

SUPPORTING INFORMATION

Rate Limiting Step Precedes C-C Bond Formation in the Archetypical Proline-Catalyzed Intramolecular Aldol Reaction

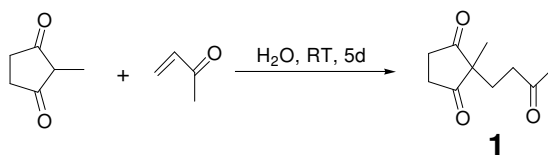
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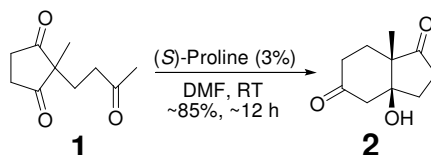


Procedure for Preparing Triketone (1)

To a single neck 100 mL RBF with a 3/4" stir bar, 2-methyl-1,3-cyclopentanedione (10.0 g, 89.2 mmol), water (21 mL, 1.17 mol), and methyl vinyl ketone (14.8 mL, 12.8 g, 0.182 mol) were added. The resulting suspension was stirred for 5 days. The resulting clear solution was extracted twice with 20 mL of benzene. Approximately 3 g of NaCl was added to the aqueous solution, and it was extracted further with three 20 mL aliquots of ethyl acetate. The collected organic layers were washed with brine, dried with Na₂SO₄, and filtered. The ethyl acetate and benzene were removed using rotary evaporation to provide a clear yellow liquid.

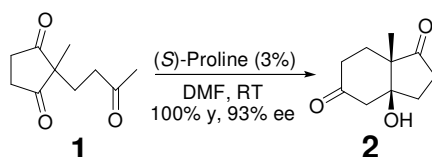
¹H NMR (400 MHz, CDCl₃): δ 2.76 (m, 4H), 2.42 (t, 2H), 2.06 (s, 3H), 1.85 (t, 2H), 1.07 (s, 3H)

¹³C NMR (125 MHz, (CD₃)₂SO): δ 218.35, 209.55, 56.84, 42.04, 39.22, 36.85, 31.79, 30.05, 19.75



Procedure for Running Partial Conversion Reactions

A dried and purged 2-neck 100 mL RBF fitted with a stir bar, septum, and nitrogen inlet under a positive pressure of nitrogen was charged with dimethylformamide (38mL) and L-proline (0.132 g, 1.15 mmol). To the reaction flask, the triketone (**1**) reactant was added via syringe (6.99 g, 38.3 mmol) while stirring. The reaction was allowed to proceed at room temperature and was checked periodically for fractional conversion by NMR. Reactions were typically quenched after approximately 16 h. Quench and workup was accomplished by pouring the reaction mixture into a 250 mL separatory funnel charged with 100 mL of deionized water. The reaction quench mixture was then extracted with 5×20 mL aliquots of ethyl acetate. The combined organic extracts were washed with 50 mL of brine. The combined organic extracts were then dried with anhydrous sodium sulfate, filtered, and concentrated using rotary evaporation. The crude reaction mixture was purified on using flash chromatography with a silica stationary phase and a 90/10 mixture of EtOAc/hexanes mobile phase to afford purified reisolated triketone (**1**). A total of 8 of these reactions were performed. Four samples of the triketone were used directly for quantitative ¹³C NMR analysis. Four samples of purified reisolated triketone (**1**) were desymmetrized by quantitative conversion to the product aldol (**2**) using the proline-catalyzed intramolecular aldol reaction as described below.



Typical Procedure for Desymmetrization of Reisolated Reactant

Quantitative conversion of reisolated triketone (1**) to product (**2**).** A dried and purged 2-neck 25 mL RBF fitted with a stir bar, septum, and nitrogen inlet under a positive pressure of nitrogen was charged with dimethylformamide (5 mL) and L-proline (20 mg, 0.17 mmol). To the reaction flask, the re-isolated triketone (**1**) reactant was added via syringe (1.00 g, 5.47 mmol) while stirring. The reaction was allowed to proceed at room temperature and was checked periodically by TLC for the disappearance of reactant triketone. The reaction was allowed to proceed for 2 additional hours after TLC showed no detectable reactant remaining. Reactions were typically worked up after approximately 24 h. Workup was accomplished by pouring the reaction mixture into a 60 mL separatory funnel charged with 10 mL of deionized water. The reaction quench mixture was then extracted with 5×10 mL aliquots of ethyl acetate. The combined organic extracts were washed with 20 mL of brine. The combined organic extracts were then dried with anhydrous sodium sulfate, filtered, and concentrated using rotary evaporation. The crude reaction mixture was purified on using flash chromatography with a silica stationary phase and a 90/10 mixture of EtOAc/hexanes mobile phase to afford purified product (**2**). A total of 4 of these reactions were performed upon **1** that was reisolated from partial conversion reactions. An additional reaction was performed upon 1 g of stock triketone.

Isotope Effect Results and Calculations

NMR Measurements. NMR samples of reisolated reactant (**1**) consisted of approximately 300 mg of **1** and were filled to the 5.0 cm mark with (CD₃)₂SO in a standard 5 mm NMR tube. The ¹³C NMR spectra were recorded at 125.62 MHz using a sweep width (49751.2 Hz) double that of width of the spectrum, with the spectrum centered. An acquisition time of 5.00 s was used to collect a total of 497512 points. Inverse gated ¹H decoupling was used, and a delay of 80.0 s was used to ensure quantitative relative ¹³C measurement. NMR samples of reisolated **1** that was desymmetrized to product (**2**) also contained approximately 300 mg of **2**. These spectra were recorded at 125.62 MHz with a sweep width of 51480.1 Hz and an acquisition time of 5.00 s, resulting in the collection of 514800 points. Inverse gated decoupling and a delay of 40.0 s were employed in these measurements.

Integrations of ^{13}C Spectra of Reisolated Reactant

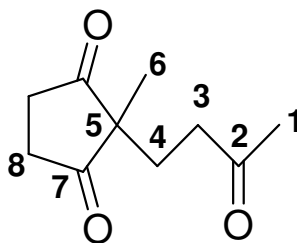


Table 1. Average ^{13}C integrations with errors for reisolated reactant.

Reaction →	F=0.9387 ± 0.002	F=0.8676 ± 0.0002	F=0.9126 ± 0.0001	F=0.8074 ± 0.0002	Standard
Position ↓					
C1	999.58 ± 4.11	997.58 ± 8.22	996.36 ± 4.64	993.19 ± 8.82	998.94 ± 2.58
C2	1153.6 ± 5.8	1142.4 ± 7.8	1160.0 ± 7.8	1135.9 ± 10.6	1153.6 ± 5.8
C3	992.80 ± 3.83	981.30 ± 12.29	990.32 ± 7.42	987.21 ± 10.5	992.80 ± 3.83
C4	980.73 ± 4.30	976.07 ± 10.69	984.64 ± 8.93	992.04 ± 11.6	980.73 ± 4.30
C5	1020.3 ± 6.7	1012.4 ± 12.3	1009.2 ± 9.4	1011.3 ± 6.3	1020.3 ± 6.7
C6	1000	1000	1000	1000	1000
C7	2137.8 ± 9.0	2094.5 ± 14.1	2123.6 ± 12.6	2102.8 ± 16.0	2137.8 ± 9.0
C8	2057.6 ± 8.36	2036.2 ± 15.1	2055.9 ± 16.6	2039.6 ± 22.5	2057.6 ± 8.4

Table 2. Relative fractionation (R/R_0) for reisolated reactant with errors in last digits in parentheses.

Reaction →	F=0.9387 ± 0.0002	F=0.8676 ± 0.0002	F=0.9126 ± 0.0001	F=0.8074 ± 0.0002
Position ↓				
C1	1.001(4)	0.999(9)	0.997(5)	0.994(9)
C2	1.069(7)	1.059(9)	1.076(9)	1.053(11)
C3	1.000(5)	0.988(13)	0.997(8)	0.994(11)
C4	1.003(6)	0.999(12)	1.007(10)	1.015(13)
C5	1.016(8)	1.008(13)	1.005(10)	1.007(7)
C6	1.000	1.000	1.000	1.000
C7	1.012(6)	0.992(8)	1.006(7)	0.996(8)
C8	0.995(6)	0.985(8)	0.994(9)	0.986(11)

Integrations of ^{13}C Spectra of Reisolated/Desymmetrized Reactant

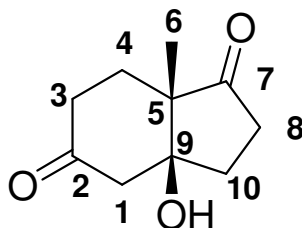


Table 3. Average ^{13}C integrations with errors for reisolated/desymmetrized reactant.

Reaction →	F=0.9100 ± 0.0002	F=0.9041 ± 0.0002	F=0.9269 ± 0.0002	F=0.9100 ± 0.0002	Standard
Position ↓					
C1	1020.1 ± 9.0	1033.3 ± 9.6	1031.6 ± 11.7	1022.0 ± 9.0	1021.7 ± 5.2
C2	1147.1 ± 13.0	1155.6 ± 8.1	1147.3 ± 10.2	1151.4 ± 4.8	1085.8 ± 5.7
C3	993.57 ± 11.80	994.70 ± 12.6	993.08 ± 5.79	992.59 ± 7.34	1003.8 ± 5.9
C4	989.44 ± 10.87	992.92 ± 9.97	989.22 ± 9.28	989.83 ± 9.63	990.66 ± 5.45
C5	1022.4 ± 10.4	1022.9 ± 9.4	1009.9 ± 7.3	1016.2 ± 6.9	1027.7 ± 6.0
C6	1000	1000	1000	1000	1000
C7	1070.5 ± 9.0	1073.3 ± 10.7	1058.7 ± 11.4	1066.4 ± 4.2	1070.1 ± 4.8
C8	1028.0 ± 13.3	1029.4 ± 8.8	1025.7 ± 6.6	1029 ± 6.2	1035.8 ± 3.7
C9	1054.8 ± 8.5	1059.2 ± 5.6	1052.0 ± 7.7	1048.7 ± 3.9	1049.3 ± 4.6
C10	1036.0 ± 10.9	1032.6 ± 10.8	1025.5 ± 7.2	1031.1 ± 7.8	1034.8 ± 6.9

Table 4. Relative fractionation (R/R_0) for reisolated/desymmetrized reactant with errors in last digits in parentheses.

Reaction →	F=0.9011 ± 0.0001	F=0.9041 ± 0.0002	F=0.9269 ± 0.0002	F=0.9100 ± 0.0002
Position ↓				
C1	0.998(10)	1.011(11)	1.010(13)	1.001(10)
C2	1.056(13)	1.064(9)	1.057(11)	1.060(7)
C3	0.990(13)	0.991(14)	0.989(8)	0.989(9)
C4	0.999(12)	1.002(11)	0.999(11)	0.999(11)
C5	0.995(12)	0.995(11)	0.983(9)	0.989(9)
C6	1.000	1.000	1.000	1.000
C7	1.000(9)	1.003(11)	0.989(12)	0.997(6)
C8	0.992(13)	0.994(9)	0.990(7)	0.994(7)
C9	1.005(9)	1.009(7)	1.003(9)	0.999(6)
C10	1.001(12)	0.998(12)	0.991(10)	0.996(10)

KIE Calculations. The ^{13}C KIEs were computed using eq 1. These measurements require the judicious choice of an internal standard. The current measurements assume an internal standard corresponding to the methyl group in **1** or **2** for the isotope effects measured on reisolated or reisolated, desymmetrized reactant. The choice of the methyl group as the internal standard was motivated by the isotope effects computed from frequency calculations based upon optimized reactant and transition structures. For each transition state, this position yielded a negligible KIE. The integrations for the peak corresponding to the internal standard are set to 1000 in both the stock and reisolated triketone for the measurements in Fig. 1A. Likewise, the integrations for the internal standard peak are set to 1000 in both the desymmetrized stock ketone and the desymmetrized reisolated triketone for the measurements reported in Fig. 1B. The relative fractionations (R/R_0) are then computed by dividing the integrations of peaks from the reisolated (or reisolated, desymmetrized) triketone by the corresponding integrations of peaks from the stock (or desymmetrized stock) ketone. These values are used in conjunction with the fractional conversions

associated with each reaction to compute the KIEs for each position (eq 1). Standard errors were propagated as in Singleton, D. A.; Thomas, A. A. *J. Am. Chem. Soc.* **1995**, *117*, 9357, using eqs 2-4.

$$KIE = \frac{k_{12C}}{k_{13C}} = \frac{\ln(1-F)}{\ln[(1-F)R/R_0]} \quad (1)$$

$$\Delta KIE = \sqrt{\left[\frac{\partial KIE}{\partial(R/R_0)}\right]^2 \times [\Delta(R/R_0)]^2 + \left[\frac{\partial KIE}{\partial F}\right]^2 \times [\Delta F]^2} \quad (2)$$

$$\frac{\partial KIE}{\partial(R/R_0)} = \frac{-\ln(1-F)}{(R/R_0)\ln^2[(1-F)R/R_0]} \quad (3)$$

$$\frac{\partial KIE}{\partial F} = \frac{-\ln(R/R_0)}{(1-F)\ln^2[(1-F)R/R_0]} \quad (4)$$

KIEs from Computed Structures

The optimized structures corresponding to the reactant (**1**) or transition structures (**TS1**, **TS2**, and **TS3**) were used to compute frequencies using the same density functional (B3LYP) and basis set [6-31+G(d,p)] used in the optimization. The ‘freq’ keyword in Gaussian03¹ was utilized, thus yielding frequencies under the harmonic approximation. The resulting frequencies were then placed into the Bigeleisen equation (eqs 5&6). The pre-multipliers in eq 5 are the ratio of tunnel corrections for ¹²C and ¹³C-labeled species followed by the ratio of the imaginary frequencies corresponding to the reaction coordinate at the first order saddle point. The following terms are the products corresponding to the 3N[‡]-7 real frequencies in the transition state and the 3N-6 real frequencies in the reactant. N[‡] is the number of atoms in the transition structure, and N is the number of atoms in the reactant. Tunneling corrections are employed in each value using Bell’s multiplicative infinite parabola correction (eq 7).

$$\frac{k_{12C}}{k_{13C}} = \frac{Q_{t,12C}}{Q_{t,13C}} \frac{v_{12C}^\ddagger}{v_{13C}^\ddagger} \prod_i^{3N^\ddagger-7} \left(\frac{u_{i,12C}^\ddagger}{u_{i,13C}^\ddagger} \right) \left(\frac{e^{\frac{u_{i,13C}^\ddagger}{2}}}{e^{\frac{u_{i,12C}^\ddagger}{2}}} \right) \left(\frac{1-e^{-u_{i,13C}^\ddagger}}{1-e^{-u_{i,12C}^\ddagger}} \right) \prod_j^{3N-6} \left(\frac{u_{j,13C}}{u_{j,12C}} \right) \left(\frac{e^{\frac{u_{j,12C}}{2}}}{e^{\frac{u_{j,13C}}{2}}} \right) \left(\frac{1-e^{-u_{j,12C}}}{1-e^{-u_{j,13C}}} \right) \quad (5)$$

$$u_{j,12C} = \frac{h v_{j,12C}}{kT} \quad (6)$$

$$\frac{Q_{t,12C}}{Q_{t,13C}} = \frac{\frac{(v_{12C}^\ddagger/2)}{\sin(v_{12C}^\ddagger/2)}}{\frac{(v_{13C}^\ddagger/2)}{\sin(v_{13C}^\ddagger/2)}} \quad (7)$$

Computed Structures

All quantum mechanical calculations were performed with Gaussian03.¹ Structures **1**, **TS1**, **TS2** and **TS3** were fully optimized using the Becke3LYP hybrid functional together with the 6-31+G(d,p) basis set. Vibrational analyses were carried out on all four stationary points. The computed structure for the triketone reactant (**1**) was found to be a minimum with all real frequencies, while the structures of TS1, TS2, and TS3 were first order saddle points having only one imaginary frequency.

Solvent effects (DMSO) in the computed geometries and frequencies were taken into account by means of the IEFPCM solvation model as implemented in Gaussian03. All IEFPCM calculations were carried out at the B3LYP/6-31+G(d,p) level of theory using a pruned integration grid of 99 radial shells and 590 angular points ("Int=(Grid=UltraFine)" option in Gaussian03). The solute cavities were generated using the United Atom Topological Model UA0 set of radii. Explicit spheres for the hydrogen atoms that are being transferred in TS1, TS2, and TS3 were added in each case. Geometry optimizations of the starting triketone (**1**) and TS3 produced structures that satisfied the default four convergence criteria for geometry optimizations in Gaussian03 (Maximum Force < 0.000450, RMS Force < 0.000300, Maximum Displacement < 0.001800, RMS Displacement < 0.001200, in Hartree/Bohr-radian units). Our attempts for optimizing the geometries of TS1 and TS2 could not provide structures satisfying the four default convergence criteria in Gaussian03. Nevertheless, for both cases (TS1 and TS2), the geometry optimizations were very close to convergence with a number of structures satisfying the two Force convergence criteria (Maximum Force < 0.000450 and RMS Force < 0.000300, in Hartree/Bohr-radian), and with variations in the energies of less than 0.0004 Hartree. The structures with the lowest Maximum Force (out of all the intermediate structures produced in the geometry optimizations) were selected as the optimized structures in each case: for TS1, the selected structure presented Maximum Force = 0.000246 and RMS Force = 0.000059 (Hartree/Bohr-radian); and for TS2, the selected structure presented Maximum Force = 0.000162 and RMS Force = 0.000044 (Hartree/Bohr-radian).

The IEFPCM optimized geometries of TS1, TS2, and TS3 in DMSO are similar to the corresponding optimized structures in gas-phase. The most notable effect in the optimized geometries in DMSO is a shift towards earlier TS: the forming N-C bond distance in TS1 and the forming C-C bond distance in TS3 become ~0.2 Å longer than the corresponding ones in gas-phase, while the breaking C-O bond distance in TS2 become ~0.2 Å shorter than that in gas-phase.

1. Gaussian 03, Revision C.02, M. J. Frisch, G. W. Trucks, H. B. Schlegel, G. E. Scuseria, M. A. Robb, J. R. Cheeseman, J. A. Montgomery, Jr., T. Vreven, K. N. Kudin, J. C. Burant, J. M. Millam, S. S. Iyengar, J. Tomasi, V. Barone, B. Mennucci, M. Cossi, G. Scalmani, N. Rega, G. A. Petersson, H. Nakatsuji, M. Hada, M. Ehara, K. Toyota, R. Fukuda, J. Hasegawa, M. Ishida, T. Nakajima, Y. Honda, O. Kitao, H. Nakai, M. Klene, X. Li, J. E. Knox, H. P. Hratchian, J. B. Cross, C. Adamo, J. Jaramillo, R. Gomperts, R. E. Stratmann, O. Yazyev, A. J. Austin, R. Cammi, C. Pomelli, J. W. Ochterski, P. Y. Ayala, K. Morokuma, G. A. Voth, P. Salvador, J. J. Dannenberg, V. G. Zakrzewski, S. Dapprich, A. D. Daniels, M. C. Strain, O. Farkas, D. K. Malick, A. D. Rabuck, K. Raghavachari, J. B. Foresman, J. V. Ortiz, Q. Cui,

A. G. Baboul, S. Clifford, J. Cioslowski, B. B. Stefanov, G. Liu, A. Liashenko, P. Piskorz, I. Komaromi, R. L. Martin, D. J. Fox, T. Keith, M. A. Al-Laham, C. Y. Peng, A. Nanayakkara, M. Challacombe, P. M. W. Gill, B. Johnson, W. Chen, M. W. Wong, C. Gonzalez, and J. A. Pople, Gaussian, Inc., Wallingford CT, 2004.

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

E(RB+HF-LYP) = -615.211761997

Zero-point correction= 0.222900
 (Hartree/Particle)
 Thermal correction to Energy= 0.237336
 Thermal correction to Enthalpy= 0.238280
 Thermal correction to Gibbs Free Energy= 0.178788
 Sum of electronic and zero-point Energies= -614.988862
 Sum of electronic and thermal Energies= -614.974426
 Sum of electronic and thermal Enthalpies= -614.973482
 Sum of electronic and thermal Free Energies= -615.032974

		E (Thermal)	CV	S
		KCal/Mol	Cal/Mol-Kelvin	Cal/Mol-Kelvin
Total		148.930	50.999	125.212
C	-1.423903	1.217094	-0.070700	
C	0.584763	-0.086661	0.895595	
H	1.252152	-0.801880	-1.054503	
H	1.252785	0.949009	-0.908177	
C	-1.707370	-0.177805	1.969415	
O	-1.033042	-2.325017	-0.275465	
C	-1.432580	-1.178705	-0.291365	
H	0.826105	0.734957	1.576655	
C	-2.517843	0.879958	-1.090489	
C	3.886943	0.174795	-1.236248	
H	4.919976	0.018252	-0.921874	
C	-0.928984	-0.056852	0.624685	
C	1.458856	0.021477	-0.355968	
C	2.953569	-0.011712	-0.054091	
O	-1.016288	2.338331	0.154521	
H	3.634624	-0.517514	-2.047521	
H	-2.298481	1.406949	-2.024366	
H	-3.469310	1.281938	-0.724057	
C	-2.523993	-0.653048	-1.231069	
H	-3.478571	-1.107279	-0.941892	
H	-2.793184	-0.159913	1.826152	
H	0.821598	-1.016386	1.420917	
H	-1.441007	-1.119844	2.457216	
H	-2.309414	-1.003265	-2.245575	
H	-1.433513	0.656724	2.621277	
H	3.780556	1.190729	-1.636150	
O	3.379197	-0.173780	1.076358	

TS1, B3LYP/6-31+G(d,p)

E(RB+HF-LYP) = -1016.37710913

Zero-point correction= 0.368566
 (Hartree/Particle)
 Thermal correction to Energy= 0.389705
 Thermal correction to Enthalpy= 0.390650
 Thermal correction to Gibbs Free Energy= 0.316373
 Sum of electronic and zero-point Energies= -1016.008544
 Sum of electronic and thermal Energies= -1015.987404
 Sum of electronic and thermal Enthalpies= -1015.986459

Sum of electronic and thermal Free Energies= -1016.060736

	E (Thermal)	CV	S
	KCal/Mol	Cal/Mol-Kelvin	Cal/Mol-Kelvin
Total	244.544	79.675	156.328
C	-3.342579	0.112596	0.871898
N	-1.900951	0.479751	0.566683
C	-1.954602	1.716741	-0.297878
C	-3.374276	2.304549	-0.118360
C	-3.982383	1.499502	1.046186
C	-0.820378	-0.763145	-0.098857
O	-1.165106	-0.904011	-1.351948
C	-4.138587	-0.713416	-0.193654
O	-3.553765	-1.169544	-1.258826
C	0.569920	-0.127534	0.100520
C	1.660174	-0.957904	-0.598054
C	3.092950	-0.441500	-0.383775
C	3.330739	1.017432	-0.792295
C	4.302213	1.691189	0.184927
C	4.463788	0.725724	1.373682
C	3.561136	-0.476207	1.075982
C	4.092188	-1.311757	-1.206079
O	2.831105	1.566695	-1.752154
O	3.263292	-1.331935	1.884450
C	-1.081204	-1.957308	0.828279
O	-5.322152	-0.869365	0.079378
H	5.243305	1.889036	-0.340421
H	3.893415	2.667275	0.464599
H	5.491774	0.364667	1.493842
H	4.172214	1.155521	2.336860
H	5.131350	-0.992406	-1.073387
H	3.843413	-1.239355	-2.268584
H	4.011230	-2.354902	-0.886825
H	1.444883	-0.974594	-1.669734
H	1.636854	-1.991974	-0.239256
H	0.566981	0.872629	-0.341707
H	0.789282	-0.039486	1.173203
H	-0.964815	-1.705330	1.888263
H	-0.348258	-2.733167	0.590222
H	-2.070423	-2.384741	0.656441
H	-2.414280	-1.082598	-1.353547
H	-1.484230	0.732420	1.463623
H	-1.746720	1.394139	-1.320307
H	-1.167123	2.400894	0.022321
H	-3.346581	3.378569	0.083081
H	-3.962452	2.153625	-1.028076
H	-3.689082	1.928503	2.013173
H	-5.070212	1.431290	1.015938
H	-3.355447	-0.476770	1.791165

TS2, B3LYP/6-31+G(d,p)

E(RB+HF-LYP) = -1016.37990590

Zero-point correction=
(Hartree/Particle)

0.366941

Thermal correction to Energy=	0.388434
Thermal correction to Enthalpy=	0.389378
Thermal correction to Gibbs Free Energy=	0.314646
Sum of electronic and zero-point Energies=	-1016.012965
Sum of electronic and thermal Energies=	-1015.991472
Sum of electronic and thermal Enthalpies=	-1015.990528
Sum of electronic and thermal Free Energies=	-1016.065260

	E (Thermal)	CV	S
	KCal/Mol	Cal/Mol-Kelvin	Cal/Mol-Kelvin
Total	243.746	81.502	157.286
C	-3.064430	0.271895	0.762650
N	-1.687475	0.249973	0.207427
C	-1.408497	1.492444	-0.566738
C	-2.693497	2.325637	-0.426715
C	-3.355743	1.777837	0.847015
C	-0.912863	-0.831032	0.151501
O	-1.462131	-1.597819	-1.594240
C	-4.152523	-0.471148	-0.087882
O	-3.783454	-1.136232	-1.133443
C	0.547855	-0.649890	-0.209586
C	1.368340	-0.121127	0.987312
C	2.839358	0.175621	0.649394
C	3.613573	-1.026061	0.092689
C	4.541111	-0.584172	-1.043384
C	4.172055	0.875735	-1.367553
C	3.021805	1.250432	-0.429350
C	3.590514	0.662248	1.923441
O	3.510178	-2.164708	0.500361
O	2.350794	2.258464	-0.521523
C	-1.244701	-1.993235	1.059511
O	-5.303577	-0.360049	0.327075
H	5.579101	-0.703588	-0.713019
H	4.405001	-1.267523	-1.887598
H	4.999281	1.574650	-1.198361
H	3.844573	1.028532	-2.400570
H	4.641679	0.893353	1.721247
H	3.554121	-0.119418	2.687748
H	3.109852	1.567379	2.306056
H	1.354234	-0.855130	1.799991
H	0.923351	0.803797	1.369386
H	0.937940	-1.619655	-0.525137
H	0.629375	0.026229	-1.062249
H	-1.078300	-1.702691	2.104332
H	-0.591616	-2.839069	0.837362
H	-2.281603	-2.313187	0.954320
H	-1.349715	-2.552202	-1.708645
H	-1.187011	1.238131	-1.606582
H	-0.539298	2.003470	-0.140921
H	-2.476580	3.395602	-0.372813
H	-3.347123	2.157913	-1.288511
H	-2.881501	2.200724	1.740864
H	-4.429309	1.960275	0.901096
H	-3.067733	-0.190343	1.752828
H	-2.605005	-1.365413	-1.402495

TS3, B3LYP/6-31+G(d,p)

E(RB+HF-LYP) = -939.932450125

Zero-point correction=	0.345327
(Hartree/Particle)	
Thermal correction to Energy=	0.362829
Thermal correction to Enthalpy=	0.363773
Thermal correction to Gibbs Free Energy=	0.301216
Sum of electronic and zero-point Energies=	-939.587123
Sum of electronic and thermal Energies=	-939.569621
Sum of electronic and thermal Enthalpies=	-939.568677
Sum of electronic and thermal Free Energies=	-939.631234

	E (Thermal)	CV	S
	KCal/Mol	Cal/Mol-Kelvin	Cal/Mol-Kelvin
Total	227.679	71.064	131.663
C	-1.293467	-0.523894	-0.819929
C	-1.004473	1.418617	0.932146
H	0.535647	0.995823	2.416266
H	-0.948220	0.072710	2.639859
C	-2.332345	1.759264	-1.168391
C	3.494933	-1.552609	-0.458161
O	-3.766968	0.555822	1.491992
C	-3.195493	0.141239	0.501579
H	-0.279889	2.034576	0.393161
C	-2.504808	-1.349182	-1.320652
C	-0.723280	-1.629068	0.660250
H	-0.424049	-2.538404	0.151724
N	1.499951	-0.762934	0.609803
C	-1.908878	0.719064	-0.092111
C	-0.249192	0.450593	1.888218
C	0.271173	-0.730146	1.113905
O	-0.279422	-0.381736	-1.608752
H	-1.571597	-1.761260	1.325892
H	1.991228	-2.811998	0.538108
C	2.045370	-1.942537	-0.127699
C	2.511615	0.304513	0.708914
H	1.448023	-2.131741	-1.018943
H	-2.263326	-2.410307	-1.416184
H	-2.732428	-0.984667	-2.328538
C	-3.654021	-1.057818	-0.337222
H	-4.595205	-0.802611	-0.836988
H	-3.056741	1.349832	-1.878656
H	-1.617284	2.091146	1.541218
H	-2.785950	2.630261	-0.685379
C	3.836793	-0.466072	0.573374
H	2.440696	0.815358	1.669898
H	4.649004	0.195165	0.269130
H	3.551954	-1.142854	-1.471432
H	4.096602	-0.914836	1.539015
H	4.165730	-2.413987	-0.408332
C	2.404525	1.412894	-0.383076
H	-3.882413	-1.888424	0.338924
H	-1.451408	2.077835	-1.731480
O	3.197854	2.335051	-0.296000

O	1.506819	1.316739	-1.335649
H	0.772992	0.542765	-1.355495

Triketone Reactant (1, PCM), B3LYP/6-31+G(d,p)

E(RB+HF-LYP) = -615.231213874

Zero-point correction=	0.222063
(Hartree/Particle)	
Thermal correction to Energy=	0.236444
Thermal correction to Enthalpy=	0.237388
Thermal correction to Gibbs Free Energy=	0.178059
Sum of electronic and zero-point Energies=	-615.009151
Sum of electronic and thermal Energies=	-614.994770
Sum of electronic and thermal Enthalpies=	-614.993826
Sum of electronic and thermal Free Energies=	-615.053155

		E (Thermal)	CV	S
		KCal/Mol	Cal/Mol-Kelvin	Cal/Mol-Kelvin
Total		148.371	50.983	124.869
C	-1.429141	1.215783	-0.057076	
C	0.579317	-0.092697	0.903184	
H	1.257695	-0.803360	-1.049551	
H	1.253029	0.942332	-0.905564	
C	-1.721713	-0.200432	1.964736	
O	-1.046330	-2.331295	-0.270714	
C	-1.431687	-1.174584	-0.305998	
H	0.811864	0.728373	1.589658	
C	-2.469542	0.893035	-1.124005	
C	3.870100	0.207596	-1.237239	
H	4.905033	0.005381	-0.955145	
C	-0.934563	-0.064042	0.625166	
C	1.457849	0.018329	-0.345780	
C	2.949959	-0.012723	-0.057103	
O	-1.052056	2.340273	0.227381	
H	3.579470	-0.425929	-2.082610	
H	-2.196716	1.414835	-2.048551	
H	-3.435885	1.302944	-0.804610	
C	-2.484205	-0.638937	-1.270249	
H	-3.453038	-1.082222	-1.006531	
H	-2.806165	-0.181851	1.813496	
H	0.809802	-1.023963	1.430648	
H	-1.455320	-1.146733	2.444675	
H	-2.244879	-0.984363	-2.282220	
H	-1.450839	0.627566	2.626504	
H	3.784443	1.248770	-1.573584	
O	3.388795	-0.200197	1.072029	

TS1 (PCM), B3LYP/6-31+G(d,p)

E(RB+HF-LYP) = -1016.42100132

Zero-point correction=	0.368085
(Hartree/Particle)	
Thermal correction to Energy=	0.389176
Thermal correction to Enthalpy=	0.390120
Thermal correction to Gibbs Free Energy=	0.316524
Sum of electronic and zero-point Energies=	-1016.052917
Sum of electronic and thermal Energies=	-1016.031825
Sum of electronic and thermal Enthalpies=	-1016.030881

Sum of electronic and thermal Free Energies= -1016.104478

	E (Thermal)	CV	S
	KCal/Mol	Cal/Mol-Kelvin	Cal/Mol-Kelvin
Total	244.212	79.551	154.897
C	-3.411267	0.243644	0.831492
N	-1.959107	0.511346	0.577122
C	-1.894891	1.669917	-0.373517
C	-3.285629	2.352828	-0.333944
C	-4.013825	1.666333	0.837197
C	-0.742852	-0.963385	-0.016831
O	-1.110848	-1.186095	-1.226889
C	-4.171481	-0.647614	-0.177929
O	-3.559957	-1.254756	-1.171536
C	0.601274	-0.255530	0.160032
C	1.765350	-1.200410	-0.205088
C	3.156530	-0.539864	-0.168111
C	3.323506	0.644063	-1.126729
C	4.130292	1.756466	-0.467975
C	4.191397	1.416929	1.031642
C	3.538574	0.048896	1.194177
C	4.247698	-1.589256	-0.541264
O	2.888873	0.678733	-2.265387
O	3.353205	-0.509482	2.262271
C	-1.095077	-1.989559	1.050816
O	-5.384045	-0.768747	-0.017395
H	5.124936	1.773734	-0.933261
H	3.662875	2.722769	-0.686028
H	5.213099	1.375154	1.427774
H	3.641976	2.133810	1.654518
H	5.254701	-1.159075	-0.534658
H	4.044614	-1.980312	-1.542582
H	4.218271	-2.411437	0.179770
H	1.607766	-1.592552	-1.215378
H	1.791218	-2.053944	0.481004
H	0.615222	0.606695	-0.512423
H	0.709777	0.098871	1.191439
H	-0.974359	-1.595081	2.063658
H	-0.412753	-2.839917	0.934387
H	-2.110087	-2.371025	0.921976
H	-2.490914	-1.237903	-1.203734
H	-1.569113	0.807565	1.485722
H	-1.654866	1.279573	-1.367281
H	-1.090024	2.337840	-0.059418
H	-3.203923	3.434191	-0.193766
H	-3.821953	2.181126	-1.273698
H	-3.760313	2.147910	1.788488
H	-5.100684	1.654523	0.736019
H	-3.517128	-0.249922	1.805310

TS2 (PCM), B3LYP/6-31+G(d,p)

E(RB+HF-LYP) = -1016.42284212

Zero-point correction=
(Hartree/Particle)

0.365862

Thermal correction to Energy=	0.386946
Thermal correction to Enthalpy=	0.387890
Thermal correction to Gibbs Free Energy=	0.314628
Sum of electronic and zero-point Energies=	-1016.056980
Sum of electronic and thermal Energies=	-1016.035897
Sum of electronic and thermal Enthalpies=	-1016.034952
Sum of electronic and thermal Free Energies=	-1016.108215

	E (Thermal)	CV	S
	KCal/Mol	Cal/Mol-Kelvin	Cal/Mol-Kelvin
Total	242.812	80.705	154.193
C	-3.045954	0.239265	0.761408
N	-1.687769	0.239089	0.182555
C	-1.428383	1.494643	-0.573474
C	-2.696803	2.338751	-0.360967
C	-3.331010	1.745271	0.906417
C	-0.918851	-0.875118	0.031420
O	-1.453244	-1.550095	-1.506626
C	-4.143881	-0.469577	-0.083376
O	-3.804695	-1.129631	-1.143381
C	0.555147	-0.639489	-0.284596
C	1.333262	-0.089635	0.927589
C	2.818764	0.207024	0.639225
C	3.611804	-1.015000	0.157051
C	4.412563	-0.684689	-1.096387
C	4.215485	0.819180	-1.351843
C	3.047579	1.240661	-0.470143
C	3.508439	0.742142	1.928421
O	3.601044	-2.101386	0.710461
O	2.397394	2.263227	-0.605359
C	-1.186290	-2.012710	1.001696
O	-5.315013	-0.375489	0.319154
H	5.457122	-0.987977	-0.968342
H	4.002392	-1.295672	-1.912691
H	5.092573	1.401750	-1.035623
H	4.016072	1.080424	-2.395539
H	4.565222	0.976332	1.762796
H	3.442220	-0.016401	2.713818
H	2.999871	1.651818	2.261136
H	1.297402	-0.805868	1.755540
H	0.872419	0.837940	1.282415
H	0.979805	-1.597645	-0.601390
H	0.633183	0.042981	-1.134465
H	-0.968096	-1.683767	2.023398
H	-0.538368	-2.861114	0.769033
H	-2.222860	-2.351959	0.965927
H	-1.252015	-2.508531	-1.641075
H	-1.249988	1.282263	-1.632862
H	-0.540559	1.991892	-0.170010
H	-2.464444	3.402775	-0.262709
H	-3.376765	2.222809	-1.212766
H	-2.825451	2.120316	1.803466
H	-4.399186	1.947824	0.999102
H	-3.044445	-0.251129	1.741803
H	-2.576830	-1.369998	-1.377480

TS3 (PCM), B3LYP/6-31+G(d,p)

E(RB+HF-LYP) = -939.961345771

Zero-point correction=	0.343889
(Hartree/Particle)	
Thermal correction to Energy=	0.361452
Thermal correction to Enthalpy=	0.362396
Thermal correction to Gibbs Free Energy=	0.299916
Sum of electronic and zero-point Energies=	-939.617457
Sum of electronic and thermal Energies=	-939.599894
Sum of electronic and thermal Enthalpies=	-939.598950
Sum of electronic and thermal Free Energies=	-939.661430

		E (Thermal)	CV	S
		KCal/Mol	Cal/Mol-Kelvin	Cal/Mol-Kelvin
Total		226.815	71.407	131.500
C	-1.322305	-0.432577	-0.895598	
C	-1.012022	1.370455	0.990467	
H	0.530478	0.884815	2.447172	
H	-0.946122	-0.055581	2.632020	
C	-2.412274	1.833625	-1.044610	
C	3.523437	-1.542554	-0.486288	
O	-3.803401	0.473600	1.496549	
C	-3.200911	0.085004	0.507837	
H	-0.294134	2.011002	0.469778	
C	-2.497737	-1.289763	-1.393201	
C	-0.683651	-1.712429	0.643407	
H	-0.396680	-2.578069	0.057875	
N	1.504152	-0.771279	0.544018	
C	-1.931783	0.726248	-0.056803	
C	-0.253221	0.360711	1.894246	
C	0.273716	-0.786137	1.071305	
O	-0.303833	-0.245316	-1.652024	
H	-1.544366	-1.859636	1.287677	
H	2.014943	-2.816412	0.478422	
C	2.073035	-1.943971	-0.183633	
C	2.510595	0.286896	0.712314	
H	1.496616	-2.148639	-1.086878	
H	-2.211586	-2.333204	-1.542419	
H	-2.785035	-0.891934	-2.375646	
C	-3.624865	-1.094521	-0.363069	
H	-4.593681	-0.865480	-0.823883	
H	-3.134737	1.455605	-1.774378	
H	-1.611473	2.027108	1.630493	
H	-2.884423	2.647134	-0.485327	
C	3.842407	-0.481554	0.577042	
H	2.427451	0.762101	1.695684	
H	4.668932	0.179255	0.308958	
H	3.598692	-1.111534	-1.491191	
H	4.072842	-0.952783	1.538953	
H	4.196769	-2.402649	-0.440507	
C	2.425387	1.424911	-0.332737	
H	-3.785715	-1.966463	0.281462	
H	-1.552460	2.230435	-1.591125	
O	3.219875	2.356738	-0.239813	

O	1.532877	1.381154	-1.297597
H	0.781624	0.628422	-1.326252