
32	1	0	-4.934901	2.161887	2.016102
33	6	0	-0.457848	1.434858	0.037529
34	8	0	-1.692145	1.523762	0.045195
35	6	0	0.340888	2.720415	0.119657
36	1	0	-0.356548	3.552311	0.225448
37	1	0	0.945236	2.872267	-0.781526
38	1	0	1.029139	2.711316	0.971441
39	7	0	3.827653	-0.985823	-0.403623
40	1	0	4.262244	-1.895553	-0.483607
41	6	0	4.682457	0.10614	-0.437412
42	8	0	4.287416	1.259645	-0.342037

43	6	0	6.151107	-0.251563	-0.642153
44	1	0	6.327511	-0.249438	-1.727402
45	1	0	6.351528	-1.274563	-0.295485
46	6	0	7.101991	0.742927	0.039121
47	1	0	6.845705	1.751872	-0.300533
48	1	0	8.119903	0.535492	-0.311221
49	6	0	7.055951	0.680416	1.568678
50	1	0	6.059113	0.934115	1.946536
51	1	0	7.765316	1.389264	2.008248
52	1	0	7.31644	-0.319991	1.936542
53	1	0	-3.118579	0.564753	0.089889

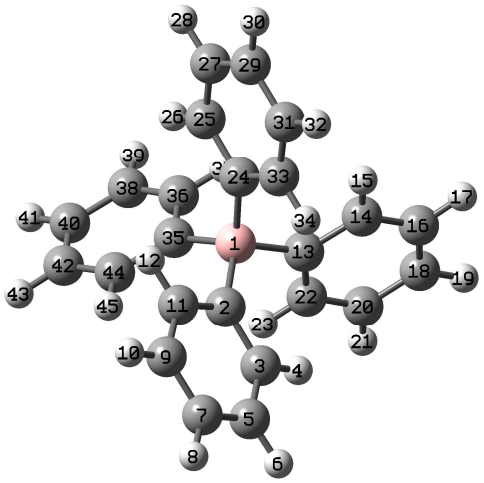


Local minimum structure of mono-protonated Acebutolol ion

*The atoms are numbered in an entirely different manner than what is seen in the case of the ion-pair (either crystal or optimized structures). Here, the numbers are presented based on the results of the Gaussian program of the shown local minimum structure.

Table S5 Atomic coordinates of the optimized structure of mono-negatively tetraphenyl borate ion

Center number*	Atomic number	Atomic type	Coordinates (Å)		
			X	Y	Z
1	5	0	0.00002	-0.000087	-0.000085
2	6	0	0.982335	-1.195079	-0.602752
3	6	0	0.805348	-1.818548	-1.8526
4	1	0	-0.01369	-1.496017	-2.490394
5	6	0	1.647229	-2.835814	-2.315841
6	1	0	1.467308	-3.281574	-3.293988
7	6	0	2.715325	-3.277849	-1.535352
8	1	0	3.373958	-4.068957	-1.890817
9	6	0	2.927792	-2.68035	-0.290211
10	1	0	3.759821	-3.004233	0.334659
11	6	0	2.081209	-1.662327	0.152704
12	1	0	2.281879	-1.202973	1.118976
13	6	0	-0.982452	0.601393	-1.195528
14	6	0	-0.807216	1.851913	-1.818132
15	1	0	0.010449	2.490966	-1.494545
16	6	0	-1.649139	2.314244	-2.835762
17	1	0	-1.470605	3.292974	-3.280812
18	6	0	-2.715552	1.532124	-3.279005
19	1	0	-3.37421	1.886881	-4.070405
20	6	0	-2.926293	0.286291	-2.682327
21	1	0	-3.756964	-0.339889	-3.007153
22	6	0	-2.079711	-0.15569	-1.663902
23	1	0	-2.279	-1.122602	-1.205281
24	6	0	0.980637	1.196628	0.60186
25	6	0	0.80371	1.819301	1.852123
26	1	0	-0.014119	1.494981	2.49061
27	6	0	1.643974	2.838136	2.314802
28	1	0	1.464162	3.283198	3.293291
29	6	0	2.710337	3.282615	1.533325
30	1	0	3.367745	4.074917	1.88839
31	6	0	2.92269	2.686003	0.28774
32	1	0	3.753372	3.011795	-0.337921
33	6	0	2.077772	1.666343	-0.154598
34	1	0	2.278311	1.207824	-1.121271
35	6	0	-0.980463	-0.603227	1.19612
36	6	0	-2.079266	0.151586	1.664619
37	1	0	-2.281143	1.117684	1.205432
38	6	0	-2.924253	-0.291754	2.683789
39	1	0	-3.756314	0.332584	3.008598
40	6	0	-2.710181	-1.536663	3.281206
41	1	0	-3.367643	-1.8925	4.073121
42	6	0	-1.642068	-2.316482	2.838023
43	1	0	-1.460969	-3.294463	3.283681
44	6	0	-0.801737	-1.852807	1.81969
45	1	0	0.017384	-2.490097	1.496303



Local minimum structure of mono-negatively tetraphenyl borate ion

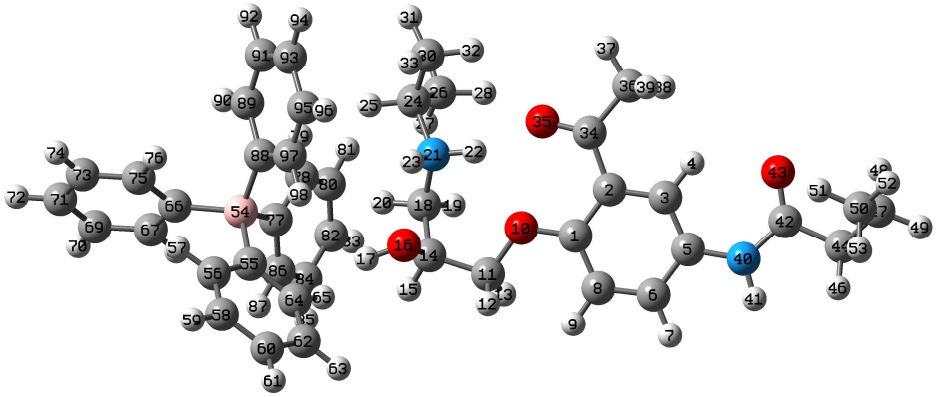
*The atoms are numbered in an entirely different manner than what is seen in the case of the ion-pair (either crystal or optimized structures). Here, the numbers are presented based on the results of the Gaussian program of the shown local minimum structure.

Table S6 Atomic coordinates of the optimized structure of Acebutolol–tetraphenyl borate ion-pair complex

Center number*	Atomic number	Atomic type	Coordinates (Å)		
			X	Y	Z
1	6	0	-3.749167	-0.772642	0.223113
2	6	0	-4.592906	0.362749	0.080295
3	6	0	-5.987039	0.182951	0.119517
4	1	0	-6.65014	1.026675	0.011511
5	6	0	-6.564773	-1.074423	0.310119
6	6	0	-5.715553	-2.177727	0.459578
7	1	0	-6.133747	-3.170624	0.611361
8	6	0	-4.334597	-2.031246	0.415542
9	1	0	-3.718126	-2.913571	0.528434
10	8	0	-2.40181	-0.600839	0.159608
11	6	0	-1.545807	-1.707439	0.461913
12	1	0	-1.722148	-2.535702	-0.233063
13	1	0	-1.742362	-2.045092	1.488753
14	6	0	-0.089563	-1.27531	0.321252
15	1	0	0.502151	-2.03514	0.845839
16	8	0	0.258968	-1.233795	-1.05409
17	1	0	1.167964	-1.591617	-1.149423
18	6	0	0.237799	0.081742	0.976616
19	1	0	-0.290354	0.221273	1.921296
20	1	0	1.313441	0.161366	1.152789
21	7	0	-0.144835	1.191182	0.042808
22	1	0	-1.180234	1.271072	-0.000765
23	1	0	0.175153	0.875445	-0.886713
24	6	0	0.459353	2.55874	0.334335
25	1	0	1.536624	2.42318	0.206684
26	6	0	0.138005	2.98526	1.764939
27	1	0	0.609727	2.334222	2.506405
28	1	0	-0.944472	3.010336	1.936826
29	1	0	0.526126	3.996084	1.923806
30	6	0	-0.06792	3.546761	-0.705381
31	1	0	0.443845	4.504302	-0.572442
32	1	0	-1.145021	3.700043	-0.592949
33	1	0	0.147894	3.205486	-1.721728
34	6	0	-4.069318	1.747031	-0.078537
35	8	0	-2.868483	2.017629	-0.043876
36	6	0	-5.053587	2.88783	-0.278089
37	1	0	-4.483515	3.809756	-0.400866
38	1	0	-5.725468	2.99198	0.581041
39	1	0	-5.680196	2.727271	-1.162102
40	7	0	-7.957254	-1.289403	0.360601
41	1	0	-8.240192	-2.252414	0.482322
42	6	0	-8.974682	-0.358361	0.29959
43	8	0	-8.78073	0.841061	0.148013
44	6	0	-10.375418	-0.943746	0.475103
45	1	0	-10.607744	-0.893126	1.548454

46	1	0	-10.389617	-2.007948	0.202343
47	6	0	-11.437736	-0.171389	-0.319223
48	1	0	-11.363766	0.887199	-0.04894
49	1	0	-12.427468	-0.517686	0.002492
50	6	0	-11.298955	-0.329141	-1.836285
51	1	0	-10.335351	0.057003	-2.186481
52	1	0	-12.086455	0.223468	-2.359875
53	1	0	-11.374834	-1.381376	-2.138613
54	5	0	4.600109	-0.274206	-0.038938
55	6	0	4.156965	-1.6887	-0.798165
56	6	0	4.797293	-2.106406	-1.983952
57	1	0	5.645729	-1.534534	-2.348884
58	6	0	4.394971	-3.229305	-2.709466
59	1	0	4.928506	-3.501772	-3.61813
60	6	0	3.319752	-4.008433	-2.276113
61	1	0	3.008008	-4.887336	-2.835353
62	6	0	2.668474	-3.645795	-1.098153
63	1	0	1.848731	-4.25539	-0.718689
64	6	0	3.084527	-2.509393	-0.386713
65	1	0	2.599244	-2.290654	0.562472
66	6	0	6.256696	-0.149679	-0.050253
67	6	0	7.068305	-0.593371	1.011697
68	1	0	6.600891	-0.989184	1.909219
69	6	0	8.463831	-0.537348	0.968598
70	1	0	9.043749	-0.891501	1.819352
71	6	0	9.11472	-0.026054	-0.154494
72	1	0	10.200965	0.021731	-0.192215
73	6	0	8.345417	0.429359	-1.225679
74	1	0	8.830128	0.838301	-2.110703
75	6	0	6.950872	0.368771	-1.164611
76	1	0	6.383995	0.748938	-2.011759
77	6	0	4.060182	-0.237329	1.532666
78	6	0	3.588462	0.927469	2.174857
79	1	0	3.545437	1.857889	1.614531
80	6	0	3.196288	0.953887	3.519135
81	1	0	2.861819	1.889571	3.96591
82	6	0	3.253749	-0.205523	4.292647
83	1	0	2.952752	-0.192511	5.33786
84	6	0	3.726175	-1.378636	3.700896
85	1	0	3.79815	-2.293046	4.287278
86	6	0	4.119738	-1.383184	2.360077
87	1	0	4.494632	-2.313413	1.939905
88	6	0	3.968433	0.992035	-0.912592
89	6	0	4.404399	2.319233	-0.693125
90	1	0	5.16954	2.498847	0.058838
91	6	0	3.932777	3.406259	-1.43372
92	1	0	4.31566	4.405034	-1.231502
93	6	0	2.999665	3.210391	-2.455636
94	1	0	2.651619	4.048115	-3.056097
95	6	0	2.544073	1.915119	-2.707695

96	1	0	1.843741	1.732194	-3.522141
97	6	0	3.017656	0.840248	-1.943196
98	1	0	2.676175	-0.158531	-2.20114



Local minimum structure of Acebutolol−tetraphenyl borate ion-pair complex

*The atoms are numbered in an entirely different manner than what is seen in the case of crystal structure. Here, the numbers are presented based on the results of the Gaussian program of the shown local minimum structure.

Table S7 Comparison of the calculated bond lengths for the protonated, ion-pair, and free form of the acebutolol framework

Bond length (Å)*	Acebutolol	mono-protonated Acebutolol ion	Ion-pair
C1−C2	1.42360	1.42064	1.42176
C2−C3	1.40495	1.40673	1.40623
C3−C5	1.39703	1.39874	1.39682
C5−C6	1.39908	1.40100	1.40028
C6−C8	1.38916	1.39091	1.38940
C1−C8	1.40387	1.39738	1.40137
C1−O10	1.35311	1.37087	1.35975
O10−C11	1.43315	1.42365	1.43133
C11−C14	1.53183	1.52728	1.52551
C14−O16	1.40932	1.43115	1.41942
C14−C18	1.55076	1.54522	1.54216
C18−N21	1.45933	1.49642	1.49975
N21−C23	1.46999	1.52183	1.52324
C23−C25	1.53960	1.52688	1.52703
C23−C29	1.53250	1.52810	1.52814
C2−C33	1.49618	1.48530	1.48849
C33−O34	1.22495	1.23752	1.23143
C33−C35	1.52410	1.51571	1.51988
C5−N39	1.41339	1.40419	1.40988
N39−C41	1.37671	1.38716	1.38048
C41−O42	1.22530	1.22300	1.22442
C41−C43	1.53019	1.52539	1.52825
C43−C46	1.53453	1.53536	1.53493
C46−C49	1.53165	1.53153	1.53154

* The numbering of the atoms is according to the local minimum structure of Acebutolol given in Table S3.

Table S8 Occupancy of natural orbitals (NBOs) and hybrids calculated for the mono-protonated Acebutolol ion (Selected).*

Bond orbital	Occupancy	Polarization	Hybrid [e]	AO (%) [*]
σ(C14−O16)	0.99672	66.90% (O16)	$sp^{4.03}d^{0.01}$ (C14)	19.84% s, 4.03% p and 0.23% d
			$sp^{2.30}d^{0.00}$ (O16)	30.24% s, 69.69% p and 0.08% d
σ(C14−C18)	0.99133	51.14 (C18)	$sp^{2.73}d^{0.00}$ (C14)	26.78% s, 73.17% p and 0.06% d
			$sp^{2.55}d^{0.00}$ (C18)	28.17% s, 71.79% p and 0.05% d
σ(C18−N21)	0.99495	63.65% (N21)	$sp^{3.81}d^{0.01}$ (C18)	20.75% s, 79.11% p and 0.14% d
			$sp^{2.85}d^{0.00}$ (N21)	25.99% s, 73.98% p and 0.03% d
σ(N21−C23)	0.99323	65.38% (N21)	$sp^{2.60}d^{0.00}$ (N21)	27.81% s, 72.17% p and 0.02% d
			$sp^{4.38}d^{0.01}$ (C23)	18.78% s, 81.06% p and 0.16% d
σ(C23−C25)	0.99296	51.89% (C23)	$sp^{2.49}d^{0.00}$ (C23)	28.67% s, 71.29% p and 0.04% d
			$sp^{2.69}d^{0.00}$ (C25)	27.09% p, 72.86% p and 0.05% d
σ(C23−C29)	0.99202	52.17% (C23)	$sp^{2.50}d^{0.00}$ (C23)	28.57% s, 71.39% p and 0.04% d
			$sp^{2.70}d^{0.00}$ (C29)	27.02% s, 72.93% p and 0.05% d
LP(1)O16	0.98909		$sp^{1.18}d^{0.00}$	45.95% s, 1.18% p and 0.00% d
LP(2)O16	0.97295		$sp^{41.44}d^{0.04}$	2.35% s, 97.56% p and 0.08% d

[a] Percentage contribution of atomic orbitals in NBO hybrid.

* The numbering of the atoms is according to the local minimum structure of Acebutolol given in Table S4.

Table S9 Occupancy of natural orbitals (NBOs) and hybrids calculated for the Acebutolol−tetraphenyl borate ion-pair complex (Selected).*

Bond orbital	Occupancy	Polarization	Hybrid [e]	AO (%) [f]
σ(C14−O16)	0.99657	66.12% (O16)	$sp^{3.87}d^{0.01}$ (C14)	20.51% s, 79.27% p and 0.22% d
			$sp^{2.39}d^{0.00}$ (O16)	29.49% s, 70.43% p and 0.08% d
σ(C14−C18)	0.99081	50.89% (C18)	$sp^{2.69}d^{0.01}$ (C14)	27.09% s, 72.78% p and 0.05% d
			$sp^{2.57}d^{0.00}$ (C18)	28.02% s, 71.93% p and 0.05% d
σ(C18−N21)	0.99505	64.31% (N21)	$sp^{3.97}d^{0.01}$ (C18)	20.09% s, 79.77% p and 0.14% d
			$sp^{2.81}d^{0.00}$ (N21)	26.22% s, 73.75% p and 0.03% d
σ(N21−C24)	0.99348	65.53% (N21)	$sp^{2.58}d^{0.00}$ (N21)	27.94% s, 72.04% p and 0.02% d
			$sp^{4.38}d^{0.01}$ (C24)	18.57% s, 81.27% p and 0.16% d
σ(C24−C26)	0.99314	51.13% (C24)	$sp^{2.56}d^{0.00}$ (C24)	28.06% s, 71.89% p and 0.04% d
			$sp^{2.64}d^{0.00}$ (C26)	27.44% p, 72.52% p and 0.04% d
σ(C24−C30)	0.99201	51.69% (C24)	$sp^{2.56}d^{0.00}$ (C24)	28.09% s, 71.89% p and 0.04% d
			$sp^{2.69}d^{0.00}$ (C30)	27.07% s, 72.89% p and 0.05% d
LP(1)O16	0.98787		$sp^{1.20}d^{0.00}$	45.36% s, 54.58% p and 0.06% d
LP(2)O16	0.96982		$sp^{99.99}d^{0.10}$	0.83% s, 99.09% p and 0.08% d

[a] Percentage contribution of atomic orbitals in NBO hybrid.

* The numbering of the atoms is according to the local minimum structure of Acebutolol given in Table S6.

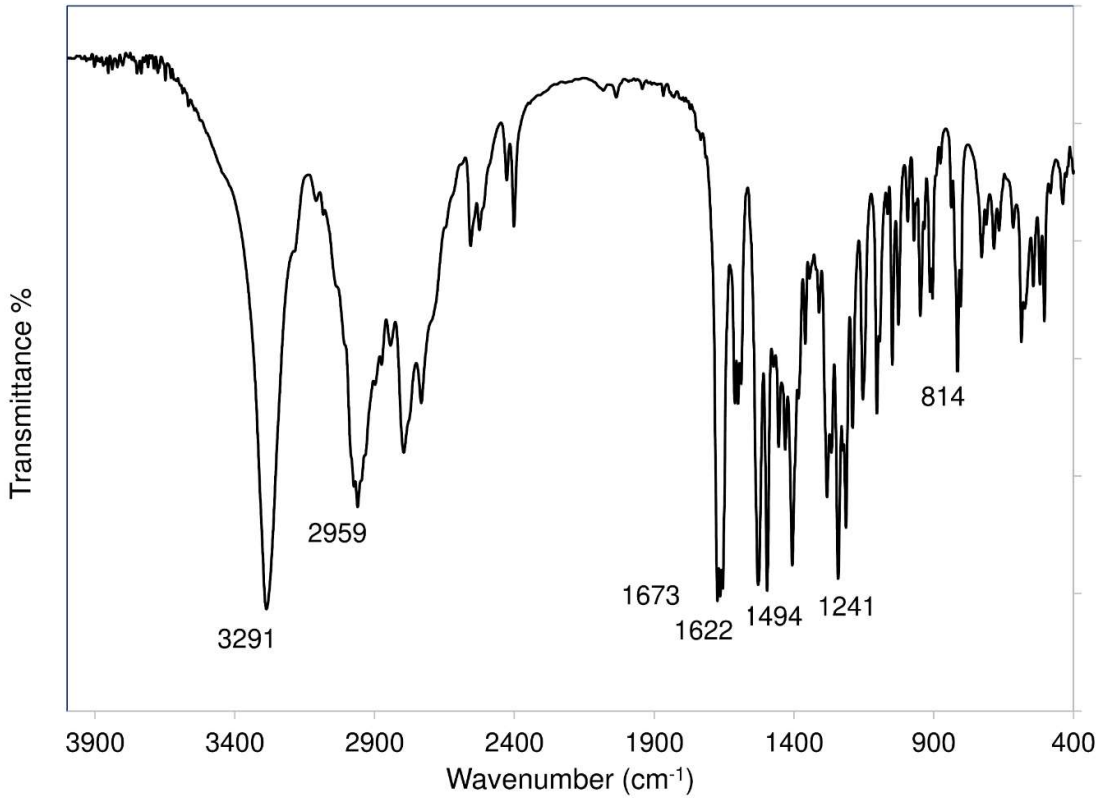


Fig. S1 IR spectrum of Acebutolol hydrochloride.

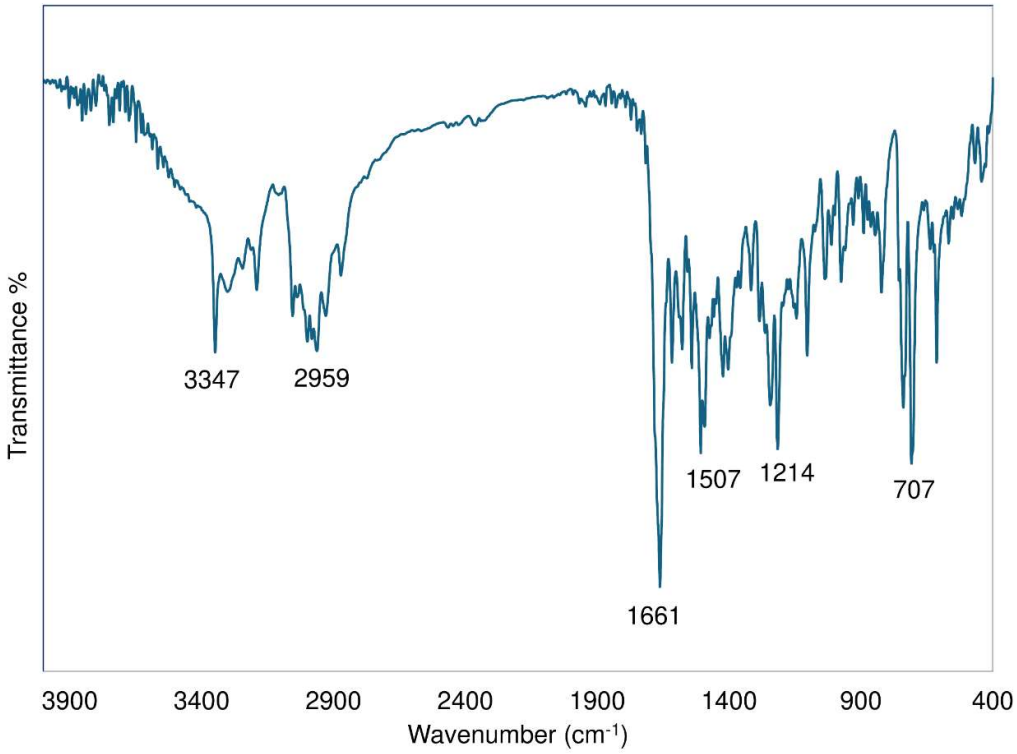
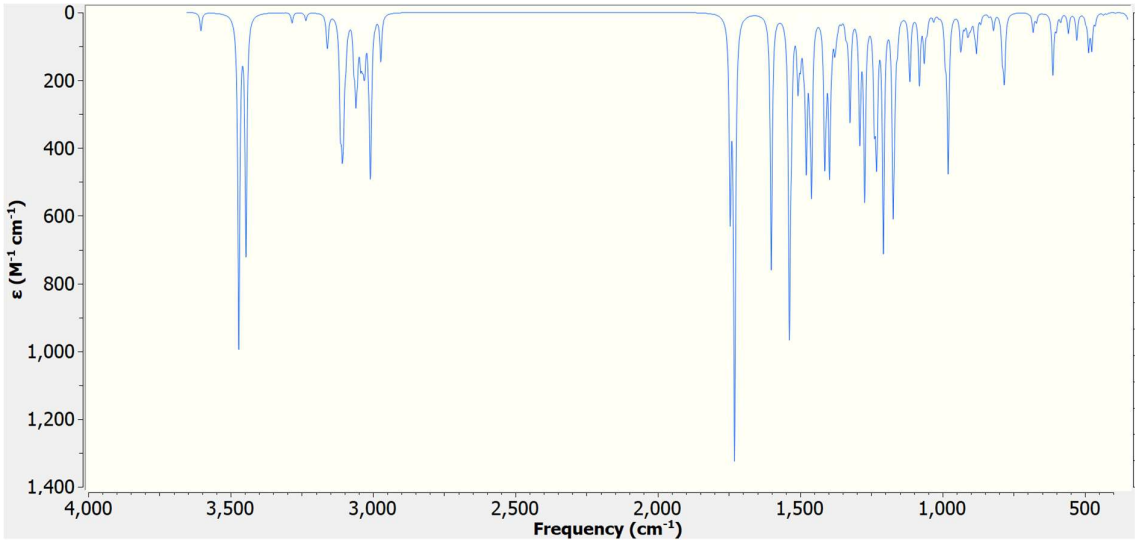
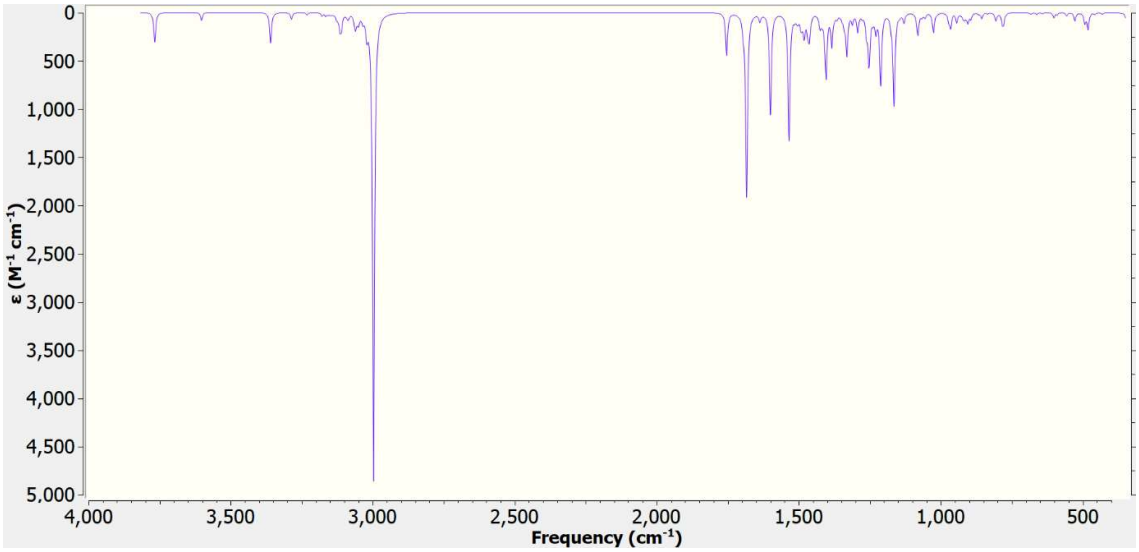


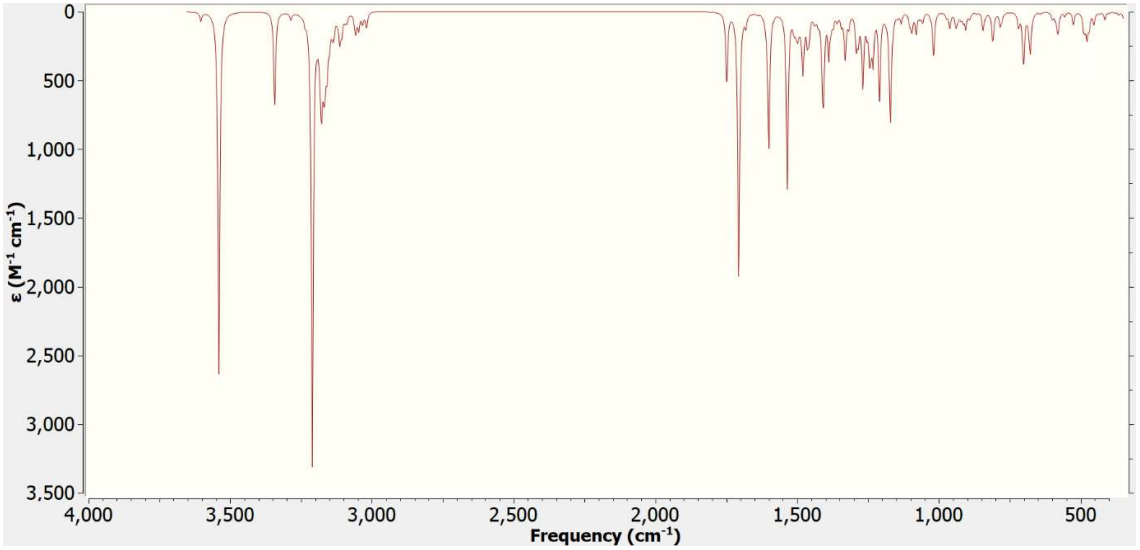
Fig. S2 IR spectrum of Acebutolol–tetraphenyl borate ion-pair complex.


0
200
400
600
800
1,000
1,200
1,400
ε (M-1 cm-1)
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
Frequency (cm-1)

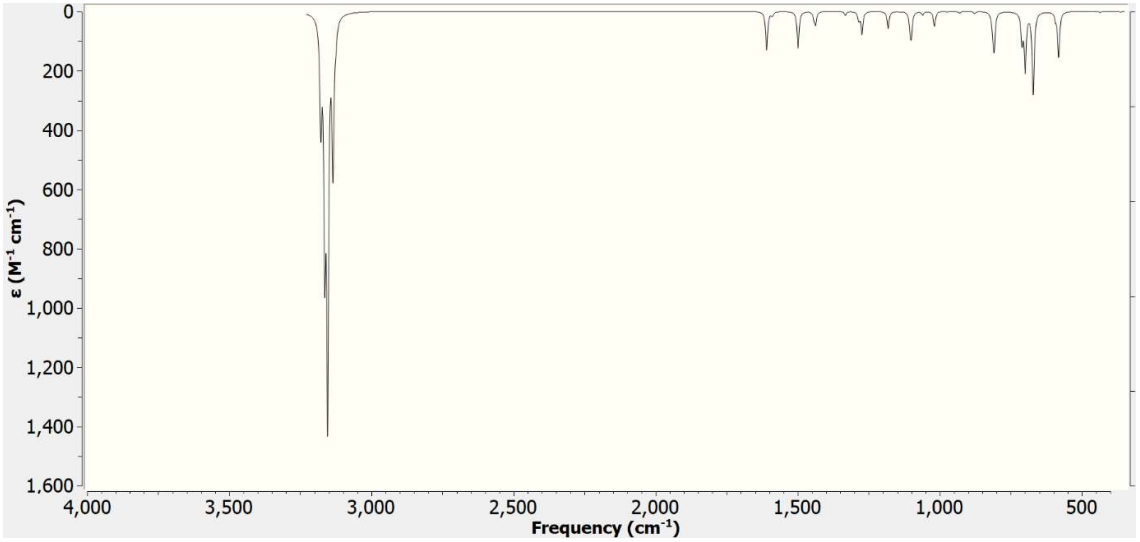
a)


0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
ε (M-1 cm-1)
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
Frequency (cm-1)

b)

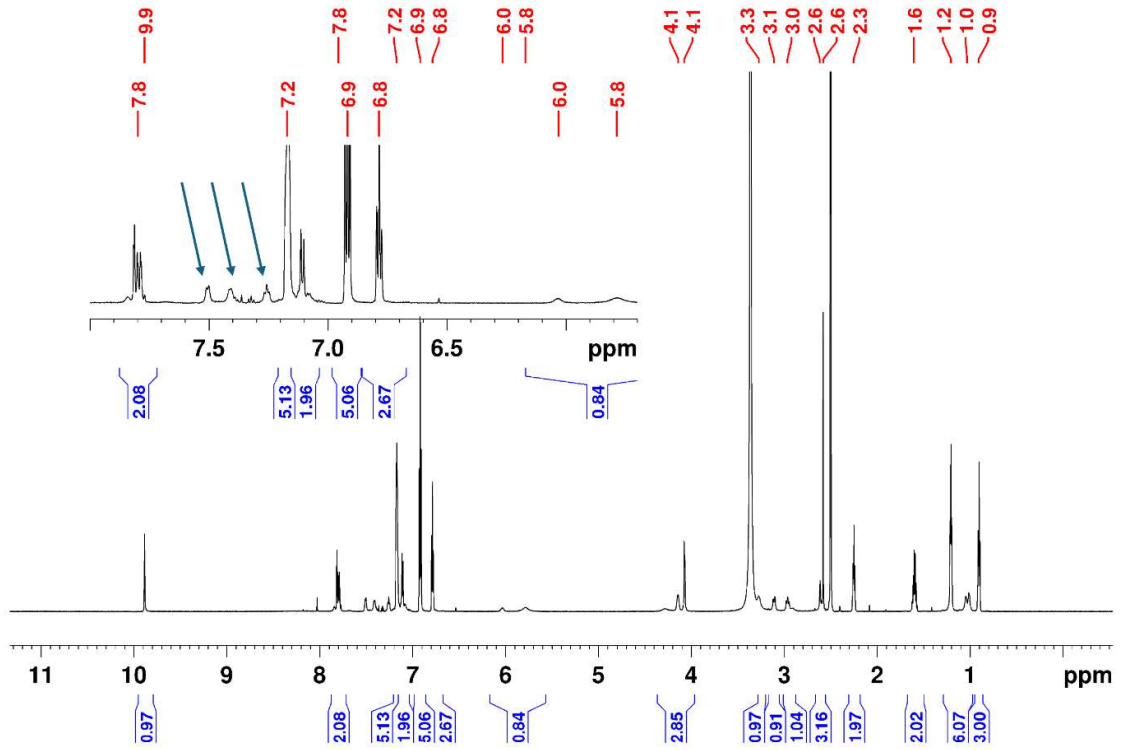


c)

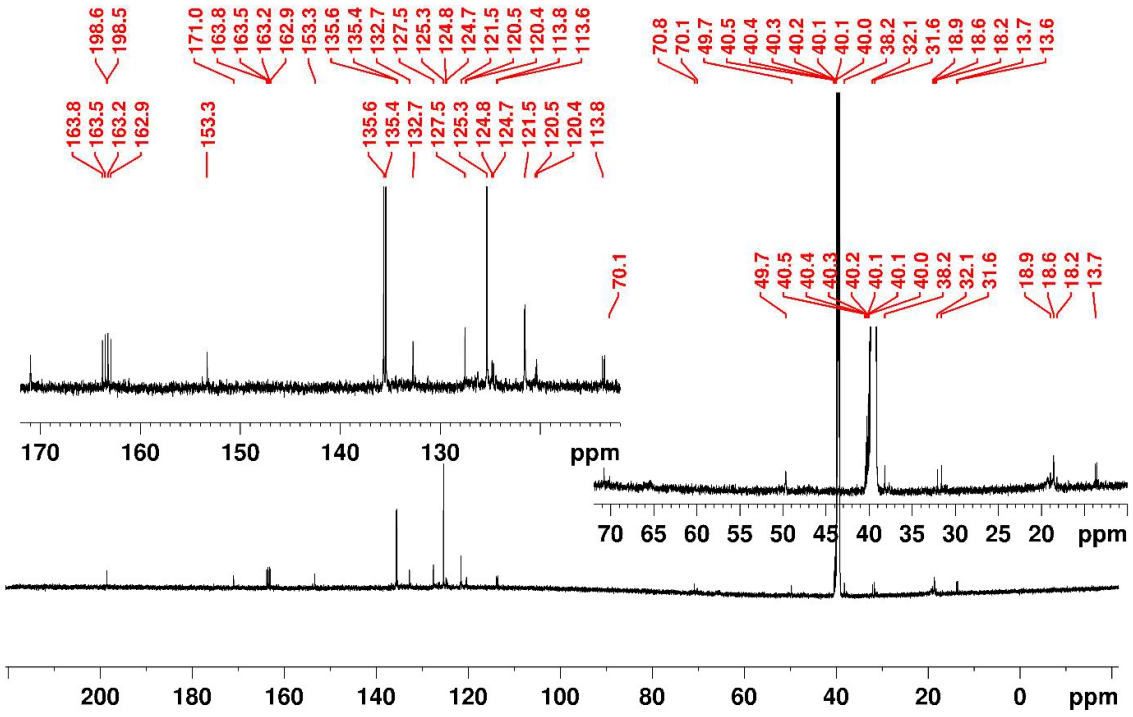


d)

Fig. S3 Calculated IR spectra of **a)** Acebutolol, **b)** Mono-protonated Acebutolol, **c)** ion-pair complex and **d)** tetraphenyl borate ion.

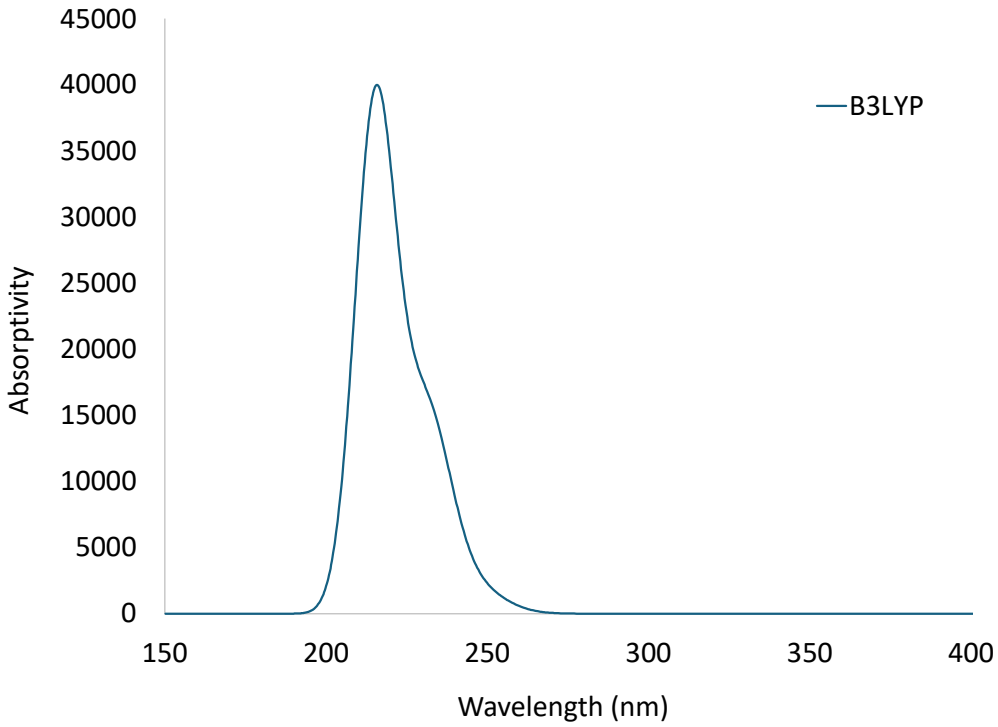


(a)

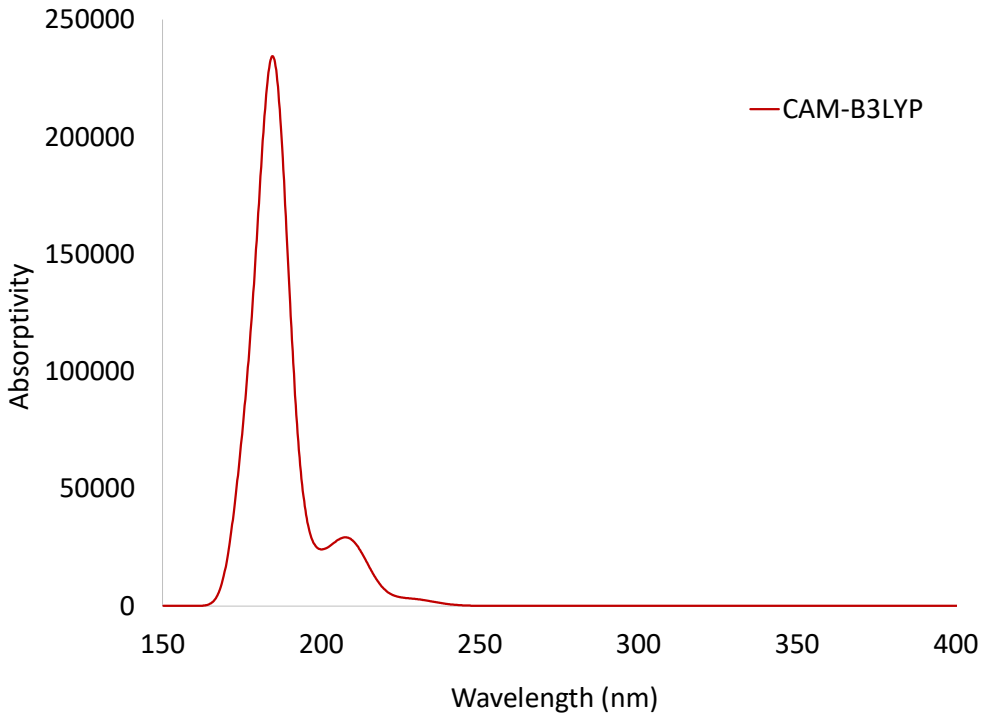


(b)

Fig. S4 NMR spectra of Acebutolol−tetraphenyl borate ion-pair; (a) ^{1}H and (b) ^{13}C.



a)



b)

Fig. S5 Calculated electronic absorption spectra of tetraphenyl borate ion **a)** B3LYP/6-31G(d), and **b)** CAM-B3LYP/6-31G(d)

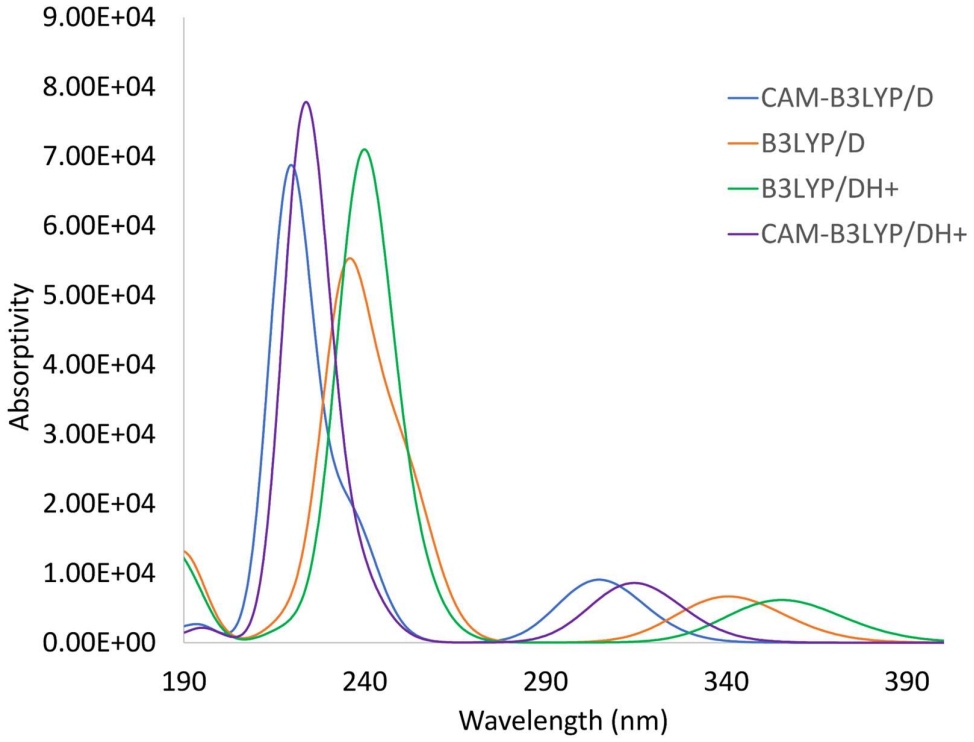
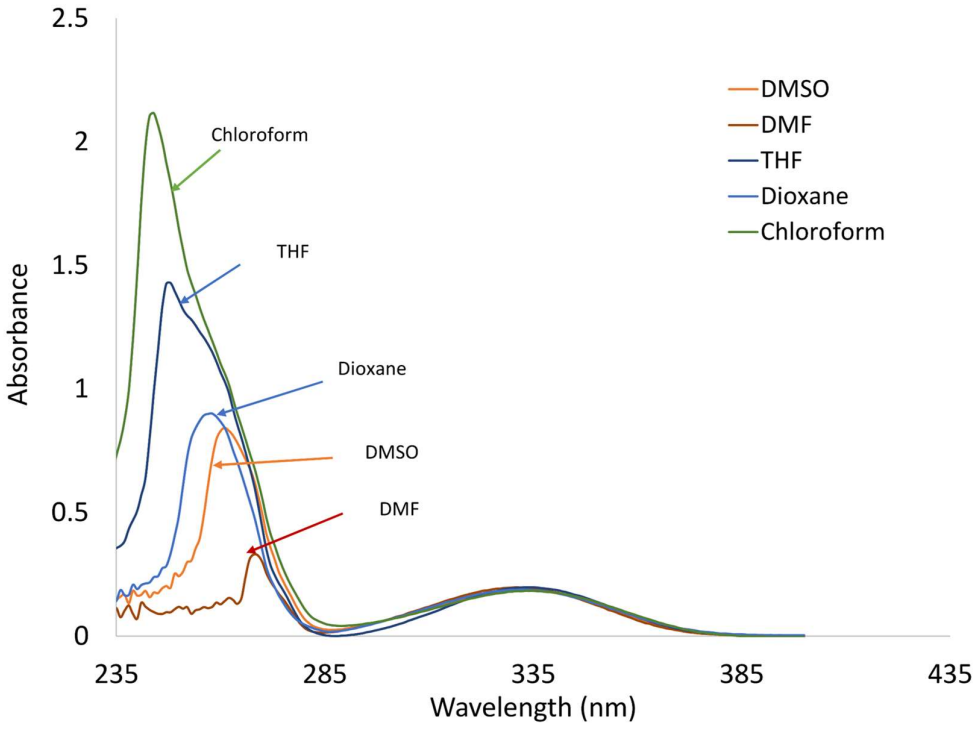
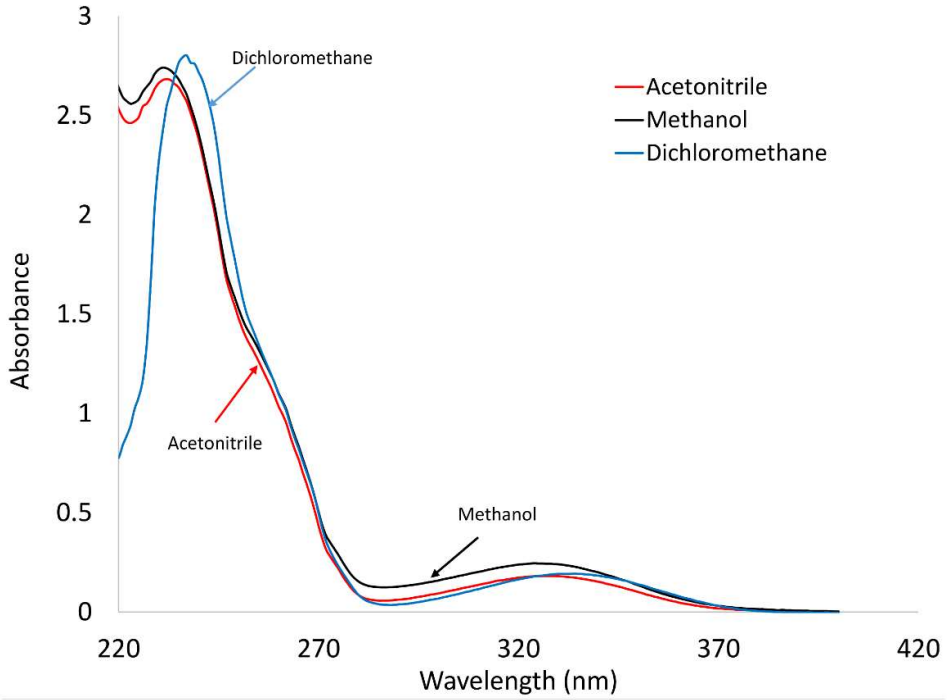


Fig. S6 Calculated electronic absorption spectra of acebutolol (D) and its mono-protonated acebutolol (DH^+) using **a)** B3LYP/6-31G(d), and **b)** CAM-B3LYP/6-31G(d)



(a)



(b)

Fig. S7 Electronic absorption spectra of Acebutolol−tetraphenyl borate ion-pair in different solvents; (a) DMSO, DMF, THF, Dioxane and chloroform; (b) Acetonitrile, methanol and dichloromethane.

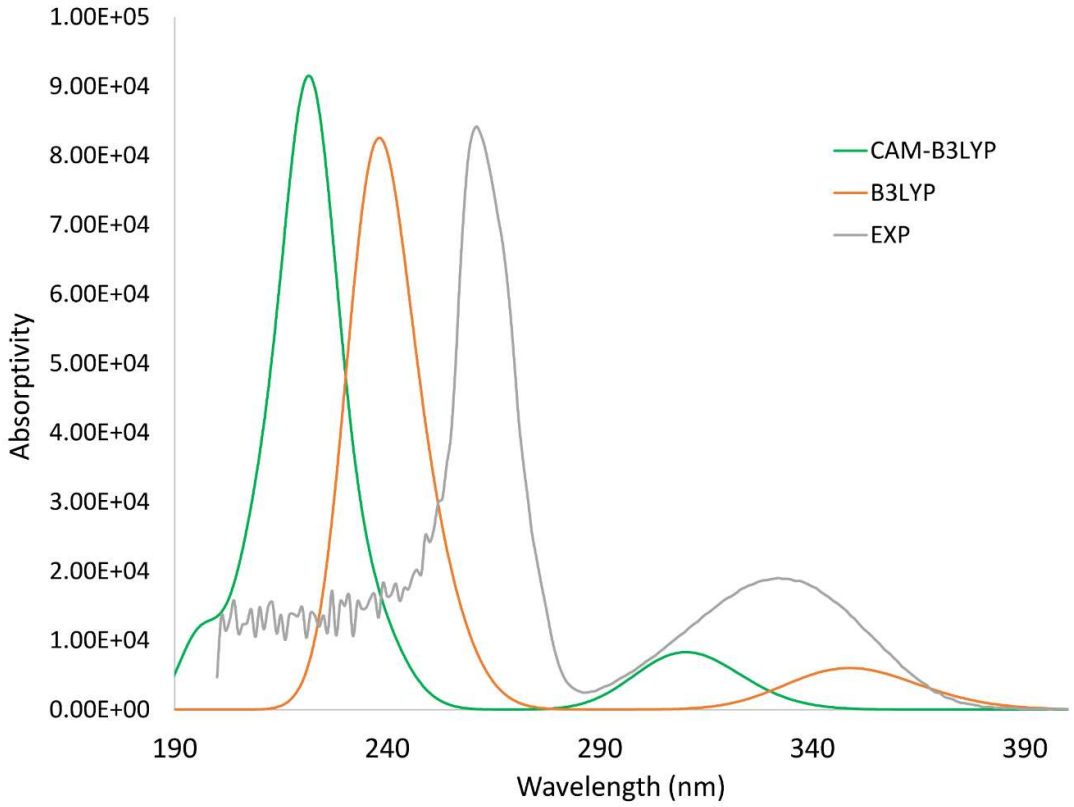
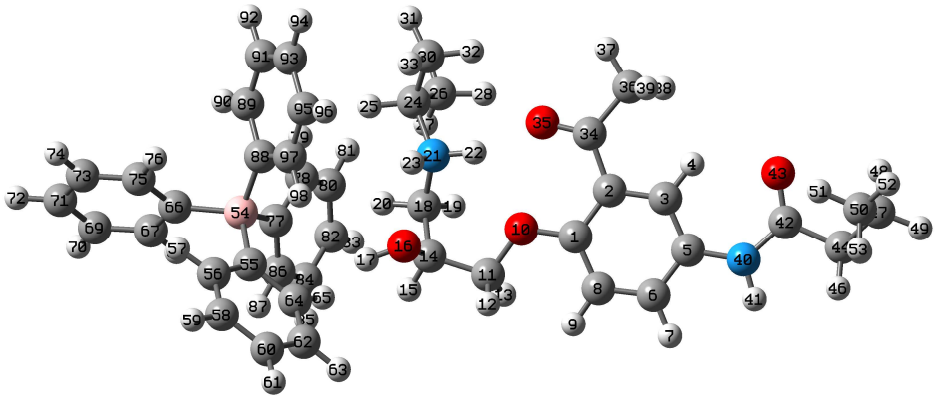


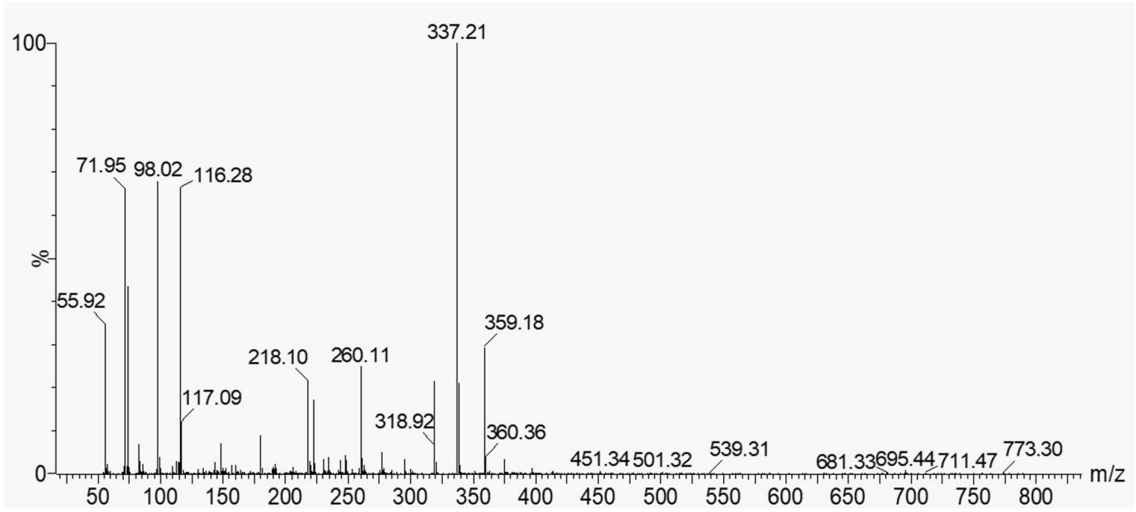
Fig. S8 Comparison between the experimental (in DMSO) and calculated electronic absorption spectra of Acebutolol−tetraphenyl borate ion-pair (using B3LYP and CAM-B3LYP functional).

Table S10 Selected experimental and theoretical chemical shifts of the ion-pair complex*

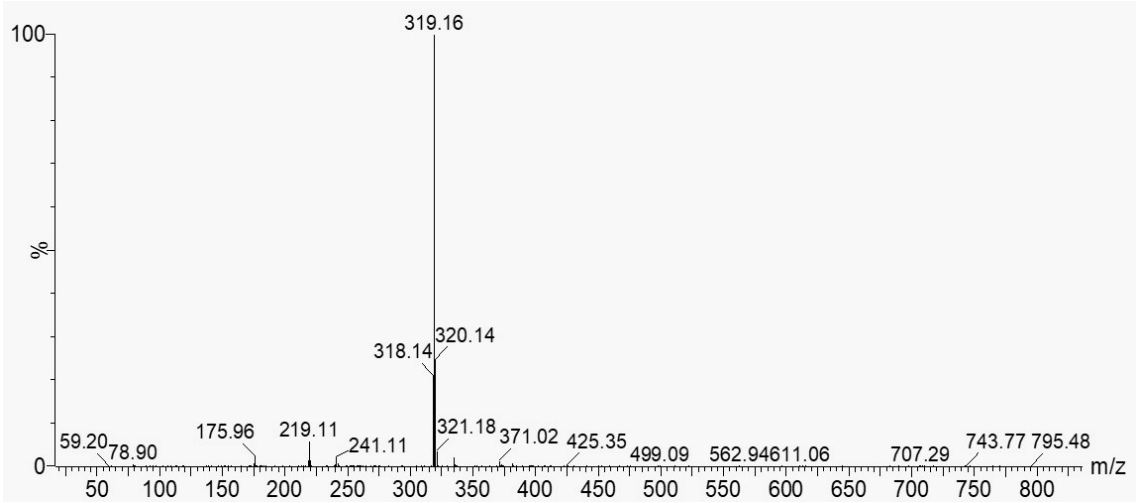
atom	δcalcd.				δExp
	B3LYP/ 6-311+G(2d,p) PCM	B3LYP/ 6-311+G(2d,p) SMD	HF/ 6-31G(d) PCM	HF/ 6-31G(d) SMD	
C14–**H15**	4.2622	4.3907	3.7744	3.9407	4.14–4.07
O16–**H17**	2.8675	2.6198	2.7487	2.5141	6.03–5.78
C18–**H19**	2.5742	2.6946	2.4646	2.5973	3.11
C18–**H20**	2.1594	2.0966	2.1491	2.1063	2.96
N21–**H22**	8.4668	8.3406	7.9858	7.8898	6.78
N21–**H23**	5.1097	5.2309	4.6628	4.8415	6.78
C24–**H25**	1.4332	1.4637	1.2151	1.2278	3.27

*The chemical shifts are referenced to TMS calculated at the same level of theory





(a)



(b)

Fig. S9 ESI MS spectra of Acebutolol−tetraphenyl borate ion-pair complex.