ORIGIN OF ENANTIOSELECTIVITY IN CF_3-PIP-CATALYZED KINETIC RESOLUTION OF SECONDARY BENZYLIC ALCOHOLS

Ximin Li,[1] Peng Liu,[2] K. N. Houk*[2] and Vladimir B. Birman*[1]

A contribution from: (1) Department of Chemistry, Washington University, One Brookings Drive, St. Louis, Missouri 63130 and (2) Department of Chemistry and Biochemistry, University of California, Los Angeles, California 90095-1569

SUPPORTING INFORMATION

I. General.

All reagents were obtained from Sigma-Aldrich and were used as received unless specified otherwise. Chloroform-d was distilled from anhydrous K_2CO_3. N,N-Diisopropylethylamine and dichloromethane were distilled from CaH_2. Preparation of (R)-CF_3-PIP and other experimental details have been previously described.[4a]

II. Kinetic resolution of 1-phenylethanol catalyzed by (R)-CF_3-PIP 1[1]

Both experiments described below were performed in duplicate. A one-dram vial was charged with 0.25 mmol of racemic 1-phenylethanol, 100 mg of Na_2SO_4, 1.00 mL of the stock solution of the catalyst (0.010 M of **1** and 0.188 M of *i*-Pr_2NEt in $CDCl_3$) and a stir bar, closed with a rubber septum and stirred at room temperature for 15 minutes. Acetic or propionic anhydride (0.188 mmol) was added via syringe through the septum. The reactions were monitored by periodically withdrawing aliquots and checking them by ^1H NMR. The reactions were stopped by quenching with methanol after reaching ca.50% conversion by NMR. The workup and HPLC analysis followed the previously described standard procedure.[4a]

Table S-1. Enantioselectivity data

Entry	Anhydride	t(h)	#	ee_{PR} %	ee_{SM} %	C_{HPLC} %	s	C_{AVG} %	s_{AVG}	ΔG_{rel}[a] (kcal/mol)
1	$(MeCO)_2O$	4.0	1	71.8	66.1	47.9	12.0	48	12	1.5
			2	72.9	67.6	48.1	12.8			
2	$(EtCO)_2O$	2.3	1	85.8	66.8	43.8	26.1	44	26	1.9
			2	86.0	66.4	43.5	26.5			

[a] ΔG_{rel} (kcal/mol) = RT ln (k_R/k_S) = 1.987×10^{-3} (kcal·K^{-1}·mol^{-1}) × 298 (K) × ln s_{AVG}

III. (a) Preparation of N-acetyl-(R)-CF_3PIP hexafluoroantimonate 5a

Acetyl chloride (10 μL, 0.14 mmol) was added via syringe to a bright-yellow solution of (R)-CF_3-PIP **1** (28.2 mg, 0.107 mmol) in CH_2Cl_2 (1 mL). The solution immediately became colorless. After 5 minutes, the solvent and the excess acetyl chloride were rotary evaporated. A solution of $AgSbF_6$ (37 mg) in CH_3CN (~ 0.5 mL) was then added to the residue, resulting in the formation of a grainy white precipitate. After 35 minutes, the precipitated AgCl was filtered off. The filtrate was left at room temperature for several days to allow slow crystallization. One of the colorless crystals of **5a** thus obtained was used in the X-ray crystallography analysis producing the structure presented below. Additional details may be found in the accompanying .cif file.

[1] The 0.25 M substrate concentration used in the present study was previously shown to give the highest selectivity (Ref. 4c)

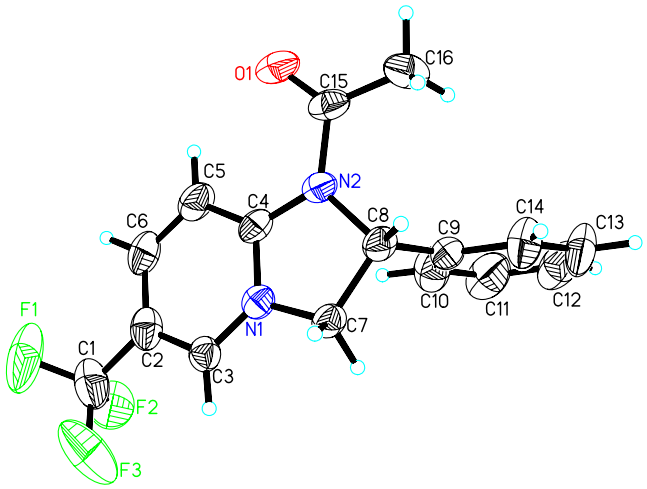


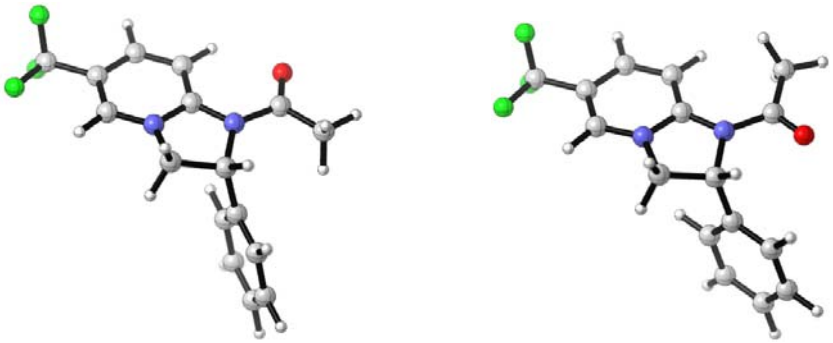
Figure S-1. Projection view of **5a** with 50% thermal ellipsoids. Anion not shown

IV. Details of the computational study.

All geometry optimizations and frequency calculations were performed in Gaussian 03.[1] Figures for the transition state structures are prepared with CYLview.[2] The Cartesian coordinates (Å), total SCF energies, enthalpies at 298K, and Gibbs free energies at 298K for the optimized structures are given below.

(a) Geometry of N-acetyl-(R)-CF_3-PIP^+ (5)

A1. Geometry of N-acetyl-(R)-CF_3-PIP^+ (**5**) was optimized at the B3LYP/6-31G* level. The global minimum (**5′**) was found to be in a good agreement with the X-ray structure **5a** shown above. Optimization of the conformer with the acetyl group rotated *ca.* 180° led to structure **5′′**, which was 4.7 kcal/mol higher in energy.



5′
ΔG_{rel} = 0.0 kcal/mol

5′′
ΔG_{rel} = 4.7 kcal/mol

Figure S-2. Geometry of N-acetyl-(R)-CF_3-PIP^+ **5a** and **5b**

5´

C	-1.64244600	2.46956000	0.13436900
O	-1.02642000	3.22993000	0.84702800
C	-3.06126300	2.68974200	-0.31973900
H	-3.10558100	2.82435600	-1.40734200
H	-3.70746700	1.84743000	-0.05530900
H	-3.42502000	3.59720600	0.16266800
N	-1.00105700	1.28684700	-0.35721900
C	0.31069600	0.98115300	-0.11686200
C	-1.67200600	0.19772800	-1.13195400
C	1.27611000	1.61520500	0.68753700
N	0.66021500	-0.13975300	-0.81022800
C	-0.45648800	-0.61718500	-1.65617000
C	2.54201000	1.06148900	0.74421800
H	1.00300900	2.50463500	1.23487100
C	1.89574900	-0.69169100	-0.75805900
H	-0.21948500	-0.39754800	-2.70122900
H	-0.59299400	-1.69139900	-1.52600500
C	2.86448700	-0.10686800	0.02128900
H	3.30106600	1.53247700	1.36158300
H	2.06034900	-1.58403300	-1.34923900
C	4.25166800	-0.70449600	0.10885800
F	4.52374100	-1.06836600	1.37228100
F	4.35931100	-1.78771200	-0.68141700
F	5.17224200	0.19594300	-0.26967300

5´´

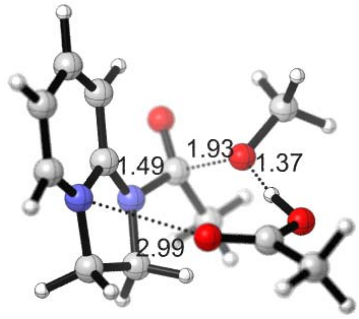
C	1.83022300	2.38703400	-0.01957100
O	2.93855900	2.43372900	0.45807500
C	1.26048900	3.45779900	-0.91489200
H	1.04697500	3.06716500	-1.91610100
H	0.34643400	3.89584700	-0.49966400
H	2.01628700	4.23927700	-0.99975500
N	1.03057600	1.23846000	0.30340600
C	-0.27787300	0.95374300	0.06138900
C	1.67274600	0.16495600	1.14666900
C	-1.23016800	1.53498800	-0.80006300
N	-0.66554600	-0.12061300	0.81555100
C	0.43757300	-0.59418600	1.68599300
C	-2.50669300	1.00773500	-0.83670800
H	-0.96537200	2.36704100	-1.43353500
C	-1.91144300	-0.64851500	0.78412700
H	0.19820300	-0.33373800	2.72088600
H	0.54250800	-1.67592000	1.59336600
C	-2.86452700	-0.09807000	-0.03756100
H	-3.24431400	1.44607700	-1.50218200
H	-2.09671000	-1.50110500	1.42619100
C	-4.26545900	-0.66569600	-0.09495100
F	-4.55924400	-1.05439600	-1.34627700
F	-4.38849700	-1.72416700	0.72450100
H	-2.19553900	0.64395300	-1.97997800
C	-2.64785100	-0.62611700	-0.30960000
C	-3.81956900	-1.08804400	-0.92267700
C	-2.37827500	-0.98401500	1.01841400
C	-4.70758200	-1.90414000	-0.22070000
H	-4.04242800	-0.80986300	-1.95065100
C	-3.27021700	-1.79532100	1.71973300
H	-1.48438400	-0.62170000	1.52038700
C	-4.43372500	-2.25853600	1.10111300
H	-5.61455100	-2.25400000	-0.70421300
H	-3.05805100	-2.06212900	2.75065300
H	-5.12711600	-2.88805200	1.65036600

SCF Done: E(RB+HF-LYP) = -1102.18571549
Sum of electronic and zero-point
Energies= -1101.907378
Sum of electronic and thermal
Energies= -1101.888783
Sum of electronic and thermal
Enthalpies= -1101.887839
Sum of electronic and thermal
Free Energies= -1101.957194

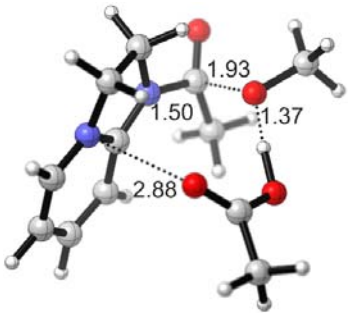
F	-5.16095700	0.26585800	0.26914800
H	2.19820000	0.66946700	1.95679400
C	2.65025200	-0.68402500	0.35859100
C	4.01216300	-0.63315900	0.67447100
C	2.21503300	-1.52928000	-0.67315500
C	4.92635300	-1.42324700	-0.02346500
H	4.35938300	0.03260000	1.45928300
C	3.12918300	-2.31410000	-1.37337000
H	1.16133300	-1.58181600	-0.94263800
C	4.48695700	-2.26339200	-1.04691600
H	5.98069800	-1.37823000	0.23159400
H	2.78351600	-2.96535000	-2.17060800
H	5.19860100	-2.87724700	-1.59080100

SCF Done: E(RB+HF-LYP) = -1102.17833646
Sum of electronic and zero-point
Energies= -1101.899847
Sum of electronic and thermal
Energies= -1101.881367
Sum of electronic and thermal
Enthalpies= -1101.880423
Sum of electronic and thermal
Free Energies= -1101.949708

A2. To verify that the same trend is observed in the transition state, a simplified system was employed, using the unsubstituted heterocyclic core—2,3-dihydroimidazo[1,2-a]pyridine (DHIP)— instead of CF_3-PIP and methanol instead of 1-phenylethanol. Transition structures for the model reaction of the two conformers of N-acetyl-DHIP acetate with the acetyl group oriented analogously to **5´** and **5´´** were optimized at the B3LYP/6-31G* level (Figure S-3). Transition state model $\mathbf{TS_{model}}$**-5´´** was confiormed to be less favorable by 4.2 kcal/mol.



TS_{model}-5′
ΔG_{rel} = 0.0 kcal/mol



TS_{model}-5′′
ΔG_{rel} = 4.2 kcal/mol

Figure S-3. TS of N-acetyl-DHIP acetate with methanol **5c** and **5d**

TS_{model}-5′

C	0.46901700	-2.19472800	-0.38905100
O	-0.89114700	-1.42828200	0.74166600
C	-1.15813900	-2.24091200	1.85063300
O	1.29188700	-2.75165900	0.33597600
C	-0.42670200	-2.98730400	-1.32715700
O	-2.82542000	0.07323000	0.47668500
C	-2.57708700	1.33002800	0.20940400
O	-1.48575300	1.78444400	-0.14286000
C	-3.79838000	2.22076500	0.37287300
H	-0.79597400	-3.84807200	-0.76680800
H	0.16739700	-3.36232300	-2.17156800
H	-1.28062900	-2.42197200	-1.70345100
H	-3.58101600	3.23285800	0.02637100
H	-4.09115300	2.25146300	1.42847400
H	-4.64583800	1.80591000	-0.18242800
H	-1.92637000	-0.56222200	0.52788400
H	-1.28731500	-1.63442500	2.76285600
H	-0.31007500	-2.92142300	2.01998900
H	-2.07053200	-2.85279400	1.72837200
N	0.84679400	-0.85985500	-0.93935600
C	1.47112700	0.04611400	-0.16678300
C	0.07522100	-0.16646800	-1.98834900
C	2.14890400	-0.11409400	1.06512100
N	1.40697300	1.29125900	-0.72124900
C	0.67420500	1.25248600	-2.00190500
H	0.19222600	-0.67275100	-2.94916200
H	-0.97918400	-0.13177200	-1.70921300
C	2.69502100	1.00331400	1.65527200
H	2.19372400	-1.10896700	1.48402900
C	1.93498400	2.39474600	-0.13887000
H	1.38572600	1.40751600	-2.82014600
H	-0.09580600	2.02248900	-1.99854000
C	2.59506700	2.28323200	1.05716600
H	3.20731600	0.90012500	2.60738600
H	1.78955200	3.32804100	-0.66935500
H	3.01561500	3.16353900	1.52767900

SCF Done: E(RB+HF-LYP) = -878.492805024
Sum of electronic and zero-point
Energies= -878.198201
Sum of electronic and thermal
Energies= -878.179204
Sum of electronic and thermal
Enthalpies= -878.178260
Sum of electronic and thermal
Free Energies= -878.247399

TS_{model}-5′′

C	1.91417100	1.13118700	-0.55352600
O	2.10456000	-0.58570400	0.30207000
C	3.45215900	-0.94320600	0.43798300
O	2.80724500	1.86233200	-0.14410900
C	1.86089300	0.62999900	-1.98545500
O	0.68445400	-2.49367300	-0.35216800
C	-0.50332300	-2.54311100	0.19806100
O	-0.99817000	-1.67680000	0.92147600
C	-1.25655000	-3.81931700	-0.14546400
H	2.87372400	0.31313100	-2.24224700
H	1.59059500	1.44974900	-2.66511900
H	1.18651900	-0.21738600	-2.12127600
H	-2.27642000	-3.77504400	0.24130400
H	-0.73776900	-4.68022700	0.29109800
H	-1.27070100	-3.97070200	-1.22984000
H	1.28182800	-1.62345100	-0.03504100
H	3.62845400	-1.46418800	1.39360100
H	4.07324100	-0.03418400	0.43259500
H	3.80465200	-1.60621200	-0.37269600
N	0.58380600	1.32999200	0.11974200
C	-0.67502700	1.15168200	-0.27881500
C	0.64100500	1.57025900	1.57305900
C	-1.25228200	1.03172200	-1.57095100
N	-1.53065300	1.15212600	0.79793800
C	-0.74950300	1.13153800	2.05503200
H	1.44249900	0.95993600	1.98413400
H	0.84561500	2.62891600	1.76255500
C	-2.61627700	0.88566500	-1.67898100
H	-0.62108900	1.06547900	-2.44572600
C	-2.86689500	0.97703700	0.69323700
H	-0.75279600	0.09915800	2.41180000
H	-1.19486200	1.80800600	2.78753300
C	-3.45373500	0.85369900	-0.53932900
H	-3.05781100	0.79924600	-2.66760800
H	-3.41428900	0.95045500	1.62821400
H	-4.52599700	0.73033400	-0.62430400

SCF Done: E(RB+HF-LYP) = -878.486723622
Sum of electronic and zero-point
Energies= -878.192047
Sum of electronic and thermal
Energies= -878.173146
Sum of electronic and thermal
Enthalpies= -878.172202
Sum of electronic and thermal
Free Energies= -878.240754

(b) Conformational search on the transition state of a model system, N- Acetyl-DHIP$^+$ AcO$^-$, with (R)- and (S)-1-phenylethanol, at HF/3-21G level of theory

To locate the most stable conformations of the transition states, a conformational search was performed at HF/3-21G level on a model system. The unsubstituted DHIP was used as a simplified model of CF_3-PIP in these calculations (Figure S-4). Diastereomeric transition state structures (R)-TS_{HF} and (S)-TS_{HF} were obtained by complexing the (R)- and (S)-enantiomers of 1-phenylethanol hydrogen-bound to the acetate anion on the *Si*-face of the carbonyl carbon C^2.

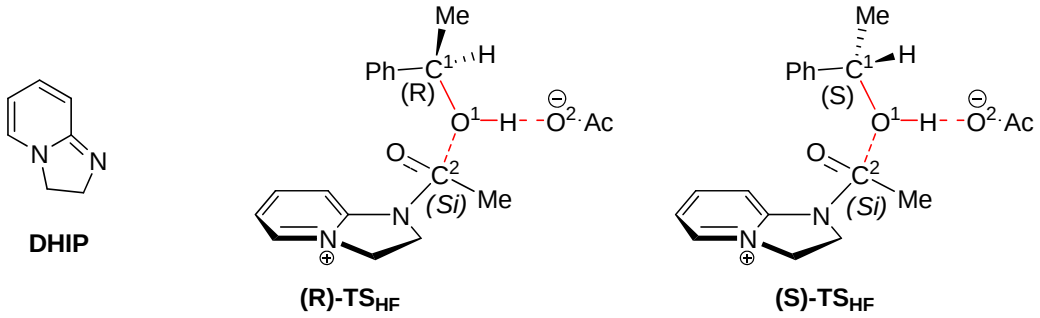
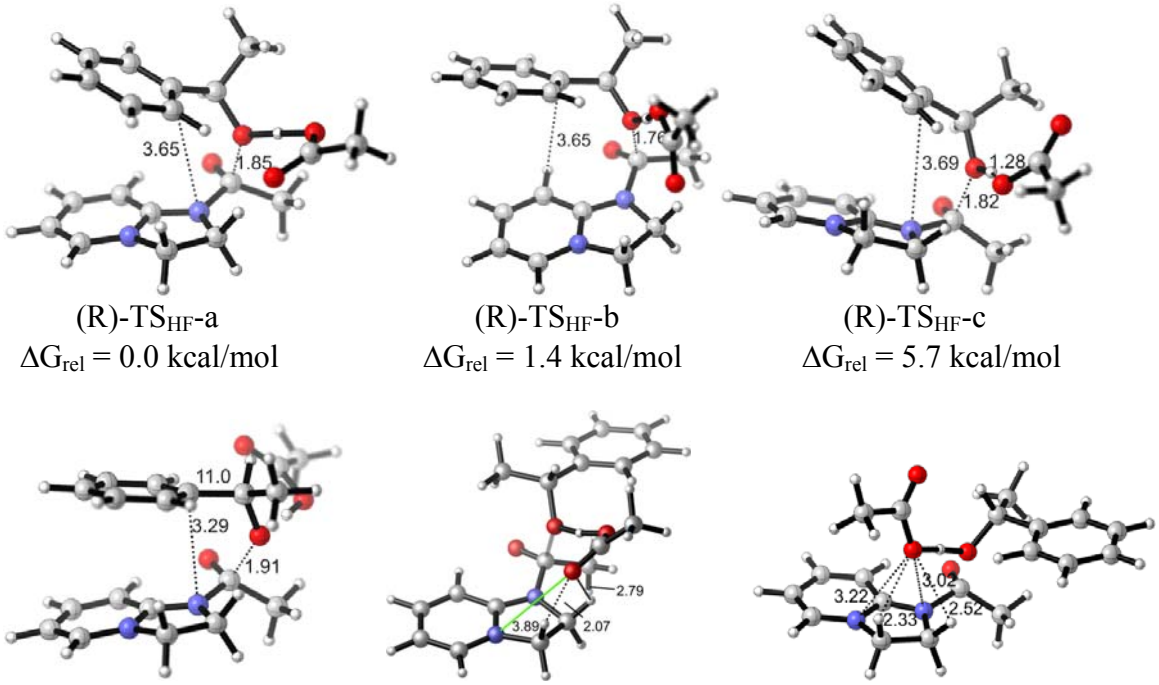


Figure S-4. Structures of DHIP-based diastereomeric transition states

For each of these structures, the starting geometries were generated by manually rotating each of the three highlighted bonds—C^1-O^1, O^1-C^2, and O^1-H-O^2—by 120°. Out of 27 structures thus generated for (R)-TS_{HF}, 8 transition state conformers were produced (Figure S-5). The analogous operation performed with (S)-TS_{HF} resulted in 6 TS structures (Figure S-6).



(R)-TS_{HF}-a
ΔG_{rel} = 0.0 kcal/mol

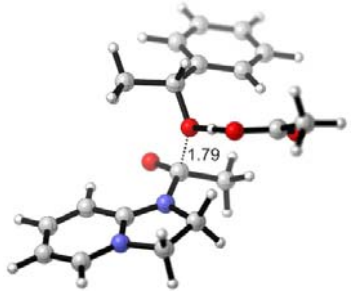
(R)-TS_{HF}-b
ΔG_{rel} = 1.4 kcal/mol

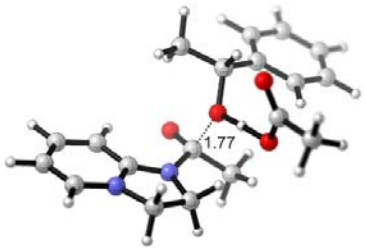
(R)-TS_{HF}-c
ΔG_{rel} = 5.7 kcal/mol

(R)-TS_{HF}-d
ΔG_{rel} = 22.5 kcal/mol

(R)-TS_{HF}-e
ΔG_{rel} = 8.3 kcal/mol

(R)-TS_{HF}-f
ΔG_{rel} = 11.0 kcal/mol





(R)-TS_{HF}-g
ΔG_{rel} = 12.2 kcal/mol

(R)-TS_{HF}-h
ΔG_{rel} = 13.3 kcal/mol

Figure S-5. TS of N-Acetyl-DHIP+ AcO^- and (R)-1-phenylethanol

(R)-**TS_{HF}-a**

```
 C  0.26654600  -1.71200400  -1.46664700
 O  1.24944300  -0.20003300  -1.05987600
 C  0.78052500   1.00125000  -1.67163900
 O -0.39914200  -1.47241000  -2.48367600
 C  1.45688000  -2.64406700  -1.47652100
 O  3.48042200  -0.23482100  -0.18321100
 C  3.59264700  -0.18081400   1.10112200
 O  2.64304600  -0.24594400   1.89493800
 C  5.01575300  -0.03139900   1.59896200
 H  1.96926400  -2.49165600  -2.41392100
 H  1.10113300  -3.66821000  -1.43423500
 H  2.14547800  -2.45356000  -0.67238600
 H  5.61630200  -0.84361900   1.20838900
 H  5.03540000  -0.02929800   2.67706200
 H  5.42911500   0.89282500   1.21316500
 H  2.35008400  -0.21382100  -0.65768600
 N -0.46129500  -1.74370800  -0.19937500
 C -1.72351500  -1.36209300  -0.05668000
 C  0.19992000  -1.96585700   1.11038500
 C -2.71479200  -1.08051200  -1.02775800
 N -2.05842900  -1.26783900   1.24562600
 C -0.87567900  -1.49777800   2.12573000
 H  0.42212600  -3.01586800   1.22973100
 H  1.08709500  -1.36401700   1.20188100
 C -3.95463100  -0.74162600  -0.59981200
 H -2.42273600  -1.13788700  -2.04775400
 C -3.29865500  -0.91706200   1.67277800
 H -1.11246500  -2.24450800   2.86653100
 H -0.60082600  -0.56386400   2.58906400
```

(R)-**TS_{HF}-b**

```
 C  0.74335900  -0.25123300  -2.14646300
 O  0.37636900   1.07418800  -1.05539900
 C -0.88683700   1.71865900  -1.30308800
 O -0.29937200  -0.53213000  -2.77827300
 C  1.93557400   0.37061800  -2.84807900
 O  1.53178700   2.21960200   0.70469200
 C  2.48642500   1.83554800   1.49510500
 O  3.06635600   0.75141700   1.43756900
 C  2.85017000   2.87188900   2.53739900
 H  1.54960200   1.13640300  -3.50363900
 H  2.42780700  -0.38246200  -3.45330400
 H  2.63845000   0.81431100  -2.16331900
 H  3.15900500   3.78158500   2.03718200
 H  3.64249000   2.50345400   3.16912800
 C -4.27321300  -0.65689300   0.78045700
 H -4.71477400  -0.52753900  -1.32343300
 H -3.43485000  -0.86464700   2.73132100
 H -5.25241700  -0.38299000   1.10669200
 C -0.01655700   1.84837300  -0.68934400
 C -1.02382200   2.68107200  -1.15366500
 C  0.26487600   1.82670200   0.66984400
 C -1.73647100   3.48853400  -0.28381100
 H -1.25329100   2.69732700  -2.20276000
 C -0.44583400   2.63800400   1.53955400
 H  1.03723900   1.18930400   1.04980700
 C -1.44818100   3.46984900   1.06939800
 H -2.51028600   4.12881200  -0.66072500
 H -0.20636600   2.62799900   2.58586100
 H -1.99253200   4.09882700   1.74649100
 C  1.97250500   1.80309700  -2.22581300
 H  2.50708600   1.20368900  -2.95332700
 H  2.65398600   2.05212300  -1.42367600
 H  1.62999000   2.71536500  -2.69896500
 H  0.13435000   0.70103200  -2.48551400

SCF:  E(RHF) =  -1135.48027039
Sum of electronic and zero-point
Energies=-1135.044929
Sum of electronic and thermal
Energies=-1135.022435
Sum of electronic and thermal
Enthalpies=-1135.021491
Sum of electronic and thermal
Free Energies=-1135.098177
```

```
 H  1.97349800   3.10844200   3.12774000
 H  1.04326100   1.59663800  -0.17358400
 N  1.16499100  -1.21431000  -1.11463600
 C  0.30769500  -1.96559200  -0.43889200
 C  2.54448700  -1.34844500  -0.58356500
 C -1.07358100  -2.18322400  -0.65031700
 N  0.90872500  -2.58431700   0.59634800
 C  2.33416400  -2.15544400   0.72143600
 H  3.16139200  -1.87210400  -1.29844400
 H  2.95071900  -0.39253800  -0.31884600
 C -1.73167200  -2.99717400   0.20908900
 H -1.51703700  -1.68414600  -1.47742400
 C  0.24936600  -3.40567800   1.45429500
 H  2.97154700  -3.02116300   0.80076900
 H  2.43892500  -1.49379600   1.56552800
 C -1.06727200  -3.63716600   1.28906700
```

```
H -2.78057000  -3.16187600   0.07071200
H  0.83335900  -3.83293000   2.24065900
H -1.59508200  -4.28033000   1.95869400
H -1.22537700   1.34876700  -2.25800700
C -1.91958600   1.34231700  -0.25162800
C -3.22391200   1.06160900  -0.62674800
C -1.58192900   1.28818700   1.09378200
C -4.18009200   0.73527300   0.32154200
H -3.49255400   1.09208300  -1.66564300
C -2.53414700   0.96206100   2.04157600
H -0.57985300   1.52201900   1.38568500
C -3.83674200   0.68240400   1.66007500
H -5.18620000   0.52404000   0.01497600
H -2.26300400   0.93024900   3.07919800
H -4.57421600   0.43272000   2.39770600
```

(R)-TS_{HF}-c

```
 C -0.08736700   1.71625700  -1.51021000
O -1.16301100   0.31137100  -1.09612500
C -0.83968600  -0.96488600  -1.65749300
O  0.57642000   1.40741100  -2.51015900
C -1.20820000   2.73168100  -1.54487100
O -2.64841400   0.66427700   0.74699600
C -3.85908800   0.18366000   0.90998200
O -4.35732700  -0.69396100   0.22585500
C -4.60749400   0.82452300   2.06641100
H -1.74149800   2.58104300  -2.47064500
H -0.78056600   3.72881700  -1.54401300
H -1.89361300   2.61520300  -0.72269500
H -4.04503600   0.67926900   2.98144400
H -5.58939700   0.38860000   2.15956400
H -4.68545800   1.89156800   1.89421200
H -1.94197300   0.39525800  -0.29001600
N  0.63674200   1.73944800  -0.22907100
C  1.86643600   1.27276100  -0.06334700
C  0.00581200   2.09601500   1.06877400
C  2.83996100   0.88546200  -1.01608700
N  2.18489800   1.19676300   1.24513900
C  1.00811800   1.51934400   2.10224800
H -0.06011800   3.17143600   1.14969500
H -0.96894400   1.64403700   1.14910300
C  4.04854200   0.47170700  -0.56598000
H  2.55780100   0.93076400  -2.03968300
C  3.39456200   0.77134300   1.69509300
H  1.28878800   2.23216900   2.86072000
H  0.64894800   0.60335500   2.54441000
```

(R)-TS_{HF}-d

```
 C  0.82085400   1.46216800  -0.57279300
O  1.52006600  -0.21516900  -1.15030700
C  1.36880300  -1.59634600  -0.75751500
O  1.04187300   1.66025700   0.62148600
C  1.56980100   2.18004000  -1.67434500
O  3.74442500   0.44810300  -0.33450200
C  3.93112900   0.20968100   0.95100300
O  3.27396400  -0.57302500   1.61256900
C  5.08369400   1.00601800   1.51278600
H  2.61005600   2.20399100  -1.39795800
H  1.18699000   3.19492000  -1.73157800
H  1.46681800   1.68897900  -2.62506000
H  5.96116200   0.84972300   0.89872000
H  5.27457800   0.71208600   2.53262500
H  4.83243400   2.05930400   1.46976700
H  2.81786400   0.12149200  -0.73851500
N -0.57473900   1.20134400  -0.93956000
C -1.59901900   1.29480900  -0.10711200
C -0.97432800   0.65301200  -2.24946400
C -1.67220000   1.82708500   1.20361900
N -2.73122100   0.84075700  -0.68039200
C -0.68348900   3.24128100  -1.35315200
H -1.62601200   3.74141800  -1.54130600
H  0.01193900   3.48986300  -2.14729600
H -0.27110600   3.58979500  -0.41646200

SCF:  E(RHF) =  -1135.47657218
Sum of electronic and zero-point
Energies= -1135.041663
Sum of electronic and thermal
Energies= -1135.019033
Sum of electronic and thermal
Enthalpies= -1135.018089
Sum of electronic and thermal
Free Energies= -1135.096005
```

```
C  4.35207100   0.41169100   0.81981000
H  4.79577300   0.17850300  -1.27511900
H  3.52068100   0.74510400   2.75586700
H  5.30739000   0.07989500   1.16273600
C -0.11162600  -1.84648100  -0.65098600
C  0.84273600  -2.75283100  -1.08639400
C -0.40382900  -1.78069500   0.70499100
C  1.49267000  -3.58555500  -0.19097700
H  1.07904700  -2.80843100  -2.13229100
C  0.24326700  -2.61459500   1.60068500
H -1.14614200  -1.09020500   1.04788800
C  1.19478800  -3.51867400   1.15822200
H  2.22539100  -4.28387100  -0.54598400
H -0.00694200  -2.57061400   2.64362200
H  1.69004400  -4.16744300   1.85384400
C -2.13075500  -1.63654800  -2.15602300
H -2.54226200  -1.05396100  -2.97277700
H -2.86550500  -1.66611700  -1.36300500
H -1.92665000  -2.64043500  -2.50898800
H -0.17809700  -0.75527400  -2.48598100

SCF:  E(RHF) =  -1135.47182965
Sum of electronic and zero-point
Energies= -1135.035629
Sum of electronic and thermal
Energies= -1135.013333
Sum of electronic and thermal
Enthalpies= -1135.012389
Sum of electronic and thermal
Free Energies= -1135.089140
```

```
C -2.45387100   0.24189400  -2.01781000
H -0.89471900   1.41518000  -3.01012600
H -0.32512600  -0.17115500  -2.46790900
C -2.88176000   1.87388700   1.80861400
H -0.76023600   2.13813100   1.65280500
C -3.94096600   0.86391100  -0.06061500
H -3.12465300   0.66074300  -2.75074800
H -2.57156200  -0.82599000  -1.94265700
C -4.05613400   1.38577300   1.17443900
H -2.95509000   2.28030200   2.79691100
H -4.76114200   0.45699500  -0.61146100
H -5.00332800   1.41746000   1.66664200
C  0.08824800  -1.86969200   0.03245700
C -0.96513200  -2.63743900  -0.43896200
C  0.00768500  -1.34417100   1.32105200
C -2.08582300  -2.87142300   0.34975600
H -0.91113400  -3.08606300  -1.41097900
C -1.10362600  -1.57957100   2.10593700
H  0.83474500  -0.76832600   1.68476500
C -2.15914000  -2.34105200   1.62252400
H -2.88236700  -3.48607500  -0.02488300
H -1.14403800  -1.17969500   3.10024000
H -3.01511600  -2.53252100   2.24011700
```

```
C  1.51886700  -2.45626100  -2.01934000
H  2.47059800  -2.22030400  -2.47803500
H  0.74141800  -2.23480700  -2.74305300
H  1.49482200  -3.51534800  -1.78814200
H  2.17363000  -1.84897400  -0.08118300
SCF:  E(RHF) =  -1135.44734199
Sum of electronic and zero-point
Energies= -1135.009787
Sum of electronic and thermal
Energies= -1134.987559
Sum of electronic and thermal
Enthalpies= -1134.986615
Sum of electronic and thermal
Free Energies= -1135.062353
```

(R)-TS_{HF}-e

```
C -0.03844200   1.12834300  -0.91432600
O  0.49104600   0.00619700   0.25848500
C  1.48760100   0.33007900   1.26249700
O -0.01684000   2.29980400  -0.46671900
C  0.83857700   0.74296500  -2.09302900
O  0.60916000  -2.36671800   0.04748800
C -0.21648600  -3.25948700   0.53125900
O -1.42061200  -3.09214200   0.68145000
C  0.45998700  -4.56944300   0.87237900
H  1.82290100   1.13930900  -1.90388600
H  0.43782000   1.21300600  -2.98397000
H  0.91444800  -0.32216400  -2.23621700
H  0.96752700  -4.94575300  -0.00730000
H -0.26666600  -5.28408700   1.22420800
H  1.21284800  -4.39416400   1.63146300
H  0.45105600  -1.20023400   0.11744500
N -1.39159400   0.51811000  -1.05622700
C -2.44950200   0.93350400  -0.37606600
C -1.66492300  -0.76510200  -1.74745700
C -2.65649400   2.13071000   0.35095400
N -3.45338100   0.03498100  -0.43400000
C -3.00537700  -1.21879500  -1.11695700
H -1.74672900  -0.59547200  -2.81111300
H -0.88866400  -1.47476000  -1.53355700
C -3.85992700   2.31902400   0.94460400
H -1.84062400   2.81197100   0.38582500
C -4.65431000   0.22100700   0.16837000
H -3.74018900  -1.52310200  -1.84436300
H -2.81029300  -1.97069500  -0.36933500
```

(R)-TS_{HF}-f

```
C -0.16781700   1.87841000  -0.07518400
O  0.61065200   0.38793600   0.39745300
C  1.76266400   0.24060800   1.26660400
O -0.53994000   2.53643100   0.91375900
C  0.87430200   2.41974200  -1.03510800
O -0.55658200  -1.66624400   0.00259700
C -0.49604800  -2.60853000   0.91999900
O  0.14629800  -2.52681400   1.95157400
C -1.31490900  -3.83542100   0.56812900
H  1.68217100   2.83188300  -0.45136200
H  0.42447000   3.22304400  -1.60827600
H  1.27368100   1.66702200  -1.69138400
H -2.35420500  -3.55086600   0.44874600
H -1.22144600  -4.57710700   1.34510600
H -0.96902000  -4.23818600  -0.37651100
H  0.01307200  -0.63588100   0.24592000
N -1.23675900   1.15587100  -0.81538600
C -2.42945800   0.89172300  -0.30262400
C -1.00055500   0.39375000  -2.06111800
C -3.05978700   1.40840500   0.85576800
N -3.10059200   0.00128500  -1.05780600
C -2.23239100  -0.54436400  -2.14139100
H -0.94933200   1.06897300  -2.90185700
H -0.09478200  -0.17449700  -1.96903200
C -4.31420700   0.98654500   1.14276200
H -2.49344300   2.09253100   1.44101300
C -4.35590400  -0.42664500  -0.76457300
H -2.74805900  -0.49393800  -3.08642900
H -1.95142300  -1.54433700  -1.86569900
```

```
C -4.89679600   1.35342600   0.85826600
H -4.03447400   3.22195800   1.49403700
H -5.36370800  -0.57076300   0.06029700
H -5.84097300   1.51147500   1.33165400
C  2.86249100   0.49996200   0.62394100
C  3.57308200   1.68631000   0.64055600
C  3.41311400  -0.60531800  -0.02008400
C  4.82025500   1.76951500   0.03709400
H  3.16090100   2.55281900   1.11433100
C  4.65347100  -0.52415100  -0.61939500
H  2.84894500  -1.51728600  -0.05328000
C  5.36410400   0.66685800  -0.59100700
H  5.35890900   2.69657700   0.05821500
H  5.06689600  -1.38400200  -1.10929800
H  6.32840400   0.73097200  -1.05565900
C  1.02513900   1.48760200   2.15057200
H  0.05241500   1.23787600   2.55753200
H  0.92597000   2.38980600   1.57405800
H  1.71957900   1.62565000   2.97146400
H  1.54309900  -0.55977700   1.88039100

SCF:  E(RHF) =  -1135.46619992
Sum of electronic and zero-point
Energies= -1135.030860
Sum of electronic and thermal
Energies= -1135.008413
Sum of electronic and thermal
Enthalpies= -1135.007469
Sum of electronic and thermal
Free Energies= -1135.084946
```

```
C -4.99634200   0.05081000   0.31972800
H -4.80510000   1.36631800   2.01574000
H -4.77853500  -1.14382500  -1.43471900
H -5.98555900  -0.27506700   0.55605100
C  2.99880900   0.01088700   0.39976100
C  4.22113400   0.61858500   0.62649100
C  2.88633300  -0.88060900  -0.66439600
C  5.31021600   0.34690800  -0.19063900
H  4.33787100   1.30603800   1.43889500
C  3.96784700  -1.15448200  -1.47556500
H  1.94563100  -1.36455300  -0.83309400
C  5.18824300  -0.53688900  -1.24334600
H  6.24922900   0.82866700   0.00057100
H  3.86595800  -1.85026200  -2.28574900
H  6.02963200  -0.74795300  -1.87355700
C  1.87985600   1.39338600   2.27057300
H  0.91589800   1.56157700   2.72306600
H  2.18270100   2.31715600   1.79761400
H  2.60082000   1.13506300   3.03765000
H  1.57588000  -0.66928800   1.82134900

SCF:  E(RHF) =  -1135.46186351
Sum of electronic and zero-point
Energies= -1135.026506
Sum of electronic and thermal
Energies= -1135.004082
Sum of electronic and thermal
Enthalpies= -1135.003138
Sum of electronic and thermal
Free Energies= -1135.080582
```

(R)-TS_{HF}-g

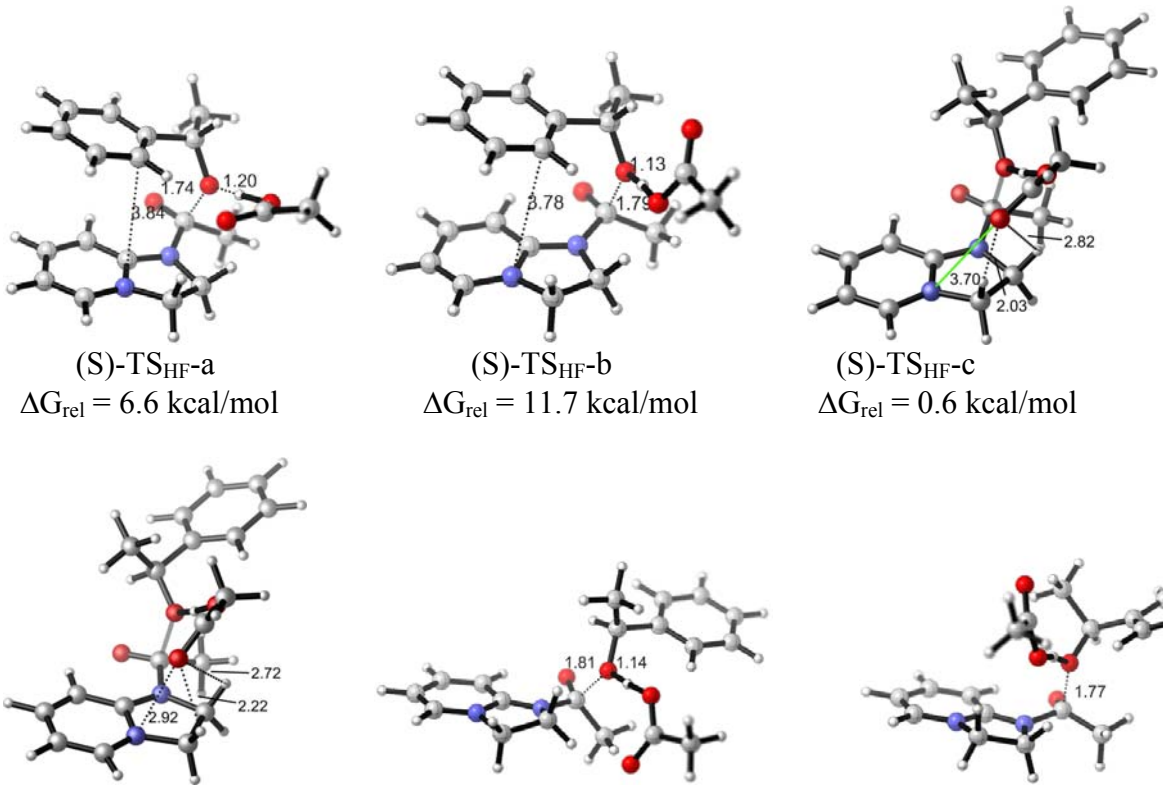
C	-0.29783900	0.55238200	-1.03264900
O	0.49330800	-0.16858800	0.40309000
C	1.33394800	0.59746200	1.29197500
O	-0.27650200	1.79047900	-0.95402100
C	0.46948900	-0.20852200	-2.09281800
O	0.43894700	-2.48932300	1.00761500
C	1.26470100	-3.28776900	0.37925900
O	1.91628300	-2.97201900	-0.60995500
C	1.34129000	-4.67498000	0.98341800
H	1.40601000	0.30878000	-2.22810100
H	-0.08959100	-0.16377600	-3.02226400
H	0.68542500	-1.22690500	-1.81987100
H	1.69488100	-4.59548900	2.00449700
H	2.00628400	-5.29609900	0.40484500
H	0.34926900	-5.10915400	1.01572800
H	0.47476000	-1.31023300	0.68686900
N	-1.62841000	-0.08109300	-0.78272200
C	-2.69209700	0.57287200	-0.35849600
C	-1.87104500	-1.54437900	-0.85365800
C	-2.90107300	1.96356600	-0.15518300
N	-3.72166900	-0.26737900	-0.10835800
C	-3.33103500	-1.68520000	-0.33640300
H	-1.77789800	-1.88139400	-1.87377200
H	-1.17541100	-2.05687600	-0.21449600
C	-4.11584300	2.37551800	0.27315500
H	-2.07706000	2.60407500	-0.35656000
C	-4.94228900	0.15108500	0.32519800
H	-3.99184700	-2.12992900	-1.06402700
H	-3.37922000	-2.22284100	0.59796200
C	-5.17572700	1.46012600	0.52519600
H	-4.28586100	3.42182900	0.42717100
H	-5.67107800	-0.61347900	0.48849200
H	-6.12977200	1.79893900	0.86503200
C	2.61266000	1.04987500	0.59123500
C	3.30420700	0.12253900	-0.18306100
C	3.13690400	2.32351300	0.73151300
C	4.49429100	0.46855000	-0.79334100
H	2.90777900	-0.86427500	-0.31671800
C	4.33161400	2.67019600	0.11828000
H	2.61910500	3.05921600	1.31123700
C	5.01473400	1.74465000	-0.64481500
H	5.01482700	-0.25846900	-1.38559800
H	4.71994900	3.66305800	0.23664000
H	5.93851200	2.01097300	-1.12005600
C	0.52812200	1.71687800	1.96148800
H	-0.37784600	1.28378900	2.36975100
H	0.26071400	2.46438000	1.23367400
H	1.08797900	2.16254100	2.77518000
H	1.63428700	-0.10351100	2.06635300

SCF: E(RHF) = -1135.46057555
Sum of electronic and zero-point
Energies= -1135.025119
Sum of electronic and thermal
Energies= -1135.002693
Sum of electronic and thermal
Enthalpies= -1135.001749
Sum of electronic and thermal
Free Energies= -1135.078806

(R)-TS_{HF}-h

C	-0.32806500	0.90024200	-1.12628200
O	0.45580700	-0.06947300	0.13558100
C	1.35321700	0.42815300	1.16317600
O	-0.33313500	2.10325200	-0.81813200
C	0.46007900	0.37637900	-2.30927200
O	0.74029200	-2.41454100	-0.28575100
C	0.93930300	-3.19803400	0.75015100
O	1.01101400	-2.80849400	1.90528700
C	1.08576300	-4.66151700	0.37798500
H	1.43680400	0.83111500	-2.26711200
H	-0.03658300	0.69463700	-3.21957500
H	0.57312300	-0.69473700	-2.29950400
H	0.21346200	-4.98407000	-0.17783700
H	1.20965700	-5.26086800	1.26601300
H	1.94536600	-4.77521000	-0.27200700
H	0.59549600	-1.18310900	-0.03801800
N	-1.63521000	0.19315100	-1.00848600
C	-2.67406800	0.67814500	-0.35357300
C	-1.86339400	-1.21211100	-1.43678200
C	-2.90112400	1.97235200	0.18259600
N	-3.64599600	-0.25018900	-0.21371000
C	-3.20859300	-1.57018700	-0.74714700
H	-1.95372200	-1.24982000	-2.51198200
H	-1.05696000	-1.84057000	-1.09904500
C	-4.08200400	2.21448700	0.79723800
H	-2.11638600	2.68041900	0.06807600
C	-4.83145900	-0.00432800	0.40760100
H	-3.94533400	-1.94951900	-1.43715300
H	-3.07204000	-2.25276600	0.07796800
C	-5.08519700	1.21368500	0.91918700
H	-4.26752000	3.18802700	1.20359600
H	-5.51663000	-0.82308500	0.45659300
H	-6.01300100	1.41790300	1.40699300
C	2.69564100	0.81380100	0.54803300
C	3.31906400	-0.11153100	-0.28594300
C	3.33284200	2.01651500	0.79617300
C	4.54937300	0.16164600	-0.84811600
H	2.82741600	-1.04178000	-0.48978900
C	4.57009600	2.29283200	0.23167500
H	2.87194200	2.74998500	1.42460400
C	5.18226200	1.36848100	-0.59016300
H	5.01680200	-0.56364300	-1.48523500
H	5.04758400	3.23145700	0.43491300
H	6.13858300	1.58116100	-1.02611100
C	0.66783400	1.52916600	1.97513100
H	-0.28718200	1.15128500	2.31989400
H	0.49571600	2.39896700	1.36367700
H	1.26434700	1.78488900	2.84298800
H	1.51626500	-0.42641500	1.80754700

SCF: E(RHF) = -1135.45845499
Sum of electronic and zero-point
Energies= -1135.022499
Sum of electronic and thermal
Energies= -1135.000076
Sum of electronic and thermal
Enthalpies= -1134.999132
Sum of electronic and thermal
Free Energies= -1135.076972



(S)-TS_{HF}-a
ΔG_{rel} = 6.6 kcal/mol

(S)-TS_{HF}-b
ΔG_{rel} = 11.7 kcal/mol

(S)-TS_{HF}-c
ΔG_{rel} = 0.6 kcal/mol

(S)-TS_{HF}-d
ΔG_{rel} = 1.0 kcal/mol

(S)-TS_{HF}-e
ΔG_{rel} = 3.7 kcal/mol

(S)-TS_{HF}-f
ΔG_{rel} = 5.8 kcal/mol

Figure S-6. TS of N-Acetyl-DHIP+ AcO^- and (S)-1-phenylethanol

(S)-**TS_{HF}-a**

```
C -0.42249600  -0.30447900  -2.08696300
O -1.24769600  -1.02434800  -0.73111700
C -0.75486500  -2.23942400  -0.12665500
O  0.59206400  -0.97102300  -2.38476300
C -1.61609500  -0.23447300  -3.02361000
O -3.23149300  -0.19851800   0.32790500
C -3.19815000   0.42733000   1.46768400
O -2.19088200   0.93437700   1.96534700
C -4.54550700   0.50473500   2.15333400
H -1.80481700  -1.23718300  -3.37476100
H -1.35329300   0.38688900  -3.87251000
H -2.50719500   0.14270700  -2.54996800
H -5.26820700   0.93727700   1.47294000
H -4.47207200   1.09072700   3.05544400
H -4.88002700  -0.49935800   2.38590700
H -2.23604900  -0.58893200  -0.20189100
N -0.16767900   1.00535100  -1.45471500
C  0.99775800   1.35326200  -0.91859100
C -1.22918100   1.97863300  -1.10967700
C  2.28252700   0.78579500  -1.07476100
N  0.86077900   2.43703800  -0.12968400
C -0.58210600   2.79633100   0.03315800
H -1.45401600   2.59216500  -1.97062200
H -2.10611500   1.46380000  -0.76991100
C  3.32113000   1.37087100  -0.43136500
H  2.34934000  -0.09378300  -1.66747500
C  1.90066800   3.01773100   0.52141500
H -0.71088000   3.86088000  -0.07528700
H -0.92973300   2.42849200   0.98502900
C  3.14510500   2.52023200   0.38256900
H  4.30052200   0.95035900  -0.53374500
H  1.66410700   3.86521400   1.12770700
H  3.97131500   2.97281500   0.88582600
C  0.54574900  -1.98119000   0.63130900
C  1.70120300  -2.71680800   0.43195500
C  0.54860700  -0.97871700   1.59736500
C  2.83573900  -2.47290000   1.19191300
H  1.72852500  -3.47986000   0.31749200
C  1.67674000  -0.73993300   2.35854400
H -0.33420400  -0.39030300   1.75585000
C  2.82671300  -1.48816000   2.16058600
H  3.71991800  -3.05756000   1.02660000
H  1.65655800   0.02493500   3.11060800
H  3.69954200  -1.30840500   2.75777700
C -0.70472000  -3.37480400  -1.15408900
H  0.01203500  -3.14227600  -1.92391100
H -1.68565400  -3.46761100  -1.60553000
H -0.46124500  -4.31538700  -0.67369600
H -1.49890900  -2.50044000   0.62020300

SCF: E(RHF) =  -1135.47104173
Sum of electronic and zero-point
Energies= -1135.035616
Sum of electronic and thermal
Energies= -1135.013383
Sum of electronic and thermal
Enthalpies= -1135.012438
Sum of electronic and thermal
```

Free Energies= -1135.087723

(S)-TS_{HF}-b

C -0.25201000 0.67979800 -2.02619600
O -1.40367900 -0.24418200 -1.01243900
C -1.34206000 -1.67124500 -0.77332300
O 0.47568900 -0.09755400 -2.66463900
C -1.32602800 1.51567200 -2.69287400
O -2.64340500 0.90094100   0.68871200
C -3.73009000 0.34089100   1.16625400
O -4.09132400 -0.79427700   0.90130400
C -4.51199300 1.24151700   2.10467100
H -1.84057400 0.87355200 -3.39000900
H -0.85069100 2.32185400 -3.24158700
H -2.03957100 1.91294600 -1.99043900
H -3.87632400 1.53490700   2.93196900
H -5.38590400 0.72659900   2.47069800
H -4.80110600 2.14249500   1.57653600
H -2.03467100 0.28241300 -0.23173400
N 0.40642800 1.42655700 -0.93269500
C 1.62657100 1.16319200 -0.48672200
C -0.25208300 2.49504900 -0.13395300
C 2.61143100 0.26805400 -0.97344000
N 1.92265900 1.91326700   0.59443200
C 0.74995800 2.71934800   1.02998500
H -0.35483600 3.38442600 -0.73768900
H -1.20638200 2.15501800   0.23109300
C 3.80126900 0.21330000 -0.33201300
H 2.34507400 -0.32714200 -1.81204700
C 3.11926300 1.85496200   1.23985800
H 1.03636300 3.75245000   1.14639100
H 0.37754800 2.31892500   1.96051400

(S)-TS_{HF}-c

C -0.24790100   1.41652600 -0.92350500
O 0.58265800   0.23122600 -0.00645500
C 1.51410700   0.75250300   0.96155500
O -0.27760000   2.49258000 -0.27714200
C 0.53542400   1.32148900 -2.21989400
O 0.62428100 -2.15092700 -0.16672700
C -0.17379000 -3.06873300   0.30730800
O -1.38348900 -2.93993500   0.46203700
C 0.53709200 -4.36454700   0.63755000
H 1.50645100   1.75649000 -2.03956100
H 0.02659700   1.90468900 -2.97885900
H 0.66879400   0.30689300 -2.55740700
H 1.06805200 -4.71174800 -0.24014600
H -0.17232900 -5.10575800   0.96910600
H 1.27407500 -4.17900500   1.40995600
H 0.51279400 -0.95840800 -0.08158000
N -1.53088200   0.68516800 -1.02055000
C -2.57421200   0.92061300 -0.23677400
C -1.73070400 -0.52985200 -1.84633400
C -2.81900700   1.98266600   0.66633100
N -3.51546300 -0.03247600 -0.37841300
C -3.03471200 -1.13717900 -1.26572900
H -1.83444400 -0.25337700 -2.88485100
H -0.90459900 -1.20306600 -1.70901500
C -3.99608600   1.99253100   1.33847300
H -2.05058700   2.71123400   0.76390200
C -4.68751300 -0.02772500   0.30347200
H -3.77788000 -1.35090600 -2.01654800
H -2.79002100 -1.98320500 -0.64572300

(S)-TS_{HF}-d

C -0.13510400   1.62373100 -0.77456600
O 0.69289200   0.28871000 -0.02051400
C 1.67131200   0.65979000   0.96668500
O -0.16855600   2.57966100   0.03309100
C 4.08213100   1.02548700   0.80018900
H 4.55188000 -0.46389800 -0.68509100
H 3.22838500   2.49534100   2.08847100
H 5.02593800   0.97341000   1.29729300
C -0.15486800 -1.98652000   0.13345200
C 0.77501800 -2.97656900 -0.12782600
C -0.02875000 -1.24681600   1.30820500
C 1.80748600 -3.23295600   0.76477100
H 0.70322100 -3.55550800 -1.02521200
C 0.99423100 -1.50293800   2.19807500
H -0.75261300 -0.48274200   1.51239600
C 1.92080300 -2.50039500   1.92893500
H 2.51491400 -4.00958300   0.54740300
H 1.06536100 -0.93881500   3.10843100
H 2.71138600 -2.70618900   2.62385500
C -1.38072700 -2.43076100 -2.10057500
H -0.51068000 -2.20240700 -2.69344600
H -2.26110700 -2.11042100 -2.64402600
H -1.46037900 -3.49777200 -1.92733200
H -2.24439700 -1.89246800 -0.21694900

SCF: E(RHF) = -1135.46211848
Sum of electronic and zero-point
Energies= -1135.026097
Sum of electronic and thermal
Energies= -1135.003723
Sum of electronic and thermal
Enthalpies= -1135.002779
Sum of electronic and thermal
Free Energies= -1135.079539

C -4.96681100   0.97309500   1.16258900
H -4.19802700   2.79117300   2.02329700
H -5.34438000 -0.84951800   0.11683000
H -5.88911800   0.98780100   1.70072100
C 2.94880700   0.64140800   0.47531700
C 3.38820300 -0.48987400 -0.20036700
C 3.84611300   1.66548900   0.73107900
C 4.70724700 -0.58890200 -0.60342600
H 2.69934300 -1.28616600 -0.39556000
C 5.16799300   1.56495000   0.32930100
H 3.50991200   2.54929500   1.23940000
C 5.60188400   0.43590300 -0.34030100
H 5.03848500 -1.46660600 -1.12360300
H 5.85088000   2.36640800   0.53308000
H 6.62351100   0.35502000 -0.65597800
C 1.32638800 -0.00185700   2.28651200
H 1.55039100 -1.05096000   2.14604600
H 0.29993400   0.09540400   2.62150100
H 1.98749000   0.39998700   3.04459900
H 1.24716200   1.79090600   1.08048900

SCF: E(RHF) = -1135.47742532
Sum of electronic and zero-point
Energies= -1135.042386
Sum of electronic and thermal
Energies= -1135.019816
Sum of electronic and thermal
Enthalpies= -1135.018872
Sum of electronic and thermal
Free Energies= -1135.097182

C 0.69480600   1.71245400 -2.04132800
O 0.35752300 -2.07350800 -0.12613900
C -0.72460200 -2.70523900   0.22462200
O -1.84514000 -2.20141000   0.25547300
C -0.48869400 -4.15808700   0.58083600
H 1.65658300   2.11720100 -1.76588500

```
H  0.21407400   2.39780100  -2.73054300
H  0.84607100   0.75442800  -2.50964200
H  0.01762000  -4.64948000  -0.24061100
H -1.42480200  -4.64779800   0.79773000
H  0.16704200  -4.20886400   1.44207000
H  0.45380700  -0.87137400  -0.08835000
N -1.40436300   0.91593700  -1.00787800
C -2.42819400   0.94840700  -0.16266300
C -1.59582300  -0.11592600  -2.05278900
C -2.61173900   1.71034500   1.01353300
N -3.41326400   0.12631400  -0.55862400
C -3.03668500  -0.63172700  -1.78261300
H -1.51034300   0.32705300  -3.03159800
H -0.86866400  -0.89719100  -1.92146100
C -3.76396700   1.54404800   1.70860200
H -1.82440400   2.37270300   1.28189100
C -4.55316300  -0.05922900   0.14890700
H -3.72232800  -0.38259400  -2.57758500
H -3.03806600  -1.67699100  -1.54235300
C -4.76800000   0.63891200   1.28215500
H -3.91743300   2.10821700   2.60621800
H -5.24169700  -0.77466600  -0.24479000
H -5.66569800   0.50237100   1.84410200
C  3.08004400   0.38034300   0.47399100
C  4.10328400   1.27468100   0.74132700
```

(S)-TS_{HF}-e

```
C  0.53970800   0.56409100   1.02767100
O -0.60050200  -0.01916700  -0.25240100
C -1.29130600   1.01230000  -0.97772700
O  0.53931800   1.80339700   1.02639500
C -0.03654000  -0.25682400   2.15628400
O -1.48218700  -2.22741500  -0.61780200
C -1.19877000  -3.28679400   0.06620500
O -0.28095900  -3.37552000   0.89073500
C -2.10116700  -4.47218600  -0.21991000
H -1.01432900   0.14209300   2.38139400
H  0.60104100  -0.12398200   3.02435700
H -0.11719900  -1.30411200   1.92212500
H -3.11402700  -4.22439600   0.07609900
H -1.75928800  -5.33983400   0.32140200
H -2.11192000  -4.66437400  -1.28536800
H -0.98806900  -1.07944600  -0.39451600
N  1.75185800  -0.07099700   0.44680300
C  2.88417100   0.56936400   0.22146600
C  1.77971300  -1.42511900  -0.16730600
C  3.24369600   1.92623600   0.43079600
N  3.82387100  -0.27167200  -0.27278700
C  3.29444200  -1.66760400  -0.33332400
H  1.28075100  -2.15772900   0.44247100
H  1.27906100  -1.36504700  -1.11967400
C  4.50787800   2.30837700   0.13481600
H  2.48369500   2.57632500   0.79214200
C  5.09228400   0.11678000  -0.56782600
H  3.71363500  -2.23051600   0.48794000
H  3.54775400  -2.12179600  -1.27732600
```

(S)-TS_{HF}-f

```
C -0.43331000   1.73760600  -0.88557500
O  0.50673400   0.49827900  -0.03350100
C  1.50207800   0.99951000   0.87501100
O -0.57710800   2.71530500  -0.12727400
C  0.41119400   1.84034800  -2.13877600
O -0.05127100  -1.82070500  -0.30072200
C  0.19674000  -2.81632700   0.51954200
O  0.55161200  -2.70226200   1.67921800
C -0.00997200  -4.17927700  -0.12137600
H  1.32485900   2.34882300  -1.87126000
H -0.11875400   2.44489200  -2.86659200
C  3.36642900  -0.78529700  -0.22554900
C  5.39885400   1.01285700   0.32536700
H  3.88770100   2.18296200   1.27172200
C  4.65868400  -1.04605000  -0.64158300
H  2.57994600  -1.48407400  -0.42664500
C  5.67948100  -0.14916800  -0.36860000
H  6.18075500   1.71538600   0.53839000
H  4.87136800  -1.94971200  -1.17902100
H  6.68016200  -0.35478300  -0.69462600
C  1.38758000  -0.10223700   2.27122000
H  1.46412000  -1.16691600   2.09682700
H  0.38400200   0.12481200   2.61329100
H  2.09772000   0.18396700   3.03742800
H  1.53508700   1.71851400   1.12836400

SCF:  E(RHF) = -1135.47819899
Sum of electronic and zero-point
Energies= -1135.042719
Sum of electronic and thermal
Energies= -1135.020304
Sum of electronic and thermal
Enthalpies= -1135.019359
Sum of electronic and thermal
Free Energies= -1135.096648
```

```
C  5.46927900   1.39516300  -0.37928300
H  4.79079700   3.33086400   0.28321400
H  5.74151300  -0.64249100  -0.94777000
H  6.46180800   1.71194100  -0.61370800
C -2.68801800   1.26495500  -0.43216300
C -3.50865400   0.21633700  -0.03994800
C -3.16936800   2.56194300  -0.35410200
C -4.78998700   0.46931900   0.41603900
H -3.14567900  -0.78851300  -0.10450200
C -4.45280000   2.81522800   0.09907800
H -2.53450900   3.37979800  -0.63735300
C -5.26763200   1.76722800   0.48658600
H -5.41659600  -0.34783200   0.71642100
H -4.80989300   3.82492600   0.15621800
H -6.26106900   1.95871300   0.84205000
C -1.35181900   0.61505100  -2.46137300
H -1.88041100  -0.32402900  -2.56383200
H -0.34721300   0.49200200  -2.85240500
H -1.86340400   1.37635000  -3.03751200
H -0.70257000   1.90635000  -0.84126700

SCF:  E(RHF) = -1135.47360824
Sum of electronic and zero-point
Energies= -1135.038056
Sum of electronic and thermal
Energies= -1135.015641
Sum of electronic and thermal
Enthalpies= -1135.014697
Sum of electronic and thermal
Free Energies= -1135.092233
```

```
H  0.66079500   0.88244000  -2.56023700
H -1.03929900  -4.28072500  -0.44747800
H  0.22958100  -4.95781800   0.58511500
H  0.62120900  -4.25982700  -0.99796400
H  0.24287000  -0.64317700  -0.05187600
N -1.60555500   0.86935700  -1.08201800
C -2.60878300   0.80354400  -0.21640600
C -1.67160200  -0.22745100  -2.07827400
C -2.94739800   1.66475000   0.85334700
N -3.38955000  -0.26772100  -0.45524800
C -2.79776300  -1.13114800  -1.51996600
H -1.91056600   0.17558300  -3.05070300
```

H	-0.75004000	-0.77610300	-2.08230300	H	6.10969400	1.60123100	0.78506400
C	-4.05383400	1.37538300	1.58074300	H	4.53671200	-1.62439100	-1.49749900
H	-2.29834100	2.48949200	1.02652000	H	6.46754000	-0.31837400	-0.71413500
C	-4.49645200	-0.55877300	0.27633300	C	1.22192300	0.46860200	2.29071200
H	-3.54951900	-1.38911800	-2.24755800	H	1.18886000	-0.61104700	2.28766400
H	-2.35902600	-1.99413400	-1.05025400	H	0.26044500	0.84512400	2.62436200
C	-4.86259900	0.24441100	1.29419400	H	1.98602500	0.80870900	2.97956100
H	-4.32536300	2.01657100	2.39457600	H	1.38749400	2.07430300	0.87071700
H	-5.03040100	-1.44066300	-0.00477800				
H	-5.73243800	0.02607600	1.87400400	SCF: E(RHF) = -1135.46923666			
C	2.89875600	0.62672000	0.40445700	Sum of electronic and zero-point			
C	3.99291400	1.36044800	0.83950400	Energies= -1135.034122			
C	3.10634200	-0.44748200	-0.44600100	Sum of electronic and thermal			
C	5.27392600	1.02365600	0.44123400	Energies= -1135.011607			
H	3.84204700	2.20139100	1.49009300	Sum of electronic and thermal			
C	4.38796300	-0.78690600	-0.84388000	Enthalpies= -1135.010663			
H	2.26581900	-1.01473100	-0.78443100	Sum of electronic and thermal			
C	5.47584200	-0.05443300	-0.40340700	Free Energies= -1135.088984			

(c) Transition state geometries of N-Acetyl-(R)-CF_3-PIP^+ AcO^- and N-Propionyl-(R)-CF_3-PIP^+ $EtCO_2^-$ with (R)- and (S)-1-phenylethanol at B3LYP/6-31G* level of theory

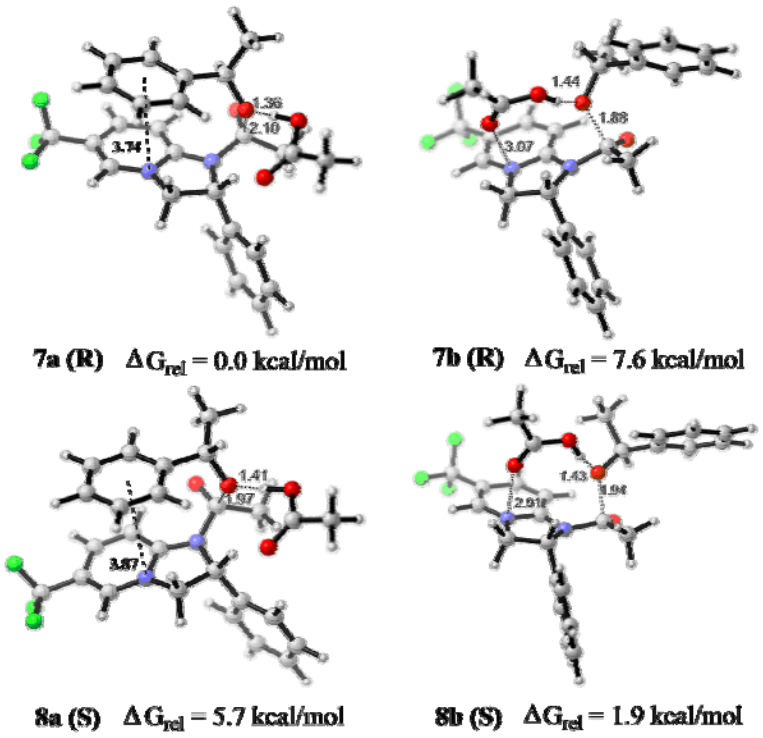


Figure S-7. TS of Ac-CF_3-PIP acetate and 1-phenylethanol

C1. The lowest-energy stacked and splayed conformers of (R)-$\mathbf{TS_{HF}}$ (structures (R)-$\mathbf{TS_{HF}}$**-a** and (R)-$\mathbf{TS_{HF}}$**–h**, respectively) and the lowest-energy stacked and splayed conformers of (S)-$\mathbf{TS_{HF}}$ (structures (S)-$\mathbf{TS_{HF}}$**-a** and (S)-$\mathbf{TS_{HF}}$**–c**, respectively), obtained as described in the preceeding section, were transformed into (R)-CF_3-PIP derivatives by attaching a trifluoromethyl group at C6 and a phenyl group to the α–face of C2. The resulting structures **7a**, **7b**, **8a**, and **8b** were optimized at B3LYP/6-31G* level of theory (Figure S-7).

7a

```
C  1.22172300  -0.08562300  -2.16872300
O  1.40547200   1.66425700  -1.02803700
C  0.36668800   2.55304800  -1.30250200
O  0.50007500   0.16743400  -3.12131200
C  2.71584700  -0.26472000  -2.28734100
O  3.51382000   2.56000400  -0.11778500
C  3.86119000   2.01956200   1.02159500
O  3.24256600   1.12161800   1.60372500
C  5.13900100   2.60688200   1.59580400
H  3.07383500   0.48996500  -2.98831800
H  2.92236500  -1.26054700  -2.69991200
H  3.24852200  -0.15612000  -1.34369400
H  5.95957600   2.48225400   0.88103400
H  5.39078800   2.11974000   2.53933600
H  5.01362900   3.68326400   1.75502500
H  2.56792400   2.16060800  -0.51399100
N  0.59882900  -0.79730700  -1.02005000
C -0.73081900  -0.88541600  -0.88146800
C  1.29179000  -0.98975800   0.28268300
C -1.76898400  -0.83901600  -1.84974500
N -1.07894100  -1.07023200   0.43156900
C  0.11761100  -1.03778700   1.29978200
H  1.89036500  -0.09990900   0.48880000
C -3.06870500  -0.95643300  -1.42331600
H -1.49512800  -0.69173000  -2.88285700
C -2.35703400  -1.17780500   0.85679300
H  0.14253700  -1.93198900   1.92597200
H  0.07300900  -0.13953900   1.91955700
C -3.38342400  -1.12266600  -0.04995400
H -3.87489800  -0.92618700  -2.14975000
H -2.50599400  -1.29786100   1.92204100
C -0.67356700   2.58109400  -0.17459900
C -2.04379400   2.66713200  -0.45268600
C -0.27246500   2.51762700   1.16889900
C -2.99260000   2.68855700   0.57378600
H -2.37213700   2.71241800  -1.48975600
C -1.21514500   2.55083600   2.19928900
H  0.78524100   2.42249900   1.39863000
C -2.58051800   2.63166400   1.90648900
H -4.05176100   2.73933200   0.33271100
H -0.88310300   2.51723200   3.23502500
H -3.31399100   2.65488200   2.70879500
C  0.89361000   3.97390300  -1.58964000
H  1.60151200   3.93764300  -2.42467200
H  1.41643100   4.37782100  -0.71578300
H  0.07643600   4.65743200  -1.84983800
H -0.15205400   2.21029300  -2.21780600
C  2.16081100  -2.23538300   0.32696500
C  3.33800200  -2.20089100   1.08704700
C  1.79778400  -3.42279100  -0.32093500
C  4.13158200  -3.34357500   1.20243500
H  3.62755300  -1.27262300   1.57374500
C  2.59647700  -4.56144700  -0.20883500
H  0.89909000  -3.45536600  -0.93188500
C  3.76405400  -4.52513000   0.55625200
H  5.04432200  -3.30623600   1.79117000
H  2.30866700  -5.47522500  -0.72206100
H  4.38684400  -5.41151600   0.64220900
C -4.81269200  -1.18544600   0.40105300
F -4.91140100  -1.52347800   1.70405700
F -5.51046200  -2.09181100  -0.31735400
F -5.43289400   0.00275900   0.23864400
SCF:  E(RB+HF-LYP) =  -1716.95496628
Sum of electronic and zero-point
Energies= -1716.465171
Sum of electronic and thermal
Energies= -1716.432162
Sum of electronic and thermal
Enthalpies= -1716.431218
Sum of electronic and thermal
Free Energies= -1716.533805
```

7b

```
C -1.17952000  -0.34495300   1.17291700
O -1.23260900   1.04727700  -0.08619600
C -1.94405900   2.25787700   0.16862900
O -1.09808100   0.10428300   2.31338800
C -2.36296000  -1.17459000   0.70867900
O -1.38259900   0.90570300  -2.57462500
C -0.25276100   0.73386900  -3.22731300
O  0.80574900   0.37018900  -2.71742600
C -0.37966400   1.03587600  -4.70894700
H -3.26676400  -0.64775800   1.01287000
H -2.33952600  -2.14700400   1.21303500
H -2.39565500  -1.32525100  -0.37144600
H -1.25329200   0.52679300  -5.12787700
H  0.52562600   0.73121800  -5.23671100
H -0.53607000   2.11158200  -4.84903200
H -1.26270500   0.86405300  -1.50916500
N  0.14850200  -0.87607500   0.58557900
C  1.26229700  -0.15124700   0.69513900
C  0.27204100  -1.86837300  -0.50789600
C  1.56244700   0.93554700   1.55993300
N  2.23366900  -0.57753800  -0.16918700
C  1.75802400  -1.72878000  -0.95569200
H -0.37162800  -1.55546900  -1.33330400
C  2.79463000   1.52781500   1.46137300
H  0.80014000   1.23854500   2.26168000
C  3.44818600   0.00607600  -0.27710600
H  2.34817500  -2.61108900  -0.69231700
H  1.84180700  -1.49671800  -2.01635700
C  3.76312200   1.06994300   0.52658700
H  3.04003900   2.36509000   2.10759100
H  4.12194400  -0.40708700  -1.01651900
C -3.44879900   2.06016700   0.36987800
C -4.29947200   2.13894900  -0.74138600
C -4.01947500   1.79907800   1.62434000
C -5.67897600   1.97195900  -0.60967800
H -3.86871600   2.32727900  -1.72255100
C -5.39894200   1.63023400   1.76077900
H -3.37881000   1.70342000   2.49548100
C -6.23485300   1.72040100   0.64557900
H -6.31898400   2.04306700  -1.48599900
H -5.82210600   1.42943700   2.74224900
H -7.30939200   1.59590600   0.75470000
C -1.29296700   3.09623500   1.27835400
H -0.24380300   3.27985700   1.02228000
H -1.32684800   2.59009100   2.24518800
H -1.79773800   4.06544500   1.37184400
H -1.84584200   2.84216200  -0.76057100
C -0.06132800  -3.29127900  -0.09183800
C -0.62188300  -4.16672500  -1.02824700
C  0.24194700  -3.76703400   1.19004100
C -0.86796700  -5.49965200  -0.69452300
H -0.87302100  -3.80269900  -2.02215600
C -0.01081100  -5.09698200   1.52634800
H  0.65172500  -3.08742900   1.93221000
C -0.56213400  -5.96791400   0.58395000
H -1.30673700  -6.16781300  -1.43048500
H  0.21868800  -5.45164400   2.52752700
H -0.75961600  -7.00322800   0.84785300
C  5.10507100   1.73288300   0.44213100
F  5.78466500   1.61258300   1.60494600
F  4.98671200   3.05461500   0.19725200
F  5.86941000   1.19820800  -0.53420600
```

SCF: E(RB+HF-LYP) = -1716.94201550
Sum of electronic and zero-point
Energies= -1716.451349
Sum of electronic and thermal
Energies= -1716.418392
Sum of electronic and thermal
Enthalpies= -1716.417448
Sum of electronic and thermal
Free Energies= -1716.521745

8a

C	1.09911100	0.31842000	-2.00114400
O	1.90713200	1.62241100	-0.75796000
C	1.40158400	2.93932300	-0.66978600
O	0.35396400	0.85776500	-2.81028700
C	2.44093500	-0.26639800	-2.39059900
O	4.19361100	1.66188100	0.20962900
C	4.27779800	1.09663800	1.39176500
O	3.36980600	0.47648000	1.94994800
C	5.64267500	1.27277600	2.03195000
H	2.93953800	0.46198800	-3.03125100
H	2.26932300	-1.18564000	-2.96454500
H	3.08471700	-0.49453000	-1.54145200
H	6.41682500	0.85886900	1.37688500
H	5.67214600	0.77606200	3.00304600
H	5.86146800	2.33910700	2.15295800
H	3.20443100	1.58798700	-0.21343300
N	0.41324200	-0.45050100	-0.89807300
C	-0.91294100	-0.48051400	-0.75114400
C	1.09697300	-0.99952500	0.30164900
C	-1.96344000	-0.19292200	-1.66753900
N	-1.25818500	-0.90689800	0.50937900
C	-0.04775100	-1.03926800	1.34831600
H	1.85096100	-0.28347000	0.63274200
C	-3.25888900	-0.38162200	-1.26000400
H	-1.69446500	0.16786700	-2.64824900
C	-2.53475100	-1.08852600	0.91573500
H	-0.07644200	-1.97526600	1.90830400
H	-0.00736400	-0.18736200	2.03165700
C	-3.56649900	-0.84134900	0.04930900
H	-4.07097500	-0.17931300	-1.95161700
H	-2.67687500	-1.42780600	1.93387800
C	0.04033600	2.95681100	0.03477800
C	-1.16036000	3.30534700	-0.59237600
C	-0.00238800	2.60218800	1.39420400
C	-2.36897800	3.30129000	0.11294700
H	-1.15716900	3.58552600	-1.64104400
C	-1.20313600	2.60122800	2.10373600
H	0.92679100	2.32942400	1.89131300
C	-2.39711900	2.95022100	1.46223300
H	-3.28902200	3.58163700	-0.39489300
H	-1.20770500	2.34749500	3.16201300
H	-3.33439700	2.96121900	2.01316300
C	1.44643300	3.68329100	-2.01198500
H	0.82072700	3.20107700	-2.76533400
H	2.47816200	3.67390900	-2.37885600
H	1.13514300	4.72918200	-1.89662400
H	2.08424600	3.48160300	0.00960800
C	1.72354300	-2.36755700	0.07609200
C	2.87243700	-2.69909800	0.80760700
C	1.16114300	-3.32075000	-0.78169200
C	3.44145900	-3.96778600	0.68641500
H	3.31627000	-1.95352900	1.46270900
C	1.73510100	-4.58691100	-0.90527500
H	0.28308800	-3.07121200	-1.37189000
C	2.87513800	-4.91461800	-0.16903600
H	4.33465800	-4.21265400	1.25505800
H	1.29307700	-5.31566700	-1.57961500
H	3.32281200	-5.89993000	-0.26701800
C	-4.99214000	-1.05310400	0.46230600
F	-5.58907000	-1.99251700	-0.30427600
F	-5.08768700	-1.45264700	1.74853100
F	-5.71647700	0.07754100	0.32596000

SCF: E(RB+HF-LYP) = -1716.94617281
Sum of electronic and zero-point
Energies= -1716.455704
Sum of electronic and thermal
Energies= -1716.422755
Sum of electronic and thermal
Enthalpies= -1716.421811
Sum of electronic and thermal
Free Energies= -1716.524792

8b

C	-1.09469100	-0.60372600	1.32372900
O	-1.33955400	0.89567300	0.11870500
C	-2.02215800	1.95099000	0.75258200
O	-0.99138400	-0.16073000	2.46395900
C	-2.28818700	-1.42550800	0.88110200
O	-1.22502800	1.22765600	-2.35349500
C	-0.08657900	1.00776000	-2.97017000
O	0.89939700	0.47621800	-2.46021000
C	-0.09775900	1.48193200	-4.41143900
H	-3.17877200	-0.89483500	1.22014600
H	-2.25927700	-2.40771700	1.36690700
H	-2.35273600	-1.55551000	-0.19988300
H	-0.96908900	1.07684000	-4.93594000
H	0.82046300	1.17912300	-4.91742000
H	-0.18644000	2.57373400	-4.43716300
H	-1.20628800	1.02697700	-1.29527000
N	0.20729500	-1.01241500	0.66046700
C	1.28404700	-0.22697200	0.76350500
C	0.33409900	-1.92668200	-0.50040700
C	1.53600800	0.87241500	1.62616200
N	2.25773800	-0.59264400	-0.12276900
C	1.82256800	-1.75281700	-0.91869200
H	-0.30270200	-1.54849600	-1.30430900
C	2.73542100	1.52827100	1.51197800
H	0.76941900	1.13555800	2.33990400
C	3.43654900	0.05448400	-0.24848700
H	2.42716500	-2.62205300	-0.64314800
H	1.92399900	-1.52096700	-1.97752300
C	3.71161900	1.12502500	0.56175400
H	2.94475900	2.37734400	2.15542200
H	4.11536600	-0.31374100	-1.00658400
H	-1.82349400	1.86900200	1.83345200
C	-1.46389100	3.30492700	0.27420100
H	-0.38203300	3.34293900	0.44768700
H	-1.93477600	4.13720700	0.81071300
H	-1.64372900	3.44411300	-0.79726600
C	-3.54258300	1.89561600	0.57546000
C	-4.38581900	2.12000700	1.67109600
C	-4.12871500	1.64752800	-0.67462900
C	-5.77537100	2.10752200	1.52866600
H	-3.94648800	2.30068500	2.65028800
C	-5.51609100	1.63251800	-0.82076000
H	-3.49375600	1.46396200	-1.53607600
C	-6.34614000	1.86340100	0.27928800
H	-6.40984500	2.28094600	2.39476400
H	-5.95246000	1.43898600	-1.79819500
H	-7.42709800	1.84903100	0.16334300
C	-0.00308200	-3.37575600	-0.19922000
C	-0.63533400	-4.15082900	-1.17701600

```
C  0.36301500  -3.97325400   1.01365200
C -0.89290500  -5.50428200  -0.95213200
H -0.93377900  -3.69207100  -2.11710800
C  0.09893000  -5.32342100   1.24205300
H  0.83300400  -3.37341000   1.78862800
C -0.52632600  -6.09339900   0.25832300
H -1.38767600  -6.09375000  -1.71909200
H  0.37714600  -5.77327600   2.19120300
H -0.73294700  -7.14475800   0.43821300
C  5.01816800   1.85416700   0.46287100
F  5.78996300   1.36848300  -0.53296400
F  4.83168600   3.17110500   0.23706600
F  5.72286500   1.75258000   1.61233600

SCF:  E(RB+HF-LYP) =  -1716.95065404
Sum of electronic and zero-point
Energies= -1716.460356
Sum of electronic and thermal
Energies= -1716.427306
Sum of electronic and thermal
Enthalpies= -1716.426362
Sum of electronic and thermal
Free Energies= -1716.530767
```

C2. The optimized TS structures of N-Acetyl-(R)-CF_3-PIP Acetate with (R)- and (S)-1-phenylethanol**, 7a** and **8b**, respectively, obtained as described above, were transformed into the analogous TS structures of N-Propionyl-(R)-CF_3-PIP Propionate, **9a** and **10b**, respectively, and re-optimized at B3LYP/6-31G* level of theory.

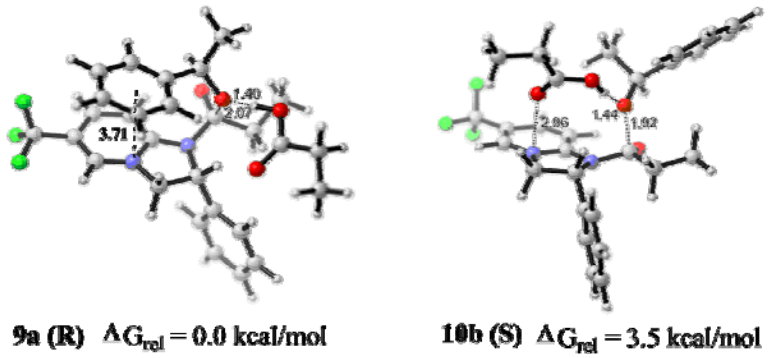


Figure S-8. TS of EtCO-CF_3-PIP propionate and 1-phenylethanol

9a (R)

```
C  0.88380300  -0.30262000  -2.16432000
O  1.23932400   1.44568700  -1.10704200
C  0.24892200   2.39459000  -1.35789400
O  0.16164200  -0.02011100  -3.10916500
C  2.35215000  -0.65846800  -2.30811900
O  3.45626800   2.21616200  -0.30443500
C  3.83015600   1.67002600   0.82748500
O  3.17662300   0.83690700   1.46241500
C  5.18438900   2.17672600   1.30909800
H  2.87953700  -0.53784900  -1.36027400
H  2.38641300  -1.72993700  -2.55695000
H  5.10018400   3.26508400   1.42756400
H  5.90085100   2.03087700   0.49059700
H  2.47939400   1.87917300  -0.63234500
N  0.21977800  -0.92741700  -0.97771100
C -1.10960300  -0.89971300  -0.82076500
C  0.91168300  -1.13338400   0.32431300
C -2.15456500  -0.80501400  -1.77931400
N -1.45514300  -1.00529700   0.50229000
C -0.24894100  -1.04824800   1.35558800
H  1.58892500  -0.29291300   0.48791000
C -3.45325600  -0.79184800  -1.33517200
H -1.88419200  -0.72635900  -2.82082400
C -2.73174400  -0.98314900   0.94475900
H -0.29105600  -1.92239500   2.00864700
H -0.21051400  -0.13164700   1.94796400
C -3.76202900  -0.87281300   0.04763200
H -4.26395700  -0.72281600  -2.05386600
H -2.87570700  -1.04800300   2.01548900
C -0.71975200   2.53891600  -0.17693300
C -2.09301100   2.72497500  -0.38387800
C -0.24895100   2.49387100   1.14435400
C -2.97731400   2.85815200   0.69050500
H -2.47524000   2.76001800  -1.40270100
C -1.12591200   2.63863400   2.22211800
H  0.81006900   2.32731900   1.32096400
C -2.49545000   2.81560200   2.00038700
H -4.04147900   2.98295600   0.50503900
H -0.73889400   2.61695700   3.23886100
H -3.17793500   2.92589800   2.83959200
C  0.85367500   3.76422200  -1.72973900
H  1.49876300   3.65264300  -2.60795400
H  1.46050600   4.15767800  -0.90678100
H  0.07062100   4.49645500  -1.96113800
H -0.34350100   2.05775100  -2.22918500
C  1.66823000  -2.44907000   0.40736700
C  2.87006700  -2.48582100   1.12695300
C  1.17282600  -3.63003100  -0.16028800
C  3.55776400  -3.69094300   1.28211000
H  3.26255300  -1.56470200   1.55060000
C  1.86556300  -4.83163000  -0.00870900
H  0.25270100  -3.61077200  -0.73924900
C  3.05853500  -4.86525600   0.71644700
H  4.49074000  -3.70892600   1.83917900
H  1.47541800  -5.74021000  -0.45980000
H  3.59864400  -5.80094500   0.83350400
C -5.18334500  -0.78153200   0.51793800
F -5.29650200  -1.08385500   1.82858000
F -5.98116400  -1.62381900  -0.17345200
```

```
F -5.68203200   0.46130900   0.34164200
C  5.66963900   1.51827300   2.59846600
H  4.95042400   1.66742600   3.40955200
H  6.63316400   1.93766900   2.90852000
H  5.79309400   0.43836800   2.46742600
C  3.02617200   0.16158300  -3.40743700
H  2.48135600   0.06852700  -4.35099100
H  4.05452800  -0.18299500  -3.55970300
H  3.05036000   1.21659500  -3.12452300
```

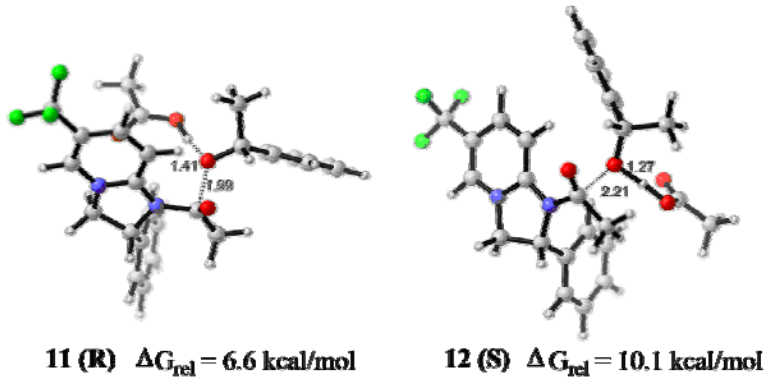
```
SCF:  E(RB+HF-LYP) =  -1795.58452550
Sum of electronic and zero-point
Energies= -1795.036948
Sum of electronic and thermal
Energies= -1795.001259
Sum of electronic and thermal
Enthalpies= -1795.000315
Sum of electronic and thermal
Free Energies= -1795.109207
```

10b (S)

```
 C -1.01837700  -0.84723800   1.48109400
 O -1.60100200   0.41493500   0.16229300
 C -2.09813100   1.60129500   0.73093500
 O -0.98726700  -0.29062200   2.57599600
 C -2.00093800  -1.96954600   1.16871700
 O -1.39766600   0.52383000  -2.32700300
 C -0.22708100   0.80327200  -2.86311000
 O  0.84230100   0.79373900  -2.25495500
 C -0.32809100   1.14814100  -4.34284500
 H -2.10651200  -2.10363700   0.08938800
 H -1.56873600  -2.89477100   1.57322500
 H -0.97865100   0.40455600  -4.81924000
 H -0.87552300   2.09802200  -4.41258700
 H -1.38536400   0.46737600  -1.25594800
 N  0.34999100  -1.07360800   0.82629100
 C  1.33288200  -0.17870200   0.98097700
 C  0.57190000  -1.88530300  -0.39963100
 C  1.49442700   0.85738100   1.94086300
 N  2.31632500  -0.34147800   0.04307000
 C  1.99918300  -1.46342800  -0.85438100
 H -0.15622900  -1.56809200  -1.15007500
 C  2.60908000   1.65442000   1.86506700
 H  0.72209000   0.97194700   2.68665500
 C  3.41120000   0.44388300  -0.04253600
 H  2.72790300  -2.26383000  -0.69736600
 H  2.01742000  -1.11144000  -1.88446600
 C  3.59299100   1.45835300   0.86082800
 H  2.74297800   2.45417500   2.58717900
 H  4.10276400   0.22635700  -0.84595400
 H -1.89521500   1.55646700   1.81323300
 C -1.36665200   2.83559700   0.16358300
 H -0.28399500   2.72496200   0.29082100
 H -1.68921600   3.75290400   0.67040300
 H -1.57582300   2.95217400  -0.90556800
 C -3.61049100   1.76701000   0.56154600
 C -4.36615600   2.37793300   1.57082600
 C -4.26778600   1.36110600  -0.60810500
 C -5.73799000   2.58754100   1.41953400
 H -3.87260700   2.68762700   2.49036300
 C -5.63984300   1.56659300  -0.76224700
 H -3.69998700   0.88055200  -1.39861500
 C -6.38101700   2.18170700   0.24907000
 H -6.30491100   3.05958800   2.21862400
 H -6.13282600   1.24376600  -1.67652300
 H -7.45002600   2.33861400   0.12804100
 C  0.48176400  -3.38778800  -0.19463500
 C -0.12256400  -4.17935800  -1.17633400
 C  1.05437200  -4.00798100   0.92348600
 C -0.15293900  -5.56934400  -1.04786000
 H -0.57892700  -3.70587300  -2.04270900
 C  1.01803800  -5.39551100   1.05656900
 H  1.50898700  -3.40154000   1.70286000
 C  0.41683100  -6.18039500   0.06927700
 H -0.62924400  -6.17137300  -1.81673100
 H  1.45538800  -5.86415700   1.93395200
 H  0.38791000  -7.26132700   0.17466500
 C  4.79891400   2.34742200   0.79396200
 F  5.63451600   1.98417400  -0.20248300
 F  4.45248500   3.63541400   0.59304300
 F  5.49749100   2.30758900   1.95061300
 C  1.02459000   1.24778100  -5.04458000
 H  1.66310200   1.98946000  -4.55604800
 H  0.89706400   1.53596200  -6.09354000
 H  1.55577200   0.28997700  -5.01842900
 C -3.36411000  -1.72106600   1.81364900
 H -3.25453500  -1.55677100   2.88921100
 H -4.01707500  -2.58661100   1.65592300
 H -3.84556700  -0.84174800   1.38021300

 SCF:  E(RB+HF-LYP) =  -1795.57744074
 Sum of electronic and zero-point
 Energies= -1795.029728
 Sum of electronic and thermal
 Energies= -1794.993985
 Sum of electronic and thermal
 Enthalpies= -1794.993041
 Sum of electronic and thermal
 Free Energies= -1795.103606
```

C3. The geometries of the transition states of (R)- and (S)-1-phenylethanol approaching N-acetyl-(R)-CF_3-PIP acetate from the α-face were optimized at B3LYP/6-31G* level.



11 (R) ΔG_{rel} = 6.6 kcal/mol **12 (S)** ΔG_{rel} = 10.1 kcal/mol

Figure S-9. Substrate approaching N-acetyl-(R)-CF_3-PIP acetate from the α-face

11 (R)

C	0.88845700	-0.01791200	-1.87078400
O	1.21415200	-1.01694800	-0.18264600
C	1.87615700	-2.23042900	-0.43026800
O	0.56487800	-0.84048200	-2.71802800
C	2.20110300	0.72968200	-1.93279200
O	0.71526600	-0.70724700	2.23603800
C	-0.41824700	-0.17232800	2.63029200
O	-1.23167900	0.38796100	1.89549600
C	-0.64214800	-0.30914900	4.12550700
H	2.95430700	0.01416000	-2.26662000
H	2.13715300	1.52954800	-2.68327700
H	2.50392000	1.14993500	-0.97747100
H	0.24603800	0.01988700	4.67399900
H	-1.51302900	0.27208000	4.43332600
H	-0.80142300	-1.36418000	4.37564800
H	0.85619100	-0.77824900	1.16097500
N	-0.24280800	0.74667600	-1.21434800
C	-1.40949900	0.13377700	-0.99829700
C	-0.42048000	2.22514000	-1.15578300
C	-1.75650300	-1.23885400	-1.10964600
N	-2.38277700	1.02173700	-0.63116000
C	-1.78162200	2.34738700	-0.42274900
C	-3.03747800	-1.61207300	-0.79618500
H	-1.00534100	-1.93158600	-1.45174300
C	-3.63347800	0.65281600	-0.27155100
H	-2.41626000	3.13532200	-0.83325700
H	-1.63907900	2.48408700	0.65179800
C	-4.00174000	-0.66219400	-0.36122600
H	-3.32463000	-2.65619800	-0.87387600
H	-4.29587000	1.43958400	0.06524900
H	1.71564700	-2.48901800	-1.49141100
C	-5.39391200	-1.09947300	-0.01798700
F	-6.02389800	-1.62382800	-1.09332900
F	-5.38844100	-2.05641000	0.93309400
F	-6.14607700	-0.07225600	0.43354700
H	-0.52562000	2.58822700	-2.18789100
C	0.65377700	3.04485200	-0.46800200
C	1.05569800	4.25145900	-1.05010800
C	1.19826100	2.66124700	0.76487900
C	1.98582700	5.07303700	-0.41021000
H	0.64301000	4.55099000	-2.01141800
C	2.13579900	3.47704600	1.39626800
H	0.91332200	1.71293200	1.20589200
C	2.52816000	4.68582600	0.81488100
H	2.29049800	6.00715100	-0.87396800
H	2.56513900	3.16409200	2.34391700
H	3.25891000	5.31801800	1.31179900
C	3.38789100	-2.14379500	-0.20443900
C	4.27439800	-2.81421200	-1.05631900
C	3.91798800	-1.41840900	0.87132900
C	5.65369800	-2.77144000	-0.84045700
H	3.87879100	-3.37346300	-1.90254700
C	5.29493400	-1.37366900	1.09147400
H	3.24226200	-0.88687800	1.53488400
C	6.16943300	-2.04980000	0.23682100
H	6.32419000	-3.29603100	-1.51727300
H	5.68854400	-0.80708400	1.93252200
H	7.24251000	-2.01093700	0.40726700
C	1.27443500	-3.37166800	0.41582300
H	0.19940000	-3.46089300	0.21781800
H	1.75167600	-4.33010800	0.18000600
H	1.40818200	-3.17529600	1.48469000

SCF: E(RB+HF-LYP) = -1716.94405748
Sum of electronic and zero-point
Energies= -1716.454481
Sum of electronic and thermal
Energies= -1716.421393
Sum of electronic and thermal
Enthalpies= -1716.420449
Sum of electronic and thermal
Free Energies= -1716.523277

12 (S)

C	0.97758200	-0.19313800	2.49901400
O	1.38021000	1.19955100	0.83692700
C	0.98671700	2.50328300	1.18075600
O	0.27738500	0.47427700	3.23646400
C	2.43381400	-0.50798200	2.72631800
O	3.68448700	1.01737900	0.08547400
C	3.90273200	1.15299200	-1.19638300
O	3.03924900	1.34274900	-2.05703200
C	5.37473500	1.02600800	-1.57014300
H	2.89076400	0.37063900	3.18211500
H	2.52147500	-1.34322300	3.43647000
H	2.96782100	-0.74554500	1.80622100
H	5.71237000	0.00015600	-1.37998900
H	5.52202000	1.26659600	-2.62495800
H	5.98403000	1.68696400	-0.94519100
H	2.56848300	1.13552400	0.38480000
N	0.27802800	-1.16429100	1.61619300
C	-0.95533900	-0.93769500	1.14525200
C	0.72798700	-2.53398800	1.25864000
C	-1.70353700	0.25955500	1.06670900
N	-1.50773400	-2.09027200	0.65178600
C	-0.63045000	-3.23395800	0.96765700
C	-2.92578700	0.22265500	0.44199100
H	-1.28916300	1.16985100	1.46499100
C	-2.71690300	-2.13835500	0.04142100
H	-1.03728700	-3.75065800	1.84410500

```
H -0.57076100  -3.92057400    0.12314900
C -3.45037500  -0.98797000   -0.08528400
H -3.48750700   1.14481300    0.33002700
H -3.04337600  -3.10380600   -0.32310100
C -0.06029500   3.04892000    0.20566100
C  0.05014300   2.80038200   -1.17076700
C -1.14554700   3.80530500    0.66856000
C -0.90864100   3.29839000   -2.05457900
H  0.89593700   2.22322300   -1.53853100
C -2.10920500   4.29999200   -0.21583000
H -1.23754700   4.00973300    1.73480100
C -1.99386100   4.04386000   -1.58347800
H -0.80786000   3.10384500   -3.12001100
H -2.94382600   4.88615700    0.16284300
H -2.73909100   4.42656900   -2.27679300
C  2.17366600   3.48185000    1.29329200
H  2.91988200   3.09406000    1.99520400
H  2.65859100   3.62344900    0.32245400
H  1.83103200   4.45985700    1.65143900
H  0.51253700   2.46177900    2.18045300
C -4.79206400  -1.00291600   -0.76178100
F -5.76760100  -0.62089000    0.08862700
F -4.82254000  -0.15415600   -1.80635900

F -5.10398200  -2.23564400   -1.21821500
H  1.19293000  -2.99417700    2.13422400
C  1.66594400  -2.62781200    0.06306600
C  2.36089400  -3.83350100   -0.11817300
C  1.78084500  -1.61210900   -0.88909600
C  3.14274900  -4.03150500   -1.25373700
H  2.29232300  -4.61996100    0.63237800
C  2.56896000  -1.81374200   -2.02714400
H  1.30492600  -0.64851400   -0.73173100
C  3.24123000  -3.02090100   -2.21452100
H  3.68083800  -4.96676500   -1.38333200
H  2.67354400  -0.99853100   -2.73510700
H  3.85533900  -3.17068200   -3.09845700

SCF:  E(RB+HF-LYP) =  -1716.93703176
Sum of electronic and zero-point
Energies= -1716.448851
Sum of electronic and thermal
Energies= -1716.415718
Sum of electronic and thermal
Enthalpies= -1716.414774
Sum of electronic and thermal
Free Energies= -1716.517683
```

(d) Comparison of performance of theoretical methods on a model system using DHIP as as a surrogate for CF_3-PIP

Calculations on a model system were carried out to compare the performance of theoretical methods. The goal was to find a method for the calculation of the real system with reasonable accuracy at a low computational cost. The unsubstituted DHIP was used as a surrogate for CF_3-PIP. The relative free energies between the model conformers corresponding to **7a'**/**8b'** and **9a'**/**10b'** calculated at various theoretical levels are shown in Table S-2.

The predicted energy differences on the model system are very close at these theoretical levels. The more efficient B3LYP/6-31G(d)//B3LYP/6-31G(d) calculations have less than 1 kcal/mol deviation from the MP2/6-31G(d)//MP2/6-31G(d) results. Thus, B3LYP/6-31G(d)//B3LYP/6-31G(d) was employed to study the real system.

Table S-2. Comparison of theoretical methods on a model system

Method	ΔG_{298} (**8b' -7a'**) kcal/mol	ΔG_{298} (**10b' -9a'**) kcal/mol
B3LYP/6-31G(d)//B3LYP/6-31G(d)	2.0	3.2
B3LYP/6-311+G(d)//B3LYP/6-31G(d) [a]	2.0	3.5
B3LYP/6-311++G(d,p)//B3LYP/6-31G(d) [a]	2.4	3.8
M05-2X/6-31G(d)//B3LYP/6-31G(d) [a]	1.2	2.5
MP2/6-31G(d)//B3LYP/6-31G(d) [a]	2.0	3.3
SCS-MP2/6-31G(d)//B3LYP/6-31G(d) [a]	1.8	3.2
M05-2X/6-31G(d)//M05-2X/6-31G(d)	2.6	3.2
MP2/6-31G(d)//MP2/6-31G(d) [a]	1.5	3.8

[a] Thermo correction is calculated at the B3LYP/6-31G(d) level.

Table S-3. Computed energies of **7a'**, **8b'**, **9a'**, and **10b'** at various levels.

B3LYP/6-31G(d)//B3LYP/6-31G(d)

	E (a.u.)	ΔG(thermo) (a.u.)	G (a.u)	ΔG_{rel} (kcal/mol)
7a'	-1148.867719	0.346242	-1148.521477	0.0
8b'	-1148.866406	0.348074	-1148.518332	2.0
9a'	-1227.497518	0.400819	-1227.096699	0.0
10b'	-1227.494576	0.402976	-1227.091600	3.2

B3LYP/6-311+G(d)//B3LYP/6-31G(d)

	E (a.u.)	ΔG(thermo)[a] (a.u.)	G (a.u)	ΔG_{rel} (kcal/mol)
7a'	-1149.155079	0.346242	-1148.808837	0.0
8b'	-1149.153798	0.348074	-1148.805724	2.0
9a'	-1227.798847	0.400819	-1227.398028	0.0
10b'	-1227.795440	0.402976	-1227.392464	3.5

[a] Thermo correction is calculated at the B3LYP/6-31G(d) level.

B3LYP/6-311++G(d,p)//B3LYP/6-31G(d)

	E (a.u.)	ΔG(thermo)[a] (a.u.)	G (a.u)	ΔG_{rel} (kcal/mol)
7a'	-1149.196535	0.346242	-1148.850293	0.0
8b'	-1149.194529	0.348074	-1148.846454	2.4
9a'	-1227.845061	0.400819	-1227.444242	0.0
10b'	-1227.841103	0.402976	-1227.438127	3.8

[a] Thermo correction is calculated at the B3LYP/6-31G(d) level.

M05-2X/6-31G(d)//B3LYP/6-31G(d)

	E (a.u.)	ΔG(thermo)[a] (a.u.)	G (a.u)	ΔG_{rel} (kcal/mol)
7a'	-1148.729316	0.346242	-1148.383074	0.0
8b'	-1148.729194	0.348074	-1148.381120	1.2
9a'	-1227.347336	0.400819	-1226.946517	0.0
10b'	-1227.345562	0.402976	-1226.942586	2.5

[a] Thermo correction is calculated at the B3LYP/6-31G(d) level.

MP2/6-31G(d)//B3LYP/6-31G(d)

	E (a.u.)	ΔG(thermo)[a] (a.u.)	G (a.u)	ΔG_{rel} (kcal/mol)
7a'	-1145.287115	0.346242	-1144.940873	0.0
8b'	-1145.285770	0.348074	-1144.937696	2.0
9a'	-1223.623235	0.400819	-1223.222416	0.0
10b'	-1223.620158	0.402976	-1223.217183	3.3

[a] Thermo correction is calculated at the B3LYP/6-31G(d) level.

SCS-MP2/6-31G(d)//B3LYP/6-31G(d)

	E (a.u.)	ΔG(thermo)[a] (a.u.)	G (a.u)	ΔG_{rel} (kcal/mol)
7a'	-1145.171268	0.346242	-1144.825026	0.0
8b'	-1145.170175	0.348074	-1144.822101	1.8
9a'	-1223.504613	0.400819	-1223.103794	0.0
10b'	-1223.501605	0.402976	-1223.098629	3.2

[a] Thermo correction is calculated at the B3LYP/6-31G(d) level.

M05-2X/6-31G(d)//M05-2X/6-31G(d)

	E (a.u.)	ΔG(thermo) (a.u.)	G (a.u)	ΔG_{rel} (kcal/mol)
7a'	-1148.867726	0.345179	-1148.522547	0.0
8b'	-1148.866406	0.348074	-1148.518332	2.6
9a'	-1227.497518	0.400819	-1227.096699	0.0
10b'	-1227.494576	0.402965	-1227.091611	3.2

MP2/6-31G(d)//MP2/6-31G(d)

	E (a.u.)	ΔG(thermo)[a] (a.u.)	G (a.u)	ΔG_{rel} (kcal/mol)
7a'	-1145.295583	0.354370	-1144.941213	0.0
8b'	-1145.289336	0.350465	-1144.938871	1.5
9a'	-1223.629487	0.407364	-1223.222123	0.0
10b'	-1223.623761	0.407665	-1223.216096	3.8

[a] Thermo correction is calculated at the B3LYP/6-31G(d) level.

Optimized geometries at B3LYP/6-31G(d) level

7a' (optimized by B3LYP/6-31G(d))

```
C   0.26090000  -2.09489800   1.22813800
O   1.27684300  -0.26075300   0.99638100
C   0.67592200   0.74186100   1.75412400
O  -0.40589800  -2.02103100   2.25050200
C   1.53967500  -2.89525400   1.13244700
O   3.59493800   0.05870400   0.26500700
C   3.73587100   0.11160800  -1.03398900
O   2.83500000  -0.06192700  -1.86191400
C   5.16064500   0.41731300  -1.46812700
H   2.07565200  -2.76534600   2.07287800
H   1.28617500  -3.95802800   1.01570400
H   2.18869800  -2.58745500   0.31286400
H   5.84827900  -0.31967900  -1.03964200
H   5.23669300   0.40945100  -2.55690700
H   5.46177700   1.39786900  -1.08326000
H   2.53622700  -0.08159000   0.58753000
N  -0.43236600  -1.90738600  -0.05409100
C  -1.69663500  -1.46602300  -0.15474900
C   0.26818800  -1.80056000  -1.35242500
C  -2.74667700  -1.43082800   0.79710900
N  -1.95284000  -1.00918000  -1.42065800
C  -0.71795600  -1.01711400  -2.23830900
H   1.20301400  -1.24598900  -1.24702400
C  -3.97336200  -0.94796100   0.40003200
H  -2.53393600  -1.77140800   1.79884600
C  -3.15884000  -0.52508200  -1.80906500
H  -0.91239200  -1.49412500  -3.20143800
H  -0.39636700   0.01612600  -2.39118800
C  -4.20056400  -0.48813600  -0.91967200
H  -4.78563700  -0.92001100   1.12030500
H  -3.22401800  -0.18326300  -2.83536900
C  -0.14663600   1.70987200   0.89294700
C  -1.29456100   2.32833000   1.40577700
C   0.23971700   2.01191000  -0.42140500
C  -2.03656400   3.22850400   0.63758700
H  -1.61112600   2.09953200   2.42227300
C  -0.49803100   2.91448600  -1.19222300
H   1.11815500   1.52712800  -0.83861200
C  -1.64016400   3.52608900  -0.66780500
H  -2.92429400   3.69633000   1.05785700
H  -0.17337700   3.14855000  -2.20436100
H  -2.21173000   4.23020800  -1.26794000
C   1.71354600   1.51574600   2.59423300
H   2.25341400   0.81493400   3.24024000
H   2.44248300   2.01197000   1.94433800
H   1.23459000   2.27678200   3.22206100
H  -0.02545400   0.26436600   2.46414300
H  -5.16525800  -0.10583700  -1.22966400
H   0.46094800  -2.80367400  -1.74793600
```

SCF: E(RB+HF-LYP) = -1148.86771883
Sum of electronic and zero-point
Energies= -1148.463983
Sum of electronic and thermal
Energies= -1148.439172
Sum of electronic and thermal
Enthalpies= -1148.438228
Sum of electronic and thermal
Free Energies= -1148.521477

8b' (optimized by B3LYP/6-31G(d))

```
C   0.00228300  -1.61860700   0.96735600
O  -0.61865500  -0.12234500  -0.01435100
C  -1.57323500  -0.51455100  -0.97007300
O  -0.09174500  -2.62712000   0.26441300
C  -0.84989100  -1.44177500   2.21416600
O  -0.26515400   2.37005100  -0.02912100
C   0.94807200   2.86717700  -0.16047800
O   1.98780600   2.21615300  -0.09332800
C   0.93692300   4.36395900  -0.40726300
H  -1.87369700  -1.70563000   1.94575600
H  -0.50531500  -2.13718500   2.99167700
H  -0.84841800  -0.42328500   2.60605100
H   0.31985900   4.86741900   0.34375700
H   1.95420400   4.75829600  -0.38569200
H   0.48583600   4.57006500  -1.38436100
H  -0.30790900   1.30848300  -0.00584700
N   1.38570100  -1.06568000   1.14750100
C   2.30582400  -1.11913200   0.17468400
C   1.72483500  -0.00041600   2.10705000
C   2.31994400  -1.85081900  -1.03890100
N   3.37890600  -0.32488500   0.46852000
C   3.19063900   0.34217600   1.77127700
H   1.07235800   0.86029600   1.94837300
C   3.40521200  -1.70594800  -1.87292800
H   1.46971500  -2.48355500  -1.24830400
C   4.44375400  -0.17393100  -0.35546500
H   3.90034600  -0.07966800   2.49085200
H   3.34912300   1.41303100   1.65231300
C   4.49105600  -0.85854400  -1.54164800
H   3.42450800  -2.25202500  -2.81161800
H   5.21452800   0.50734100  -0.01541100
H  -1.44386100  -1.59532000  -1.13932100
C  -1.31655300   0.19879900  -2.31173500
H  -0.28961900   0.00299700  -2.64205800
H  -2.00802600  -0.15708300  -3.08485900
H  -1.44614500   1.28197000  -2.21202200
C  -3.01507300  -0.29636000  -0.50460900
C  -4.00478800  -1.23994100  -0.80805400
C  -3.38843900   0.85257700   0.20691900
C  -5.33294400  -1.04322200  -0.42377200
H  -3.72837300  -2.14394400  -1.34778000
C  -4.71407100   1.05325400   0.59340600
H  -2.63329700   1.59137900   0.45788500
C  -5.69289800   0.10704500   0.27962100
H  -6.08348500  -1.79190900  -0.66689700
H  -4.98477900   1.95169400   1.14380300
H  -6.72483500   0.26329300   0.58442900
H   5.33959800  -0.73776500  -2.20379600
H   1.61354500  -0.35931000   3.13269800
```

SCF: E(RB+HF-LYP) = -1148.86640646
Sum of electronic and zero-point
Energies= -1148.460844
Sum of electronic and thermal
Energies= -1148.436290
Sum of electronic and thermal
Enthalpies= -1148.435346
Sum of electronic and thermal
Free Energies= -1148.518332

9a' (optimized by B3LYP/6-31G(d))

```
C   0.06322900   2.30530900   0.35436400
O  -0.88163000   0.53912900   0.98906100
C  -0.14277600  -0.09204300   1.98649000
O   0.81242200   2.66282700   1.25294900
C  -1.24708500   3.00216700   0.02781700
O  -3.26028300  -0.03300800   0.70305900
C  -3.53791300  -0.58400600  -0.45281100
O  -2.72923300  -0.77457100  -1.36623200
C  -5.00343000  -0.98805200  -0.58045400
H  -1.91668600   2.33503100  -0.51882600
H  -0.99451700   3.83587600  -0.64767600
H  -5.21587800  -1.70278000   0.22567200
H  -5.61087200  -0.10369700  -0.34856700
H  -2.19225300   0.19876600   0.82264800
N   0.66566900   1.61018800  -0.79622200
C   1.94098500   1.19490800  -0.83069100
C  -0.12690000   0.97418200  -1.87096000
C   3.06124800   1.56661000  -0.04442600
N   2.12738200   0.27636200  -1.83048900
C   0.83892800  -0.06307200  -2.47613300
H  -1.01258100   0.48455200  -1.46029200
C   4.27890800   0.99017600  -0.32635400
H   2.90662700   2.27759000   0.75271400
C   3.32584400  -0.29869000  -2.10179900
H   0.93592000   0.01534600  -3.56139600
H   0.57060200  -1.08545300  -2.19872000
C   4.43129800   0.04324400  -1.36840200
H   5.14344500   1.27046700   0.26817300
H   3.33269600  -1.02052700  -2.91008200
C   0.63758100  -1.30380600   1.45831400
C   1.87990400  -1.65093200   2.00564500
```

10b' (optimized by B3LYP/6-31G(d))

```
C  -0.12451300  -1.84034400   0.86326200
O  -0.77634900  -0.20770100   0.22150000
C  -1.58323200  -0.37521300  -0.91829500
O  -0.36327500  -2.73109100   0.04246200
C  -0.77207500  -1.83056800   2.24977100
O  -0.11690800   2.21183400   0.54572500
C   1.09312900   2.62559800   0.21881400
O   2.03977600   1.88878700  -0.04671100
C   1.19980800   4.14414100   0.20502400
H  -0.71995000  -0.83170800   2.69245700
H  -0.17809300  -2.50740000   2.88469100
H   0.74203300   4.52222700   1.12735100
H   0.55308000   4.50367100  -0.60679900
H  -0.27635800   1.17746100   0.39970600
N   1.31847000  -1.40073800   0.95021000
C   2.16972500  -1.47328300  -0.07805200
C   1.83693700  -0.48847800   1.98445100
C   2.04780300  -2.12320100  -1.33402200
N   3.33365900  -0.80614600   0.19529900
C   3.29181600  -0.21481700   1.54620700
H   1.24590900   0.42849800   1.99821500
C   3.09409600  -2.02732100  -2.22222200
H   1.13203300  -2.66193400  -1.52875600
C   4.36098300  -0.70422100  -0.68291400
H   4.02837700  -0.72065800   2.17901900
H   3.50933900   0.85013100   1.47654500
C   4.27483500  -1.30864400  -1.90925900
H   3.00867600  -2.51335200  -3.18981000
H   5.21473800  -0.12639500  -0.34906800
H  -1.56055100  -1.44488200  -1.17997400
C  -1.01883900   0.41050500  -2.12035500
H   0.02418700   0.12298400  -2.29635900
C   0.11791500  -2.10530300   0.43057700
C   2.58638600  -2.76644200   1.54989600
H   2.29896200  -1.03658200   2.80110500
C   0.81939000  -3.22496100  -0.02518500
H  -0.83644000  -1.84013100  -0.01628900
C   2.05751600  -3.56028300   0.53024800
H   3.54910900  -3.01552100   1.99109100
H   0.39184900  -3.84397300  -0.81172300
H   2.60067100  -4.43344700   0.17646200
C  -1.03425600  -0.50813200   3.17574700
H  -1.54065400   0.37517000   3.58001900
H  -1.79888700  -1.22327600   2.85306500
H  -0.44442900  -0.97136200   3.97603800
H   0.60146300   0.62797800   2.37608400
C  -5.36690800  -1.57116800  -1.94406500
H  -4.76787100  -2.46077100  -2.16151300
H  -6.42617700  -1.85004700  -1.97786500
H  -5.17561800  -0.84877200  -2.74406700
C  -1.93473000   3.53289900   1.28423000
H  -1.25933400   4.17736400   1.85361100
H  -2.82838900   4.10671200   1.01673500
H  -2.23283600   2.69616000   1.92032700
H   5.38934900  -0.41225000  -1.58642800
H  -0.41966300   1.73107100  -2.60629900
```

```
SCF:  E(RB+HF-LYP) =  -1227.49751796
 Sum of electronic and zero-point
 Energies= -1227.035839
 Sum of electronic and thermal
 Energies= -1227.008440
 Sum of electronic and thermal
 Enthalpies= -1227.007495
 Sum of electronic and thermal
 Free Energies= -1227.096699
```

```
H  -1.59681700   0.20898500  -3.03020900
H  -1.05321100   1.48934700  -1.93243500
C  -3.04420000   0.00752200  -0.67297200
C  -4.06490900  -0.62324400  -1.39722500
C  -3.39874000   1.01011700   0.23901200
C  -5.40167700  -0.26115900  -1.22556300
H  -3.80751700  -1.41386400  -2.09999100
C  -4.73501900   1.37468400   0.41499600
H  -2.62009200   1.50147300   0.81338000
C  -5.74225900   0.74249700  -0.31668500
H  -6.17744800  -0.76852500  -1.79447300
H  -4.99044200   2.15504200   1.12846200
H  -6.78271400   1.02509800  -0.17627000
C   2.62741400   4.65769800   0.03241400
H   3.07235500   4.27048500  -0.88891700
H   2.64326000   5.75215000  -0.00759700
H   3.26587800   4.33904200   0.86358700
C  -2.21897800  -2.31819000   2.20220600
H  -2.27358300  -3.30030400   1.72483000
H  -2.62974900  -2.39470200   3.21516700
H  -2.84036100  -1.62524600   1.62951000
H   5.09318600  -1.22613000  -2.61385500
H   1.79034300  -0.96243900   2.96766100
```

```
SCF:  E(RB+HF-LYP) =  -1227.49457587
 Sum of electronic and zero-point
 Energies= -1227.031246
 Sum of electronic and thermal
 Energies= -1227.004133
 Sum of electronic and thermal
 Enthalpies= -1227.003188
 Sum of electronic and thermal
 Free Energies= -1227.091600
```

Optimized geometries at M05-2X/6-31G(d) level

7a' (optimized by M05-2X/6-31G(d))

```
C   0.30653400  -1.93343900   1.46495500
O   1.26502600  -0.13599800   1.03067700
C   0.66703800   0.92115200   1.71379000
O  -0.39564600  -1.75168300   2.45083200
C   1.60128200  -2.71467400   1.50985400
O   3.55790900   0.16183400   0.18309500
C   3.65959600   0.13255900  -1.12205700
O   2.73888600  -0.11185300  -1.90797600
C   5.06473700   0.43558900  -1.61529400
H   2.09652700  -2.46794000   2.44939800
H   1.37157600  -3.78919200   1.50583400
H   2.27863600  -2.48689000   0.68688500
H   5.78245100  -0.24302300  -1.14236700
H   5.11580000   0.33687100  -2.70100500
H   5.34616800   1.45354800  -1.32373700
H   2.52370200   0.03703900   0.54748100
N  -0.35494800  -1.94670600   0.14824100
C  -1.61153300  -1.51893000  -0.05281600
C   0.38710700  -2.01569300  -1.12814800
C  -2.68401200  -1.33233800   0.85518900
N  -1.83097500  -1.25518800  -1.37915900
C  -0.57731400  -1.39214400  -2.15403900
H   1.30122400  -1.42256400  -1.07785900
C  -3.89423700  -0.90352800   0.35893800
H  -2.49796700  -1.51985100   1.90164500
C  -3.02230500  -0.82737600  -1.86736800
H  -0.74884500  -2.02070300  -3.03080000
H  -0.24505400  -0.39919900  -2.46749600
C  -4.08440300  -0.64789300  -1.02083100
H  -4.72253600  -0.75778800   1.04592700
H  -3.05882900  -0.64463200  -2.93494900
C  -0.21573900   1.78350500   0.80230700
C  -1.33001200   2.46044900   1.31602500
C   0.07949200   1.92841000  -0.56094300
C  -2.12696200   3.26544000   0.49949000
H  -1.57657800   2.35273000   2.37123100
C  -0.71366700   2.73588000  -1.38065700
H   0.93501700   1.40082200  -0.97397700
C  -1.82125400   3.40678500  -0.85583300
H  -2.98711600   3.78127500   0.92094100
H  -0.45907600   2.84943100  -2.43282500
H  -2.43670000   4.03632100  -1.49424100
C   1.71764400   1.79487800   2.43132100
H   2.30682800   1.17077500   3.11207600
H   2.40151000   2.25019600   1.70668600
H   1.24457800   2.59711500   3.01046500
H   0.00807000   0.49759500   2.49460000
H  -5.03669700  -0.30891400  -1.40957100
H   0.61742200  -3.05994100  -1.36424200
```

SCF: E(RB+HF-LYP) = -1148.86772607
Sum of electronic and zero-point
Energies= -1148.463748
Sum of electronic and thermal
Energies= -1148.438916
Sum of electronic and thermal
Enthalpies= -1148.437972
Sum of electronic and thermal
Free Energies= -1148.522547

8b' (optimized by M05-2X/6-31G(d))

```
C   0.00228300  -1.61860700   0.96735600
O  -0.61865500  -0.12234500  -0.01435100
C  -1.57323500  -0.51455100  -0.97007300
O  -0.09174500  -2.62712000   0.26441300
C  -0.84989100  -1.44177500   2.21416600
O  -0.26515400   2.37005100  -0.02912100
C   0.94807200   2.86717700  -0.16047800
O   1.98780600   2.21615300  -0.09332800
C   0.93692300   4.36395900  -0.40726300
H  -1.87369700  -1.70563000   1.94575600
H  -0.50531500  -2.13718500   2.99167700
H  -0.84841800  -0.42328500   2.60605100
H   0.31985900   4.86741900   0.34375700
H   1.95420400   4.75829600  -0.38569200
H   0.48583600   4.57006500  -1.38436100
H  -0.30790900   1.30848300  -0.00584700
N   1.38570100  -1.06568000   1.14750100
C   2.30582400  -1.11913200   0.17468400
C   1.72483500  -0.00041600   2.10705000
C   2.31994400  -1.85081900  -1.03890100
N   3.37890600  -0.32488500   0.46852000
C   3.19063900   0.34217600   1.77127700
H   1.07235800   0.86029600   1.94837300
C   3.40521200  -1.70594800  -1.87292800
H   1.46971500  -2.48355500  -1.24830400
C   4.44375400  -0.17393100  -0.35546500
H   3.90034600  -0.07966800   2.49085200
H   3.34912300   1.41303100   1.65231300
C   4.49105600  -0.85854400  -1.54164800
H   3.42450800  -2.25202500  -2.81161800
H   5.21452800   0.50734100  -0.01541100
H  -1.44386100  -1.59532000  -1.13932100
C  -1.31655300   0.19879900  -2.31173500
H  -0.28961900   0.00299700  -2.64205800
H  -2.00802600  -0.15708300  -3.08485900
H  -1.44614500   1.28197000  -2.21202200
C  -3.01507300  -0.29636000  -0.50460900
C  -4.00478800  -1.23994100  -0.80805400
C  -3.38843900   0.85257700   0.20691900
C  -5.33294400  -1.04322200  -0.42377200
H  -3.72837300  -2.14394400  -1.34778000
C  -4.71407100   1.05325400   0.59340600
H  -2.63329700   1.59137900   0.45788500
C  -5.69289800   0.10704500   0.27962100
H  -6.08348500  -1.79190900  -0.66689700
H  -4.98477900   1.95169400   1.14380300
H  -6.72483500   0.26329300   0.58442900
H   5.33959800  -0.73776500  -2.20379600
H   1.61354500  -0.35931000   3.13269800
```

SCF: E(RB+HF-LYP) = -1148.86640646
Sum of electronic and zero-point
Energies= -1148.460844
Sum of electronic and thermal
Energies= -1148.436290
Sum of electronic and thermal
Enthalpies= -1148.435346
Sum of electronic and thermal
Free Energies= -1148.518332

9a' (optimized by M05-2X/6-31G(d))

```
C   0.06322900   2.30530900   0.35436200
O  -0.88163000   0.53913000   0.98906100
C  -0.14277600  -0.09204100   1.98649000
O   0.81242200   2.66282800   1.25294700
C  -1.24708500   3.00216700   0.02781500
O  -3.26028300  -0.03300800   0.70305900
C  -3.53791300  -0.58400700  -0.45281000
O  -2.72923300  -0.77457200  -1.36623100
C  -5.00343000  -0.98805300  -0.58045300
H  -1.91668600   2.33503000  -0.51882800
H  -0.99451700   3.83587500  -0.64767900
H  -5.21587800  -1.70278000   0.22567400
H  -5.61087200  -0.10369800  -0.34856700
H  -2.19225300   0.19876600   0.82264800
N   0.66566900   1.61018700  -0.79622300
C   1.94098500   1.19490700  -0.83069200
C  -0.12690000   0.97418000  -1.87096100
C   3.06124800   1.56661000  -0.04442700
N   2.12738200   0.27636000  -1.83048900
C   0.83892800  -0.06307400  -2.47613300
H  -1.01258100   0.48455100  -1.46029200
C   4.27890800   0.99017600  -0.32635400
H   2.90662700   2.27759100   0.75271200
C   3.32584400  -0.29869200  -2.10179800
H   0.93592000   0.01534300  -3.56139600
H   0.57060200  -1.08545500  -2.19871900
C   4.43129800   0.04324300  -1.36840200
H   5.14344500   1.27046700   0.26817200
H   3.33269600  -1.02053000  -2.91008100
C   0.63758100  -1.30380500   1.45831500
C   1.87990400  -1.65093000   2.00564700
C   0.11791500  -2.10530300   0.43057900
C   2.58638600  -2.76644100   1.54989900
H   2.29896200  -1.03658000   2.80110600
C   0.81939000  -3.22496100  -0.02518200
H  -0.83644000  -1.84013100  -0.01628700
C   2.05752000  -3.56027700   0.53024500
H   3.54910900  -3.01551900   1.99109400
H   0.39184900  -3.84397400  -0.81171900
H   2.60067500  -4.43344200   0.17646000
C  -1.03425600  -0.50812900   3.17574800
H  -1.54065400   0.37517300   3.58001900
H  -1.79888700  -1.22327400   2.85306600
H  -0.44442900  -0.97135900   3.97603900
H   0.60146300   0.62798000   2.37608400
C  -5.36690800  -1.57117000  -1.94406400
H  -4.76787100  -2.46077300  -2.16151100
H  -6.42617700  -1.85004900  -1.97786300
H  -5.17561800  -0.84877500  -2.74406600
C  -1.93473000   3.53290000   1.28422700
H  -1.25933400   4.17736500   1.85360800
H  -2.82838900   4.10671300   1.01673200
H  -2.23283600   2.69616100   1.92032500
H   5.38934900  -0.41225100  -1.58642700
H  -0.41966300   1.73106900  -2.60630000
```

```
SCF:  E(RB+HF-LYP) =  -1227.49751796
 Sum of electronic and zero-point
 Energies= -1227.035839
 Sum of electronic and thermal
 Energies= -1227.008440
 Sum of electronic and thermal
 Enthalpies= -1227.007495
 Sum of electronic and thermal
 Free Energies= -1227.096699
```

10b' (optimized by M05-2X/6-31G(d))

```
C  -0.12508200  -1.83982500   0.86334800
O  -0.77661500  -0.20734200   0.22132900
C  -1.58354400  -0.37485900  -0.91846100
O  -0.36396100  -2.73071700   0.04272600
C  -0.77262500  -1.82972500   2.24987300
O  -0.11592800   2.21175100   0.54567600
C   1.09417100   2.62496600   0.21829800
O   2.04026300   1.88771400  -0.04799700
C   1.20171800   4.14345500   0.20501300
H  -0.72031400  -0.83080900   2.69241400
H  -0.17876800  -2.50657800   2.88488600
H   0.74411900   4.52152700   1.12743000
H   0.55523600   4.50359600  -0.60673900
H  -0.27605200   1.17748900   0.39915700
N   1.31800800  -1.40043700   0.95024400
C   2.16932300  -1.47336300  -0.07793800
C   1.83671600  -0.48831300   1.98448100
C   2.04728000  -2.12334500  -1.33386000
N   3.33345600  -0.80659100   0.19544900
C   3.29173700  -0.21523100   1.54634300
H   1.24601700   0.42887700   1.99814700
C   3.09366700  -2.02788100  -2.22199100
H   1.13135100  -2.66180700  -1.52860000
C   4.36086800  -0.70505500  -0.68270400
H   4.02804800  -0.72135900   2.17922000
H   3.50972100   0.84962800   1.47672400
C   4.27460900  -1.30954800  -1.90900700
H   3.00816300  -2.51397000  -3.18954200
H   5.21478200  -0.12747000  -0.34885100
H  -1.56086000  -1.44452000  -1.18014900
C  -1.01919400   0.41091000  -2.12049600
H   0.02384100   0.12344600  -2.29652500
H  -1.59719100   0.20939100  -3.03033700
H  -1.05360500   1.48975000  -1.93255700
C  -3.04446900   0.00791800  -0.67302700
C  -4.06536600  -0.62356000  -1.39638300
C  -3.39876900   1.01133600   0.23815800
C  -5.40210300  -0.26138300  -1.22462400
H  -3.80815200  -1.41480000  -2.09851500
C  -4.73500600   1.37598700   0.41423700
H  -2.61996100   1.50326100   0.81183300
C  -5.74244600   0.74307600  -0.31655200
H  -6.17802900  -0.76930600  -1.79282700
H  -4.99024800   2.15698000   1.12707300
H  -6.78287000   1.02575000  -0.17606200
C   2.62962000   4.65625100   0.03258200
H   3.07437600   4.26900400  -0.88882300
H   2.64609200   5.75070300  -0.00716300
H   3.26787500   4.33704200   0.86370500
C  -2.21962000  -2.31708100   2.20239100
H  -2.27440400  -3.29930500   1.72526100
H  -2.63043600  -2.39325800   3.21536000
H  -2.84085600  -1.62416200   1.62950300
H   5.09303200  -1.22734400  -2.61355600
H   1.78986300  -0.96219300   2.96771700
```

```
 SCF:  E(RB+HF-LYP) =  -1227.49457571
 Sum of electronic and zero-point
 Energies= -1227.031250
 Sum of electronic and thermal
 Energies= -1227.004135
 Sum of electronic and thermal
 Enthalpies= -1227.003191
 Sum of electronic and thermal
 Free Energies= -1227.091611
```

Optimized geometries at MP2/6-31G(d) level

7a' (optimized by MP2/6-31G(d))

```
C  -0.68093600   2.25656100   0.88192200
O  -0.96158500   0.32079100   0.78427500
C  -0.17892900  -0.32638300   1.76110400
O   0.17481700   2.48920100   1.74127600
C  -2.11654900   2.68408300   1.07586100
O  -3.32462800  -0.42982400   0.38650200
C  -3.46403600  -1.21912000  -0.66798700
O  -2.54794600  -1.58166000  -1.41458400
C  -4.89676200  -1.65126800  -0.87225900
H  -2.35024500   2.51356400   2.12766400
H  -2.19088900   3.75741800   0.86737800
H  -2.83918300   2.14198400   0.46925600
H  -5.54714500  -0.77432200  -0.91251700
H  -4.98217200  -2.23026800  -1.79127300
H  -5.21648600  -2.25631300  -0.01980100
H  -2.29847900  -0.17640400   0.56019000
N  -0.22143900   2.30044500  -0.54726300
C   1.03456500   1.77575900  -0.69693200
C  -1.06843500   1.69986900  -1.60255900
C   2.22398700   2.13299400  -0.04353100
N   1.06614100   0.77149300  -1.61022700
C  -0.29111400   0.48573300  -2.11688900
H  -2.02844800   1.38960400  -1.19908900
C   3.37647300   1.42025200  -0.33713800
H   2.20162900   2.94589900   0.66808300
C   2.17592500   0.05949300  -1.90785000
H  -0.26544600   0.41733900  -3.20706100
H  -0.64561000  -0.44464300  -1.67408700
C   3.35885900   0.36968900  -1.26789000
H   4.30601000   1.68214700   0.16156900
H   2.06250800  -0.73424700  -2.63720600
C   0.87436900  -1.20304100   1.10942600
C   2.20247700  -1.18866800   1.55293900
C   0.51949700  -2.08713500   0.07772000
C   3.15968400  -2.03834500   0.98869600
H   2.48512500  -0.50833200   2.35603000
C   1.47512700  -2.93137300  -0.49386500
H  -0.51227200  -2.11581800  -0.26856900
C   2.79799500  -2.91290600  -0.03840900
H   4.18404300  -2.02401500   1.35760600
H   1.18064800  -3.62392200  -1.28099100
H   3.53664900  -3.58439400  -0.47193600
C  -1.04916000  -1.14615100   2.71547600
H  -1.78505200  -0.49228800   3.19331200
H  -1.58377200  -1.92732700   2.16632800
H  -0.43977300  -1.62261300   3.49130500
H   0.34617600   0.45032200   2.34619400
H   4.25240800  -0.19948600  -1.49657000
H  -1.22661600   2.44421200  -2.39015600
```

```
E(RHF) = -1141.77441741
E2 = -0.3521166017D+01
EUMP2 = -0.11452955834244D+04
```

8b' (optimized by MP2/6-31G(d))

```
C  -0.17213300  -1.64658400   1.01990000
O  -0.42573300  -0.08620500  -0.09584400
C  -1.36349100  -0.38107100  -1.11360300
O  -0.37608600  -2.64845000   0.32537300
C  -1.09151200  -1.27110000   2.15862400
O  -0.11334900   2.35544600   0.17513700
C   1.12009200   2.79043100   0.00041800
O   2.12685200   2.07199600  -0.05239300
C   1.18993500   4.29504400  -0.12756600
H  -2.11037700  -1.43550800   1.80660800
H  -0.89781400  -1.93593100   3.00936100
H  -0.99267100  -0.23104000   2.46828500
H   0.66599000   4.76374000   0.70873200
H   2.22966900   4.62096100  -0.15531100
H   0.68145200   4.60291700  -1.04519300
H  -0.20082900   1.25993300   0.07311400
N   1.24543900  -1.28367100   1.27320000
C   2.08505200  -1.26144700   0.20672300
C   1.59035900  -0.13979600   2.13792800
C   2.00692300  -1.91867500  -1.03690900
N   3.15279200  -0.45943100   0.45161600
C   3.06474100   0.09552600   1.81286000
H   0.98888800   0.72984100   1.86397100
C   3.00980300  -1.68653800  -1.96018800
H   1.15903100  -2.56548700  -1.21775700
C   4.14101800  -0.21846000  -0.43961400
H   3.73415000  -0.47832000   2.46237700
H   3.33876800   1.14897200   1.79218400
C   4.09008200  -0.83038100  -1.67120100
H   2.95390200  -2.17063500  -2.93169000
H   4.91380700   0.47425200  -0.12620200
H  -1.25512000  -1.44909400  -1.36372000
C  -1.04915100   0.44289500  -2.36143500
H  -0.01635600   0.25213300  -2.67138700
H  -1.72515000   0.17942500  -3.18218500
H  -1.15616800   1.51075200  -2.15229000
C  -2.78744500  -0.17413600  -0.63795400
C  -3.71585200  -1.22003500  -0.69715200
C  -3.19405500   1.06120800  -0.11170400
C  -5.02962000  -1.03875000  -0.25558600
H  -3.39795600  -2.18913700  -1.07920100
C  -4.50483900   1.24476200   0.32926800
H  -2.47732100   1.87613400  -0.03759300
C  -5.42788300   0.19664700   0.25762600
H  -5.73808900  -1.86317600  -0.30543800
H  -4.80878600   2.20793600   0.73467400
H  -6.44869000   0.34198300   0.60430500
H   4.86969200  -0.63645800  -2.39913400
H   1.43675800  -0.39201700   3.18898500
```

```
E(RHF) = -1141.78143441
E2 = -0.3507901417D+01
EUMP2 = -0.11452893358233D+04
```

9a' (optimized by MP2/6-31G(d))

```
C  -0.13120000   2.44800400  -0.06733400
O  -0.80452500   0.69298000   0.83786800
C   0.10874100   0.25181800   1.79884600
O   0.58918700   3.02439700   0.74463300
C  -1.53220900   2.89968600  -0.40461600
O  -3.12728100  -0.11746100   0.92951500
C  -3.43779000  -0.84260200  -0.12153800
O  -2.67113800  -1.11894700  -1.05975200
C  -4.87192100  -1.33831900  -0.09270600
H  -2.11608200   2.07113800  -0.80888400
H  -1.43573500   3.65764800  -1.19665000
H  -4.99833000  -1.91594300   0.83016100
H  -5.51983100  -0.46153900   0.01901500
```

```
H  -2.06823400   0.21471700   0.90059200
N   0.51923000   1.68224200  -1.14029500
C   1.75954300   1.17735200  -0.94017700
C  -0.27146700   0.75709700  -1.98052000
C   2.84054700   1.66771600  -0.17625100
N   1.94483700   0.03845200  -1.66256700
C   0.75312800  -0.27414700  -2.47418000
H  -1.04010800   0.27532900  -1.37577400
C   4.01718300   0.94191000  -0.16291600
H   2.70372500   2.58165600   0.38366700
C   3.08887600  -0.68604600  -1.65527000
H   1.01443700  -0.15580700  -3.52963600
H   0.44414200  -1.30153800  -2.27337800
C   4.15037800  -0.25284100  -0.89399000
H   4.85361100   1.30639100   0.42793300
H   3.08938900  -1.58960200  -2.25472900
C   0.88621700  -0.96687600   1.31934600
C   2.16749200  -1.24917300   1.81373400
C   0.30072600  -1.86723700   0.41743400
C   2.85291000  -2.40258800   1.42255600
H   2.62932100  -0.55916200   2.52066400
C   0.98714100  -3.01937900   0.01994800
H  -0.69445200  -1.65705400   0.03084100
```

10b' (optimized by MP2/6-31G(d))

```
C   0.28200600  -1.91132000  -0.94415700
O   0.65961200  -0.16957200  -0.23976600
C   1.43003100  -0.24972300   0.94144900
O   0.64835500  -2.75903900  -0.12028700
C   0.96734300  -1.74514800  -2.28740200
O  -0.11194900   2.14125900  -0.71604400
C  -1.33459900   2.44309200  -0.31942800
O  -2.17565900   1.62208900   0.07139900
C  -1.62112300   3.92959400  -0.38951700
H   0.76321600  -0.75407300  -2.69943300
H   0.52624800  -2.49151700  -2.96544800
H  -1.27704800   4.29155100  -1.36427200
H  -0.97421700   4.41601300   0.35042400
H   0.15541000   1.10489100  -0.48956600
N  -1.18528500  -1.67191200  -1.04116000
C  -1.92215400  -1.62168200   0.09177800
C  -1.74136400  -0.70268800  -2.00216000
C  -1.67377200  -2.14513300   1.37804600
N  -3.09054500  -0.95907900  -0.12123500
C  -3.18835500  -0.54335300  -1.53017200
H  -1.19641400   0.24099900  -1.93631700
C  -2.61434600  -1.92140200   2.36667500
H  -0.75201400  -2.68816100   1.53726100
C  -4.01902200  -0.73008500   0.83425200
H  -3.87428700  -1.22541100  -2.04336700
H  -3.54714600   0.48368100  -1.57878800
C  -3.79972200  -1.20691800   2.10639900
H  -2.42666500  -2.30339500   3.36680800
H  -4.88824100  -0.15614300   0.53282600
C   2.26377800  -3.29343900   0.52112600
H   3.84286100  -2.60988900   1.82594700
H   0.50896200  -3.72164600  -0.66206600
H   2.78863300  -4.19929800   0.22368300
C  -0.59183900  -0.06305700   3.12519600
H  -1.11131900   0.83180800   3.48037800
H  -1.32970900  -0.85589400   2.97111300
H   0.12202800  -0.38990200   3.88948300
H   0.83845100   1.06447600   1.98852100
C  -5.24956200  -2.15847000  -1.31737800
H  -4.60395300  -3.03428200  -1.40906400
H  -6.28815600  -2.49576100  -1.25159600
H  -5.13288300  -1.56836600  -2.22886300
C  -2.22345500   3.48452400   0.81888300
H  -1.63465100   4.30174200   1.23944200
H  -3.21483700   3.86086500   0.55170500
H  -2.33200400   2.70410300   1.57274800
H   5.06554100  -0.83354200  -0.87166300
H  -0.72252400   1.30315600  -2.81283000

E(RHF) = -1219.85043945
E2 = -0.3779047882D+01
EUMP2 = -0.12236294873333D+04
```

```
H   1.45191600  -1.30921300   1.24862800
C   0.78737900   0.57613400   2.05967700
H  -0.25283500   0.26640700   2.20057300
H   1.33414100   0.44892200   3.00063000
H   0.80235300   1.63774500   1.79590200
C   2.86414700   0.18854100   0.71680500
C   3.92043300  -0.49278800   1.33315100
C   3.15436400   1.30816000  -0.07542700
C   5.24141300  -0.07057700   1.16609800
H   3.70496200  -1.37442700   1.93618200
C   4.47338100   1.73184900  -0.24502800
H   2.34257400   1.84048800  -0.56472400
C   5.52117000   1.04609800   0.37604200
H   6.05136200  -0.61705600   1.64508700
H   4.68611100   2.60035300  -0.86541700
H   6.54867000   1.37582800   0.23890400
C  -3.08420600   4.26882100  -0.14496200
H  -3.40684800   3.89640900   0.82909000
H  -3.24079500   5.35062800  -0.17616200
H  -3.72256300   3.80881200  -0.90380600
C   2.46734100  -1.97043300  -2.16408000
H   2.66781800  -2.95264000  -1.73217800
H   2.94357900  -1.91056200  -3.14731800
H   2.90452600  -1.21084300  -1.51475900
H  -4.53137000  -1.01938200   2.88402700
H  -1.68656200  -1.09710600  -3.01866800

E(RHF) =  -1219.84980859
E2 = -0.3773952085D+01
EUMP2 = -0.12236237606706D+04
```

(e) Single-point calculations on TS structures 7a, 8b, 9a, and 10b using additional computational methods and solvation correction

TS structures **7a**, **8b**, **9a**, and **10b** optimized at B3LYP/6-31G* level of theory as described above were subjected to single-point energy calculations using several computational methods in gas phase (Table S-4). Subsequently, these results were subjected to solvent correction using the CPCM[3] polarizable conductor calculation model

as implemented in Gaussian 03 (Table S-5). Chloroform was specified as the solvent. The UFF atomic radii were used. Hydrogens have individual spheres.

Table S-4. Free energies of **7a**, **8b**, **9a**, and **10b** in gas phase

Method	G_{298} of **7a** (a.u.)	G_{298} of **8b** (a.u.)	ΔG_{rel} (**8b -7a**) (kcal/mol)	G_{298} of **9a** (a.u.)	G_{298} of **10b** (a.u.)	ΔG_{rel} (**10b -9a**) (kcal/mol)
B3LYP/6-31G*	-1716.533805	-1716.530767	1.9	-1795.109207	-1795.103606	3.5
MP2/6-31G*// B3LYP/6-31G* [a]	-1711.434669	-1711.427432	4.5	-1789.716955	-1789.707359	6.0
SCS-MP2/6-31G*// B3LYP/6-31G* [a]	-1711.254999	-1711.249121	3.7	-1789.534322	-1789.525727	5.4
M05-2X/6-31G*// B3LYP/6-31G* [a]	-1716.368694	-1716.364145	2.9	-1794.932492	-1794.924754	4.9

[a] Thermal correction is calculated at B3LYP/6-31G* level.

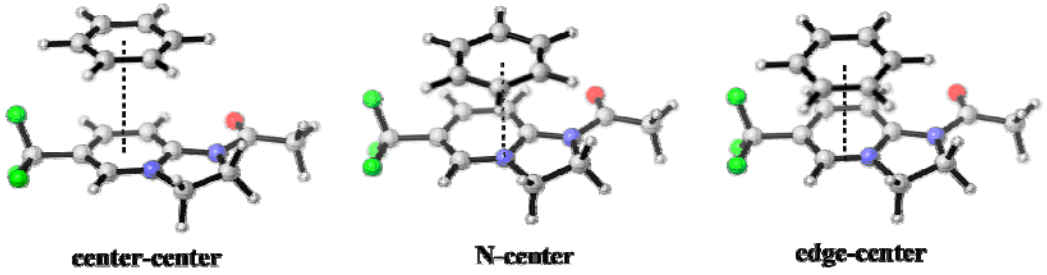
Table S-5. Free energies of **7a**, **8b**, **9a**, and **10b** in chloroform

Method	G_{298} of **7a** (a.u.)	G_{298} of **8b** (a.u.)	ΔG_{rel} (**8b -7a**) (kcal/mol)	G_{298} of **9a** (a.u.)	G_{298} of **10b** (a.u.)	ΔG_{rel} (**10b -9a**) (kcal/mol)
B3LYP/6-31G*	-1716.511641	-1716.509035	1.6	-1795.081571	-1795.077051	2.8
MP2/6-31G*// B3LYP/6-31G* [a]	-1711.451895	-1711.443409	5.3	-1789.732726	-1789.722749	6.3
SCS-MP2/6-31G*// B3LYP/6-31G* [a]	-1711.272472	-1711.265275	4.5	-1789.550318	-1789.541284	5.7
M05-2X/6-31G*// B3LYP/6-31G* [a]	-1716.348901	-1716.344598	2.7	-1794.907011	-1794.900313	4.2

[a] Thermal correction is calculated at B3LYP/6-31G* level.

(e) Interaction energies of benzene and N-acetyl-6-CF_3-DHIP$^+$

N-acetyl-6-trifluoromethyl-DHIP cation lacking the phenyl group at C2 was used instead of the analogous CF_3-PIP derivative to simplify the calculation. Geometries of the complexes of benzene and this cation are shown in Figure S-9. Intermolecular distances are the distance between the centers of benzene and pyridinium ring (center-center), between the pyridinium nitrogen and the center of benzene (N-center), and between the midpoint of the N-C bond and the center of benzene (edge-center).



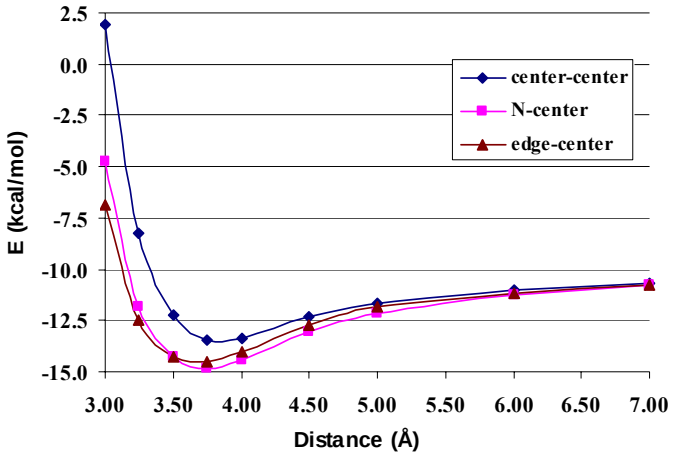


Figure S-10. Interaction energies of benzene and **N-acetyl-6-CF_3-DHIP**$^+$

(f) Electrostatic potential of 7a

The electrostatic potential of **7a** was calculated in Gaussian 03.

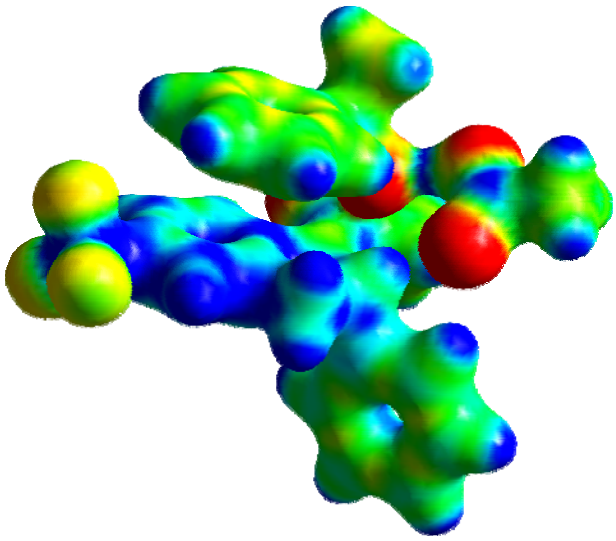


Figure S-11. Electrostatic potential of **7a**

REFERENCES

[1] Gaussian 03, Revision D.01: Frisch, M. J.; Trucks, G. W.; Schlegel, H. B.; Scuseria, G. E.; Robb, M. A.; Cheeseman, J. R.; Montgomery Jr., J. A.; Vreven, T.; Kudin, K. N.; Burant, J. C.; Millam, J. M.; Iyengar, S. S.; Tomasi, J.; Barone, V.; Mennucci, B.; Cossi, M.; Scalmani, G.; Rega, N.; Petersson, G. A.; Nakatsuji, H.; Hada, M.; Ehara, M.; Toyota, K.; Fukuda, R.; Hasegawa, J.; Ishida, M.; Nakajima, T.; Honda, Y.; Kitao, O.; Nakai, H.; Klene, M.; Li, X.; Knox, J. E.; Hratchian, H. P.; Cross, J. B.; Bakken, V.; Adamo, C.; Jaramillo, J.; Gomperts, R.; Stratmann, R. E.; Yazyev, O.; Austin, A. J.; Cammi, R.; Pomelli, C.; Ochterski, J. W.; Ayala, P. Y.; Morokuma, K.; Voth, G. A.; Salvador, P.; Dannenberg, J. J.; Zakrzewski, V. G.; Dapprich, S.; Daniels, A. D.; Strain, M. C.; Farkas, O.; Malick, D. K.; Rabuck, A. D.; Raghavachari, K.; Foresman, J. B.; Ortiz, J. V.; Cui, Q.; Baboul, A. G.; Clifford, S.; Cioslowski, J.; Stefanov, B. B.; Liu, G.; Liashenko, A.; Piskorz, P.; Komaromi, I.; Martin, R. L.; Fox, D. J.; Keith, T.; Al-Laham, M. A.; Peng, C. Y.; Nanayakkara, A.; Challacombe, M.; Gill, P. M. W.; Johnson, B.; Chen, W.; Wong, M. W.; Gonzalez, C.; Pople, J. A., Gaussian, Inc., Wallingford CT, 2004.

[2] CYLview, version 1.0b, Legault, C. Y., UCLA, 2007.

[3] (a) Barone, V.; Cossi, M. *J. Phys. Chem. A* **1998**, *102*, 1995. (b) Cossi, M.; Rega, N.; Scalmani, G.; Barone, V. *J. Comp. Chem.* **2003**, *24*, 669.