Supporting Information

Polystyrene-Supported Aminobenzenesulfonic Acids as Bifunctional Heterogeneous Catalysts for the Synthesis of Isoxazoline Skeletons.

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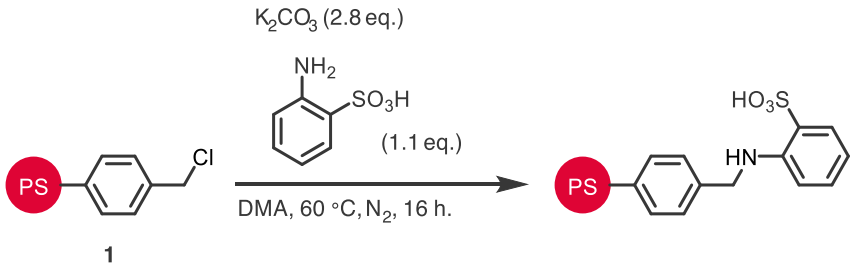
1. General

^{1}H and ^{13}C NMR spectra were recorded on Bruker Avance NEO 400 MHz NMR spectrometer, JEOL ECZR-500 and JEOL ECS-400 in $CDCl_3$ unless otherwise noted. Tetramethylsilane (TMS) served as an internal standard ($\delta = 0$) for ^{1}H NMR, and $CDCl_3$ served as an internal standard ($\delta = 77.16$) for ^{13}C NMR. Gas chromatography was measured on a Shimadzu GC-2030 spectrometer with N_2 gas as a carrier, using Agilent DB-17 column (Length: 30 m, I.D.: 0.250 mm, Film: 0.25 μm). Energy Dispersive X-ray Spectroscopy (EDX) was measured on a Shimadzu EDX-8000. High Resolution Mass Spectroscopy was carried out using a Waters Cyclic-IMS. A dual plunger pump (UI-22 series) was purchased from FLOM, Inc., and flow reactor (MCR-1000), column (CLM-1005) and fraction collector (DC-1000) were purchased from Tokyo Rikakikai Co., Ltd. Other chemicals and solvents were purchased from Tokyo Chemical Industry Co., Ltd, FUJIFILM Wako pure chemicals, Kishida chemical Co., Ltd., and Sigma-Aldrich. COOH silica gel (MB-100-75-200), CARiACT Q-10 and Q-15 were purchased from Fuji-Silysia Chemical Ltd. The substrates **2c**[1], **2d**[2], **2f**[3], **2g**[4] and **2h**[5] were synthesized by known methods..

2. Catalyst preparation

Procedure for the synthesis of C1



1

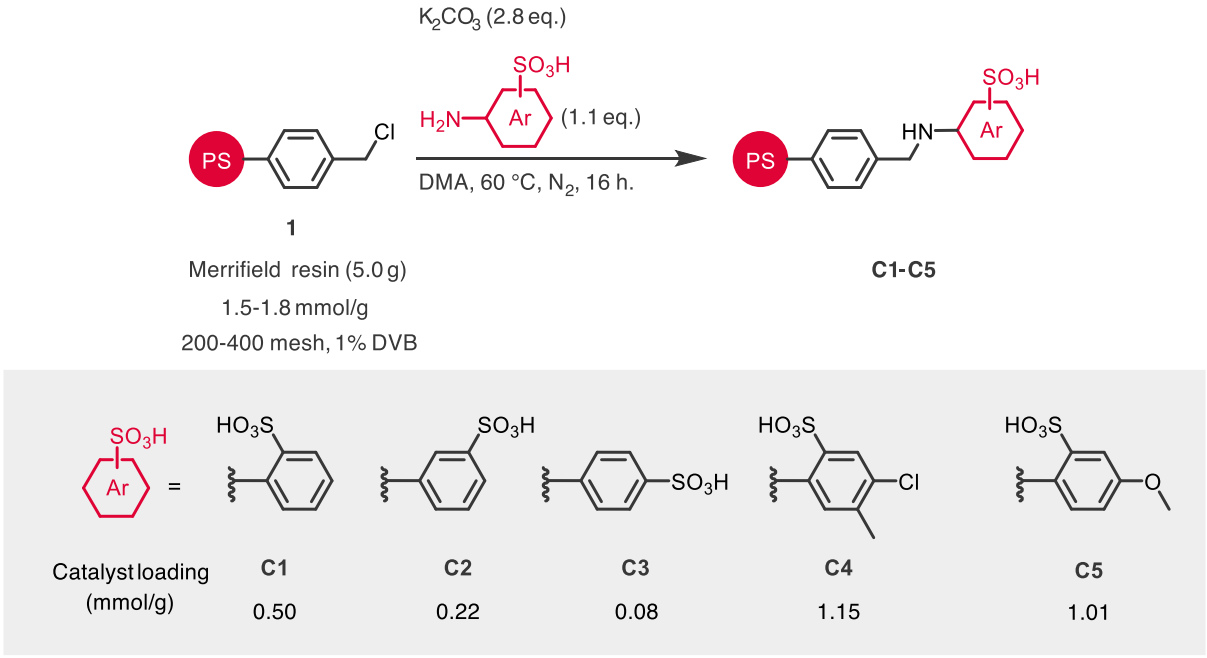
Merrifield resin (5.0 g)
1.5-1.8 mmol/g
200-400 mesh, 1% DVB

C1, Loading = 0.78 mmol/g

In a nitrogen atmosphere, to a 300 mL round bottom flask equipped with a mechanical stirrer was added Chloromethyl Polystyrene Resin (5.0 g, Tokyo Chemical Industry Co., Ltd., 200-400 mesh, crosslinked 1% DVB, 1.5-1.8 mmol/g of Cl atom). Then, *N,N*-dimethylacetoamide (DMA) (50 mL), potassium carbonate (3.46 g, 25 mmol. 2.8 eq.) and Orthanilic acid (1.73 g, 10 mmol, 1.1 eq.) were added to the flask. The slurry was stirred at 60 °C for 16 hours. The reaction mixture was cooled at room temperature and quenched by 0.5 M HCl aq. (50 mL). The slurry was stirred for 1 hour and the solid was collected by filtration. Then, the solid was washed with MeOH (50 mL), water (50 mL), 0.1 M HCl aq. (50 mL) and MeOH (50 mL). Finally, the solid was dried under vacuum at room temperature for 24 h to get catalyst **C1** as a colorless solid (5.18 g).

The Energy Dispersive X-ray Spectroscopy analysis was carried out and the amount of loading was

evaluated based on the sulfur atom (0.50 mmol/g of sulfur atom.). The catalysts **C2-C5** were synthesized by the same procedure. The loadings of catalysts C1-C5 were shown in **Scheme S-1**.



Scheme S-1 The loadings of catalysts **C1-C5**

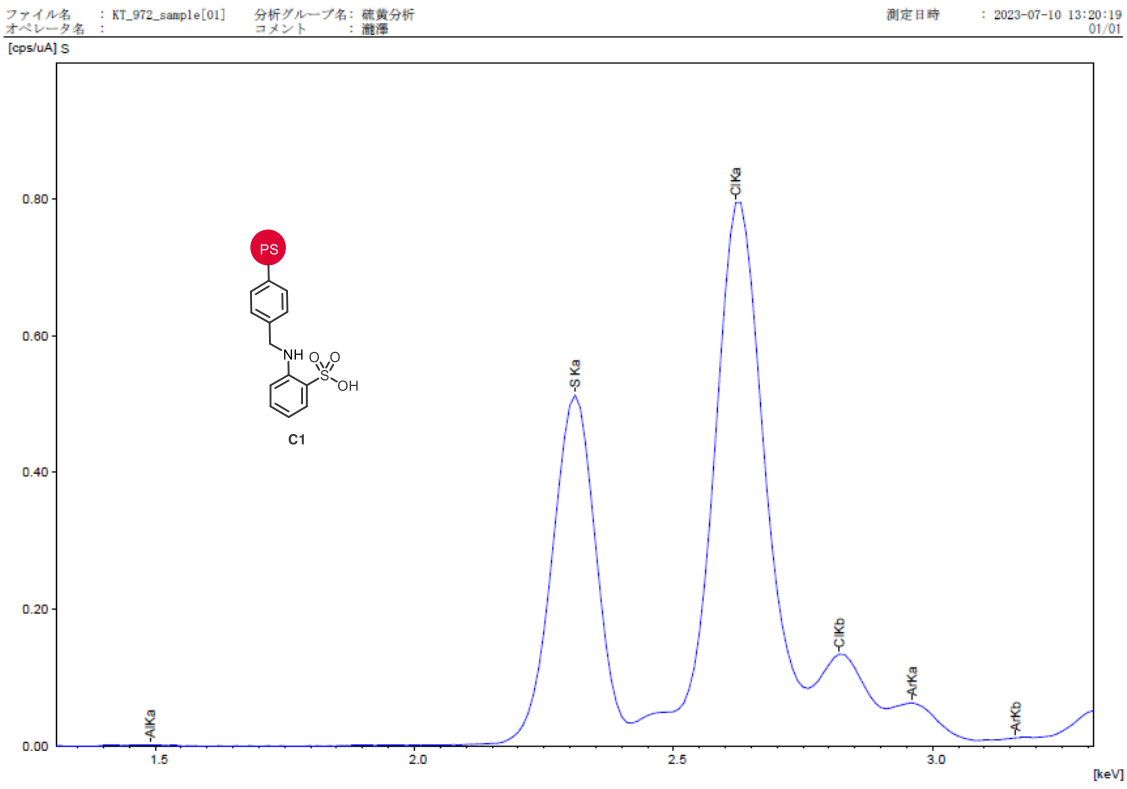


Figure S-1 EDX spectrum of **C1**

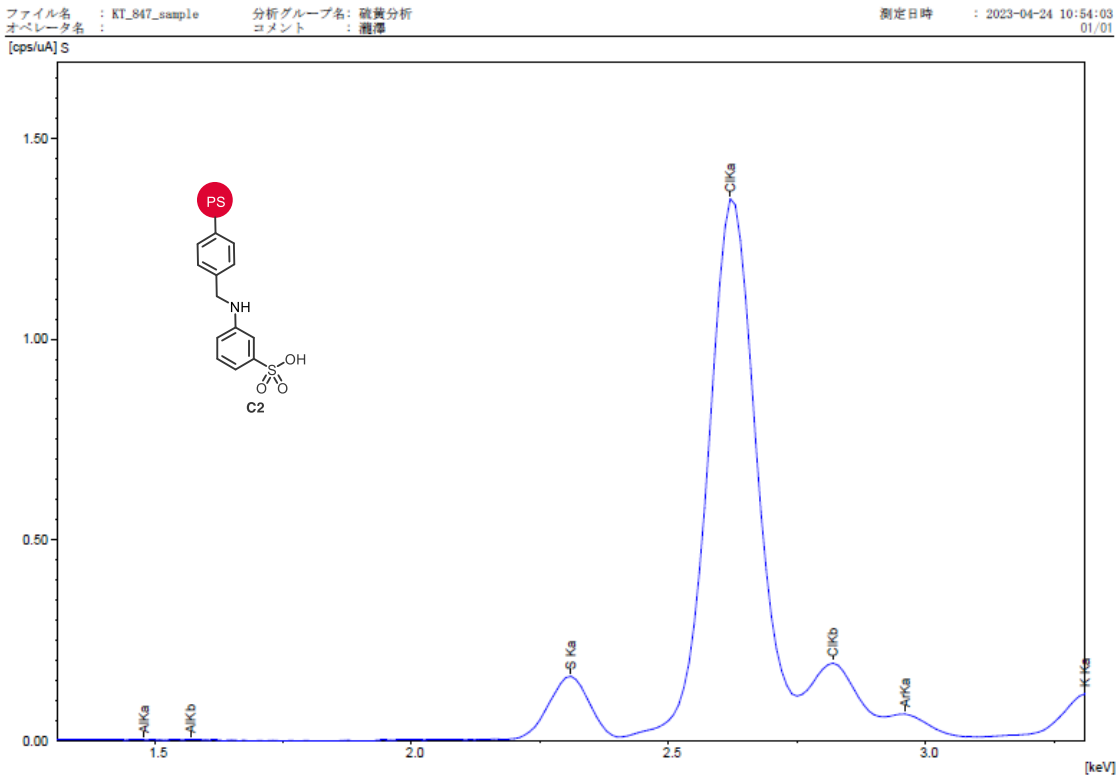


Figure S-2 EDX spectrum of **C2**

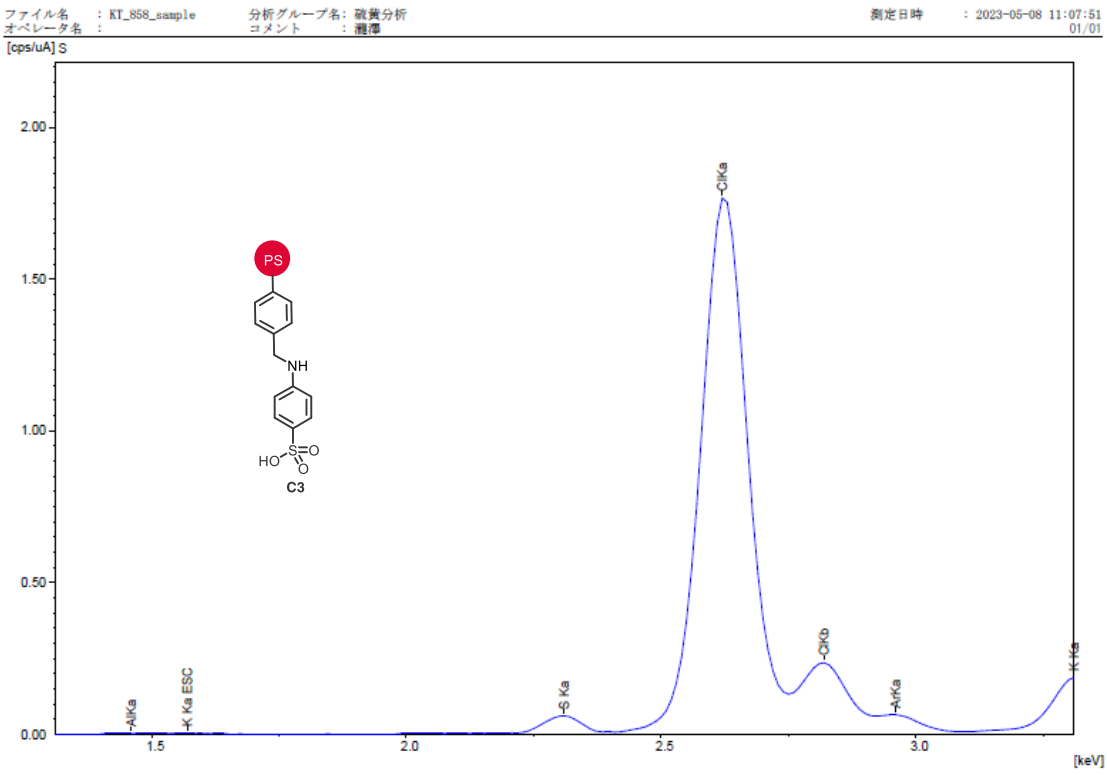


Figure S-3 EDX spectrum of **C3**

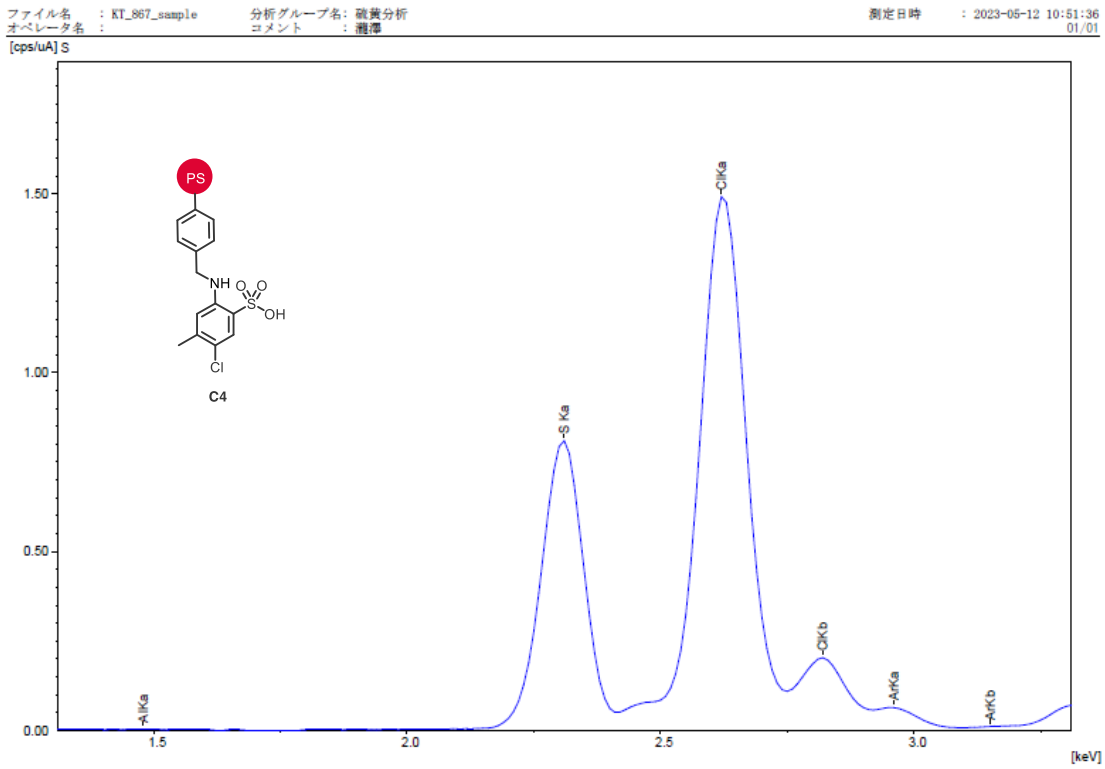


Figure S-4 EDX spectrum of **C4**

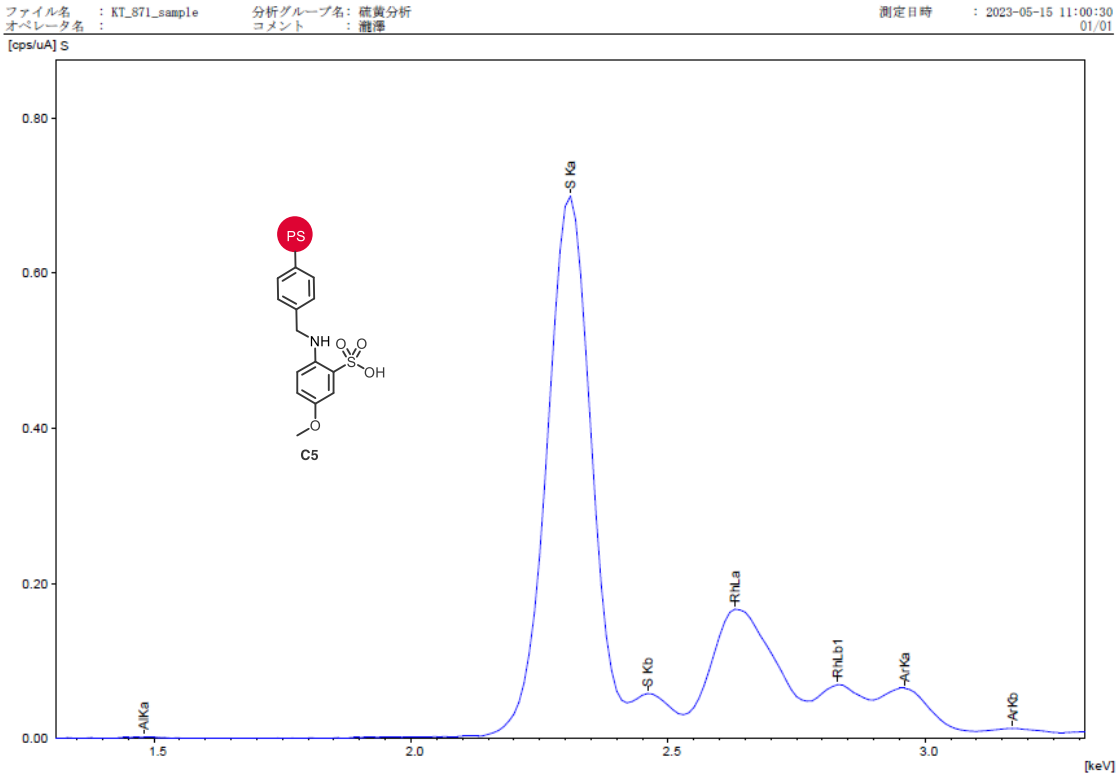


Figure S-5 EDX spectrum of **C5**

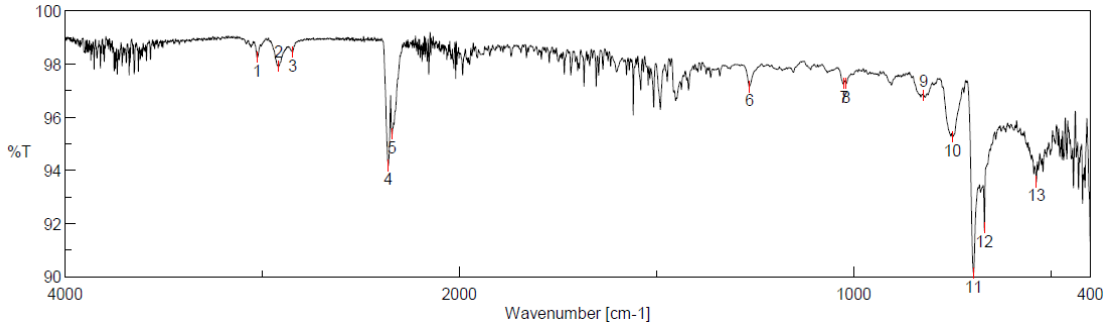


Figure S-6 FT-IR (ATR) spectrum of merrifield resin

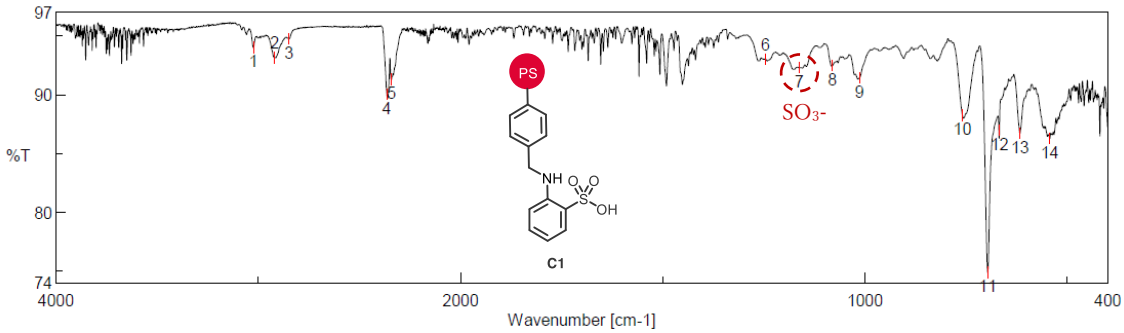


Figure S-7 FT-IR (ATR) spectrum of **C1**

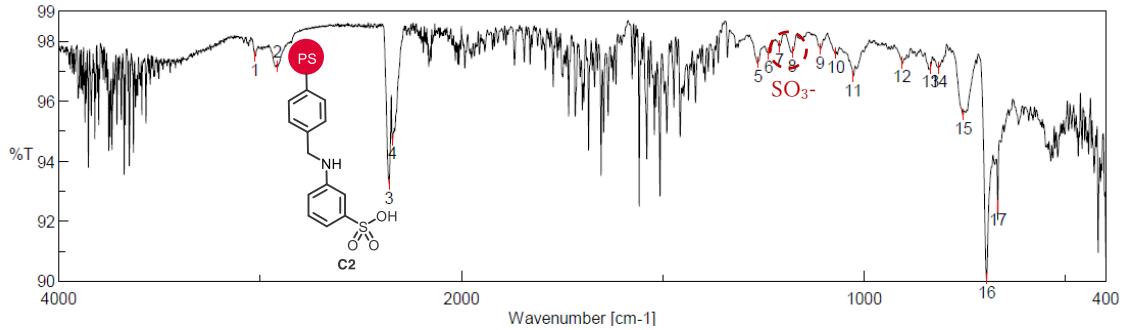


Figure S-8 FT-IR (ATR) spectrum of **C2**

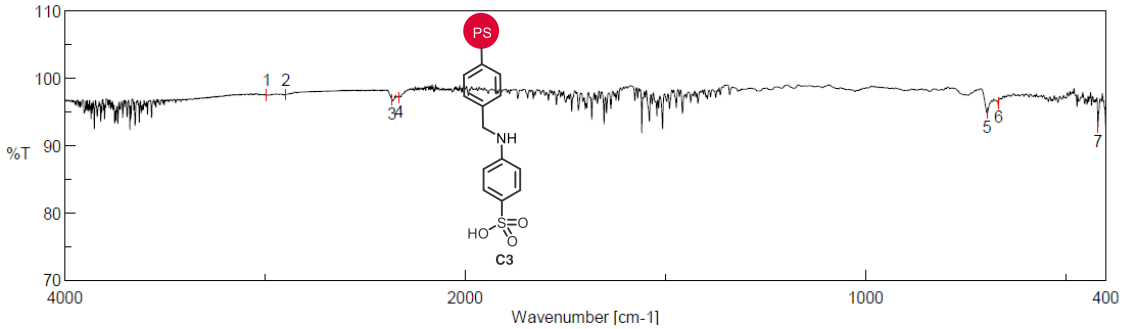


Figure S-9 FT-IR (ATR) spectrum of **C3**

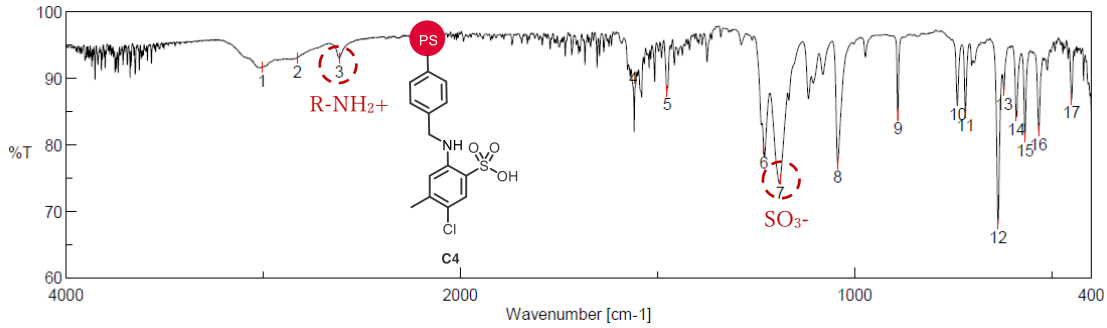


Figure S-10 FT-IR (ATR) spectrum of **C4**

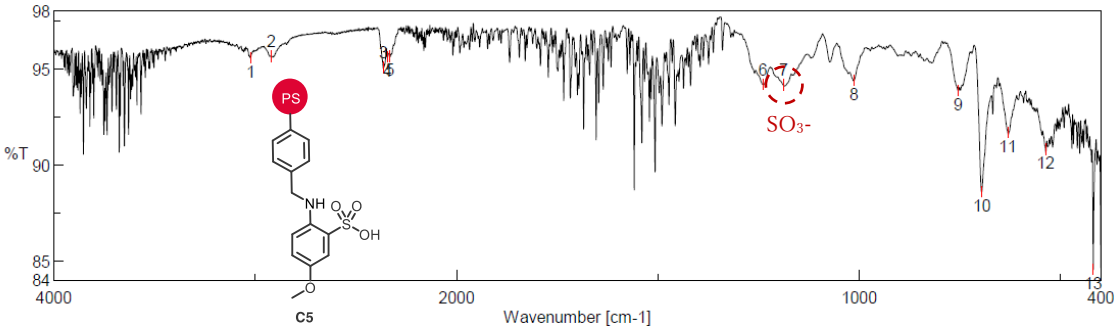
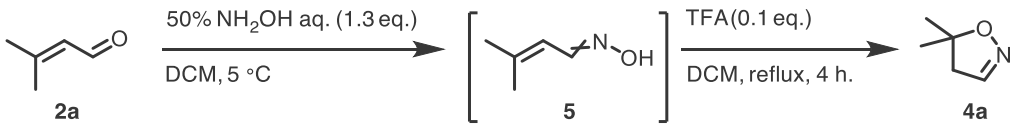


Figure S-11 FT-IR (ATR) spectrum of **C5**

The peaks derived by SO_3^- and NH_2^+ were observed clearly in the case of high loading catalysts **C4** and **C5**.

3. Synthesis of authentic sample 4a

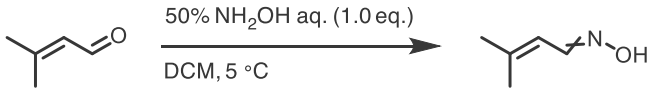


To a 500 mL flask was added dichloromethane (350 mL), 3-methyl-2-butenal (60.0 g, 710 mmol, 1.0 eq.). Then, 50 w% hydroxylamine aqueous solution (59.4 g, 899 mmol, 1.3 eq.) was added dropwise for 2 hours under 5 ℃. After confirming the consumption of **2a** confirmed by gas chromatography analysis, the reaction mixture was heated to room temperature. The reaction mixture was transferred to the separatory funnel and collected the organic layer. The resulting **5** was used without further purification.

To a 500 mL flask was added **5** in dichloromethane and trifluoroacetic acid (8.1 g, 0.1 eq. based on **2a**). The reaction mixture was heated under reflux for 4 hours. After confirming the consumption of **5** by gas chromatography analysis, dichloromethane was evacuated under reduced pressure. Then, **4a** was purified by distillation under reduced pressure (5.0 kPa, 71 ℃). **4a** was obtained as a colorless oil (46.1 g, 66%).

^{1}H NMR (500 MHz, $CDCl_3$): δ (ppm): 7.06 (s, 1H), 2.75 (s, 1H), 2.75 (s, 1H), 1.40 (s, 6H)
^{13}C NMR (125 MHz, $CDCl_3$): δ (ppm): 146.11, 82.43, 47.40, 27.10
IR (neat) ν = 1144, 1259, 1302, 1369, 1440, 1463, 1600, 2873, 2932, 2975, 3073 cm^{-1}
HRMS (FAB) m/z : $[M+H]^+$ Calcd for $C_5H_{10}NO^+$ 100.0757; Found 100.0762

4. Synthesis of α,β-unsaturated oxime 5 for mechanism investigation.



2a **5**

79%

To a 500 mL flask was added dichloromethane (350 mL), 3-methyl-2-butenal (59.7 g, 710 mmol, 1.0 eq.). Then, 50 w% hydroxylamine aqueous solution (46.9 g, 710 mmol, 1.0 eq.) was added dropwise for 1 hour under 5 ℃. After the consumption of **2a** by gas chromatography analysis, the reaction mixture was heated to room temperature. The reaction mixture was transferred to the separatory funnel and collected the organic layer. The solvent was evacuated under reduced pressure. The reaction mixture was placed in a refrigerator to induce crystallization and the resulting crystal was filtered then vacuum dried. **5** was obtained as a colorless crystal (56.6 g, 79%, E/Z = 3/2).

^{1}H NMR (400 MHz, $CDCl_3$): δ(ppm): 9.72 (br, 1H), 8.04 (d, *J* = 10.4 Hz, 1H, *E*-isomer), 7.34 (d, *J* = 10.0 Hz, 1H, *Z*-isomer), 6.53 (d, *J* = 10.0 Hz, 1H, *Z*-isomer), 5.92 (d, *J* = 10.4 Hz, 1H, *E*-isomer), 1.91 (s, 3H, *Z*-isomer), 1.88 (s, 3H, *Z*-isomer), 1.86 (s, 3H, *E*-isomer), 1.83 (s, 3H, *E*-isomer)

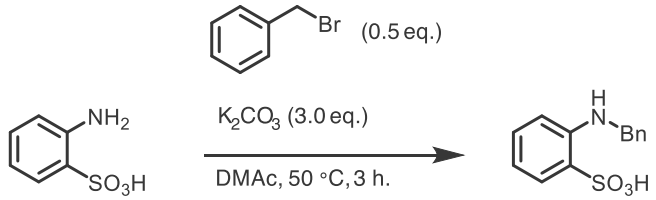
^{13}C NMR (125 MHz, $CDCl_3$): δ(ppm): 148.94 (*E*-isomer), 146.77 (*Z*-isomer), 145.51 (*Z*-isomer), 144.32 (*E*-isomer), 118.32 (*E*-isomer), 113.57 (*Z*-isomer), 26.61 (*E*-isomer), 26.39 (*Z*-isomer), 18.72, 18.71

IR (neat) ν = 849, 932, 1051, 1152, 1377, 1438, 1650, 2912, 3187 cm^{-1}

HRMS (ESI-Q-TOF) m/z : $[2M+H]^+$ Calcd for $C_{10}H_{19}N_2O_2^+$ 199.1441; Found 199.1442

5. Synthesis of *N*-benzylorthanilic acid 6 and *N*-benzylmetanilic acid 7

5-1. Synthesis of *N*-benzylorthanilic acid 6



6

20.0 mmol 25%

To a 100 mL flask was added *N,N*-dimethylacetoamide (20 mL), Orthanilic acid (3.46 g, 20.0 mmol, 1.0 eq.), benzyl bromide (1.2 mL, 10.0 mmol, 0.5 eq.) and potassium carbonate (4.15 g, 30.0 mmol, 3.0 eq.). Then, the reaction mixture was heated at 50 ℃ for 3 hours. After the reaction mixture was cooled at room temperature, 35% HCl aq. (5 mL) and H_2O (20 mL) were added. The aqueous phase was extracted with chloroform (6 times) and the combined organic layers were dried over $MgSO_4$, filtered, and concentrated under reduced pressure. The resulting crude mixture was purified by column chromatography ($CHCl_3$/MeOH = 3/1) and recrystallization (MeOH/isopropanol = 1/2). The resulting slurry was filtered and washed with diisopropylether to afford *N*-benzylorthanilic acid as a bluish crystal (0.67 g, 25%).

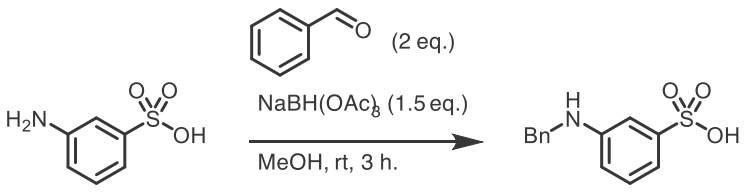
^{1}H NMR (500 MHz, DMSO-d_6): δ (ppm): 7.61 (dd, J = 1.4, 7.6 Hz, 1H), 7.42 (d, J = 7.6 Hz, 2H), 7.36 (t, J = 7.3 Hz, 2H), 7.29 (t, J = 7.3 Hz, 1H), 7.19 (td, J = 8.7, 1.6 Hz, 1H), 6.66-6.83 (m, 4H, NH, SO_3H, C-H*2), 4.45 (s, 2H).

^{13}C NMR (125 MHz, DMSO-d_6): δ (ppm): 138.34, 135.97, 135.35, 130.36, 128.57, 128.55, 127.94, 127.63, 121.50, 117.06, 50.37

IR (neat) ν = 510, 537, 559, 607, 763, 1012, 1143, 1169, 1454, 1539 cm^{-1}

HRMS (ESI-Q-TOF) m/z : $[M+H]^+$ Calcd for $C_{13}H_{14}NO_3S^+$ 264.0689; Found 264.0698

5-2. Synthesis of *N*-benzylmetanilic acid 7



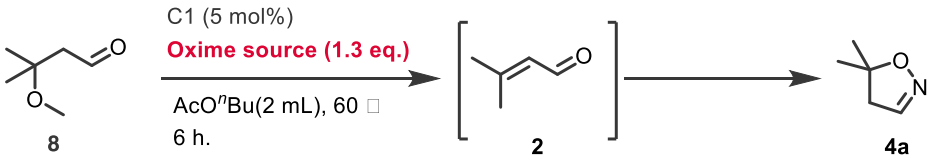
10 mmol — **7** — 28%

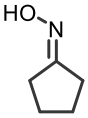
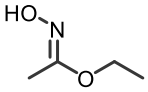
To a 50 mL flask was added MeOH (10 mL), metanilic acid (1.73 g, 10.0 mmol, 1.0 eq.) and benzaldehyde (2.12 g, 20.0 mmol, 2.0 eq.). Then, sodium triacetoxyborohydride (3.18 g, 15.0 mmol, 1.5 eq.) was added and react for 3 hours. After that, H_2O (20 mL) was added and the residual benzaldehyde in the aqueous phase was removed by extraction with ethyl acetate for three times. The resulting aqueous layer was concentrated by rotary evaporator. The resulting crude mixture was purified by recrystallization (MeOH/isopropanol = 1/2) to afford *N*-benzylmetanilic acid **7** as a pale red crystal (0.73 g, 28%).

^{1}H NMR (400 MHz, DMSO-d_6): δ (ppm): 7.28-3.36 (m, 4H), 7.19-7.23 (m, 1H), 6.93-6.98 (m, 2H), 6.77 (d, J = 7.6 Hz, 1H), 6.45 (d, J = 8.0 Hz, 1H), 6.29 (t, J = 6.4 Hz, 1H), 4.26 (s, 1H), 4.25 (s, 1H).
^{13}C NMR (125 MHz, DMSO-d_6): δ (ppm): 148.93, 148.03, 140.27, 128.24, 127.92, 127.02, 126.53, 113.39, 111.76, 110.08, 46.40.
IR (neat) ν = 609, 624, 690, 698, 731, 790, 883, 987, 1038, 1116, 1182, 1219, 1334, 1480, 1603. 3386 cm^{-1}
HRMS (ESI-Q-TOF) m/z : $[M-H]^-$ Calcd for $C_{13}H_{14}NO_3S^+$ 262.0543; Found 262.0549

6. The optimization of the reaction condition

6-1 Oxime source



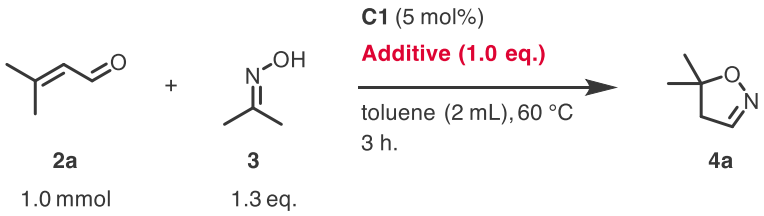
entry	Oxime	conv.(%)[a]	**4a** (%)[a]	TON (**4a**)
1		100	74.0	14.8
2		99.6	39.5	7.9
3		100	28.2	5.6
4		100	69.3	13.9
5		98.0	34.6	6.9

a. GC yield. Ph_2 was used as an internal standard.

Table S-1 The screening of oxime sources

As a result, the reaction with acetoxime **3** provided **4a** most efficiently. In entry 2, the oxime exchange reaction was observed. When the benzaldoxime and ethyl *N*-hydroxyacetimidate were used (entries 3 and 4), the hydrolysis of these oxime was slow. Therefore, the yields of **4a** were lower.

6-2 Proton source

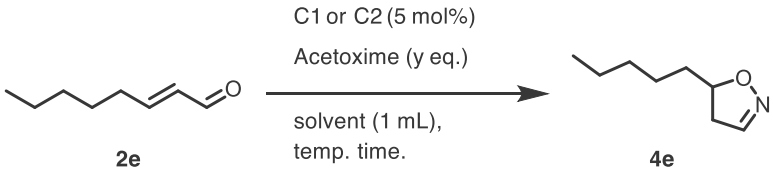


entry	Additive	Conv. (%)	**4a** (%)
1	-	87	76
2	H_2O	74	58
3	MeOH	90	79
4	AcOH	75	55

Table S-2 The screening of proton sources

Proton sources sometimes work dramatically in the enamine catalysis[6]. Therefore, we added the proton source in the reaction condition. In entry 3, the conversion and yield slightly improved in the presence of methanol. In other proton sources, the result did not improve.

6-3 The optimization of the reaction condition for 2e



2e

1 mmol

4e

entry	C1 or C2	y (eq.)	solvent	temp. (°C)	time (h.)	conv.(%)[a]	**4e** (%)[a]
1	C1	1.3	$CHCl_3$	60	14	91	**35**
2	C1	1.3	$CHCl_3$	30	17	99	**23**
3	C1	5	$CHCl_3$	30	17	99	**35**
4	C2	5	$CHCl_3$	30	17	99	**46**
5	C2	5	$CHCl_3$	30	7	99	**60**[c]
6	C2	5	$CHCl_3$	0	15	99	**18**
7[b]	C2	5	$CHCl_3$	30	15	99	**27**
8[b]	C2	5	toluene	30	15	99	**24**
9	C2	5	AcOEt	30	16	99	**27**

a. The yield and conversion was evaluated by ^{1}H-NMR and 1,3,5-trimethoxybenzene was used as an internal standard.

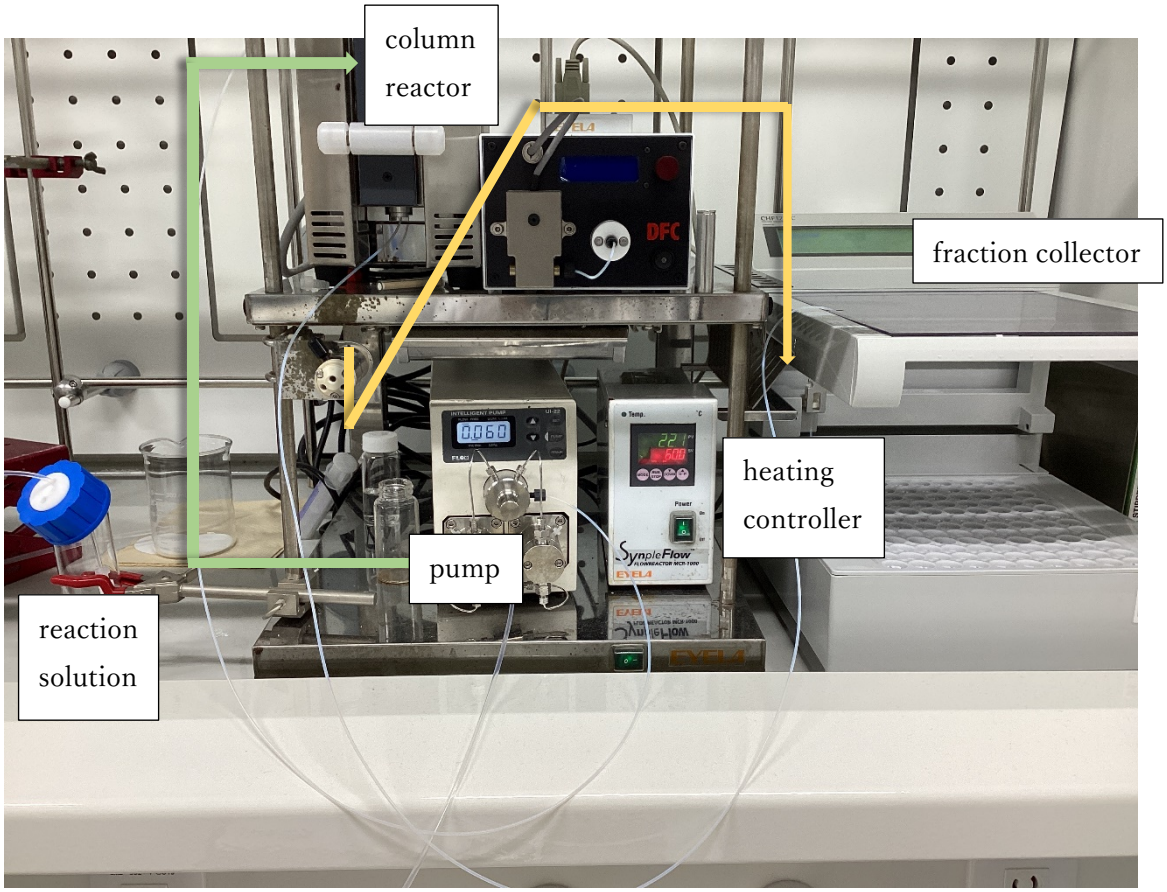
b. 10 mL of solvent was used

c. The isolated yield was shown in parenthesis

Table S-3 The investigation of optimal condition for **2e**

The reaction was carried out at 60 °C in the presence of catalyst **C1**, but the yield of **4e** was low at 35% (entry 1). When the temperature was lowered to 30 °C and the equivalent of acetoxime was increased, the yield of **4e** improved (entries 2 and 3). When the condition of entry 3 was applied to **C2**, the yield of **4e** improved (entry 4, 5). The reaction was further conducted at 0 °C, but although the conversion was good, the yield decreased (entry 6). Several peaks that could not be observed at 30 ℃ existed, suggesting that the reaction stopped at an intermediate. Concentration and solvent were also investigated, but the yields of **4e** were lower than that in entry 4 and 5 (entries 7-9).

7. Procedure for continuous-flow condition

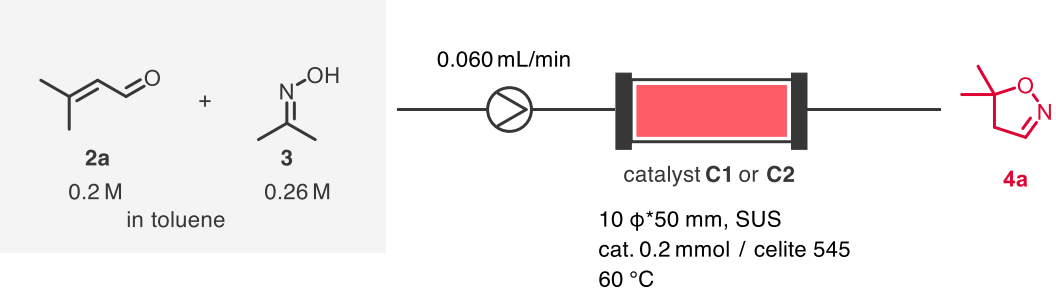


Pump: UI-22 110P, Tokyo Rikakikai Co., Ltd.

Flow reactor (heating controller and column reactor): MCR-1000, Tokyo Rikakikai Co., Ltd.

Fraction collector: CHF122SC, TOYO ROSHI KAISHA, Ltd.

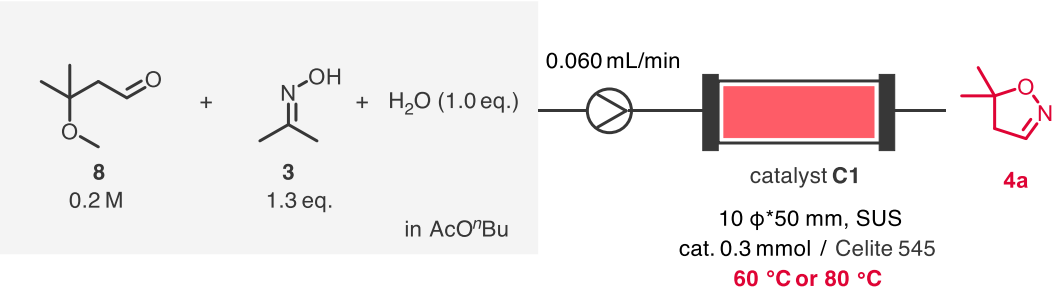
7-1 The experimental procedure of the continuous-flow condition



A catalyst **C1** was pre-mixed with Celite (272.4 mg catalyst **C1**/1.0 g Celite545, 0.20 mmol of catalyst loading) and then packed into a column (I.D. φ10×50 mm). The catalyst column was set onto the reactor and toluene (blank solvent) was flowed at 0.5 mL/min flow rate for 30 min to remove residual air inside and wet the column. Then, the flow rate was adjusted at designed flow rate (0.06 mL/min) for at least 30 min to stabilize liquid flow. Next, toluene solution of **2a** (0.20 M) and acetoxime (0.26 M) with biphenyl (internal standard) was provided at 0.06 mL/min of flow rate. Then, the column reactor was heated at 60 ℃. Selected fractions were analyzed GC-FID to determine yield.

7-2 The optimization of the continuous-flow condition

・Temperature



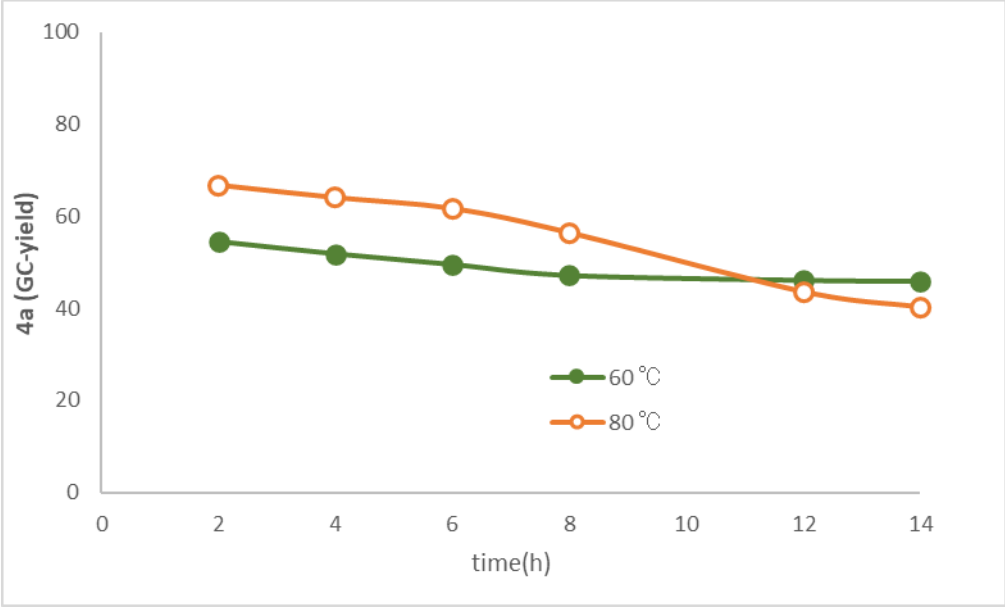
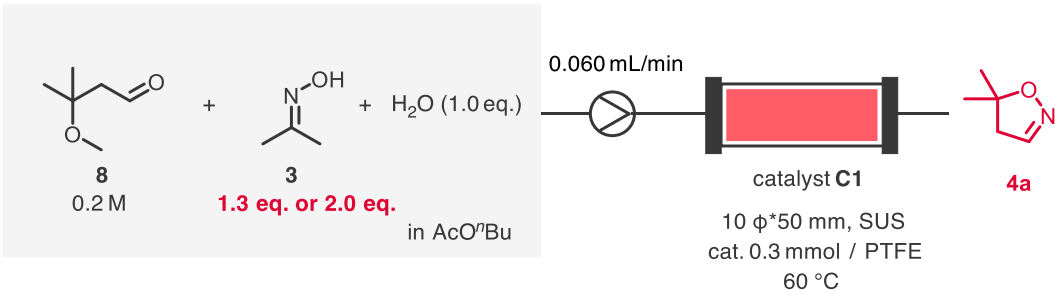


Figure S-12 The optimization of temperature

The yield of **4a** maintained at 60 ℃ (●), however, it decreased at 80 ℃ (○). Therefore, 60 ℃ was optimal.

・**The equivalent of acetoxime 3**



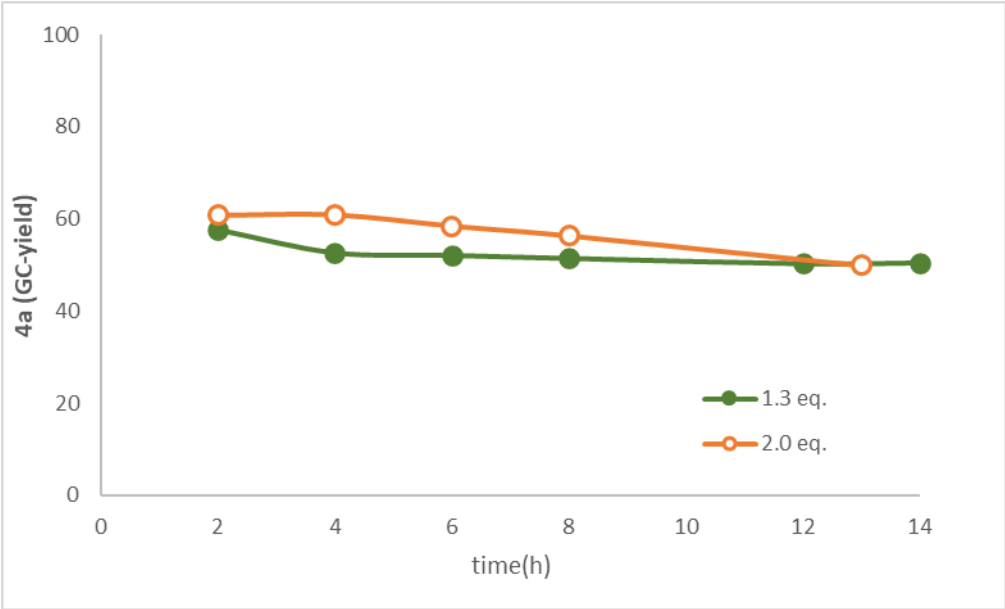


Figure S-13 The optimization for the equivalent of acetoxime 3

Although the initial reaction rate was faster in the condition using 2.0 eq. of acetoxime **3**, the deactivation of the catalyst also accelerated (● vs ○). Therefore, the conditions employing 1.3 eq. of acetoxime 3 were adopted.

・**The catalyst loading**

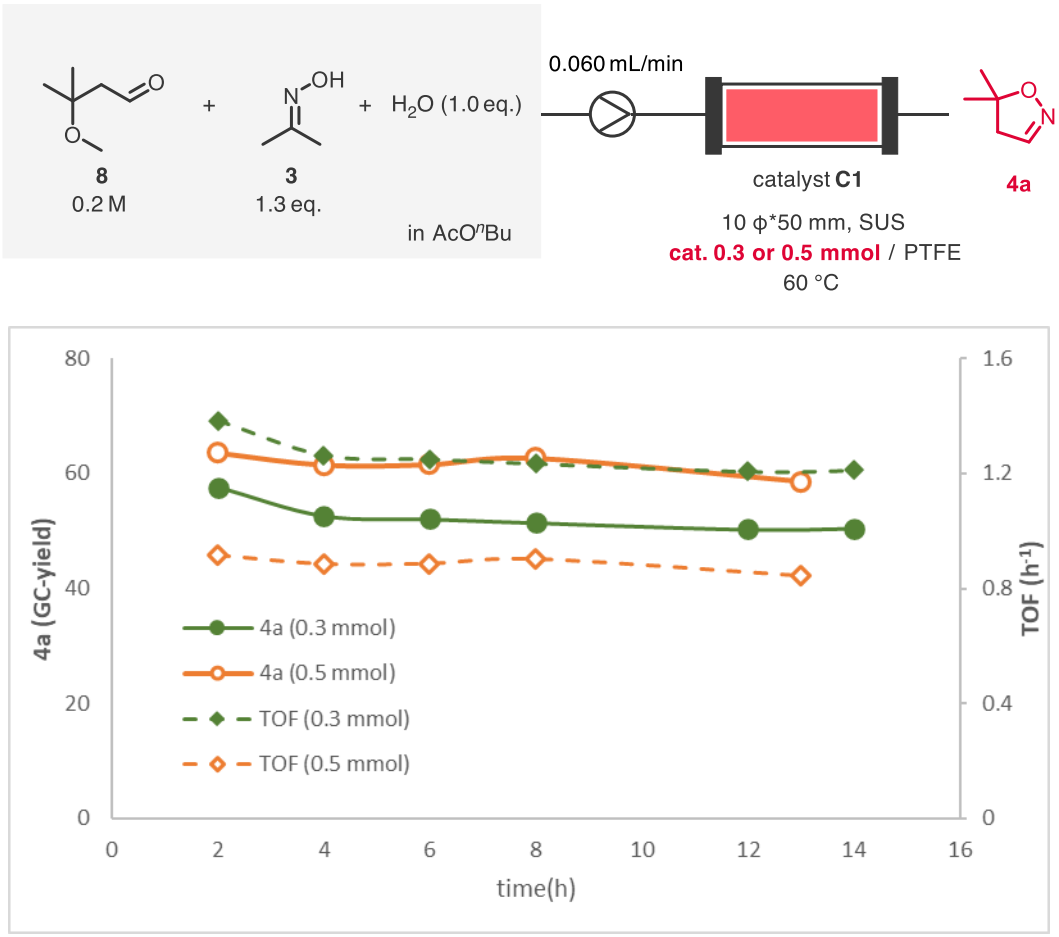
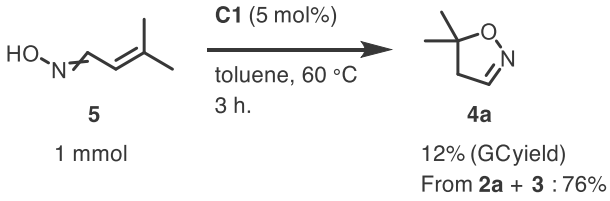


Figure S-14 The optimization of the catalyst loading

In the high loading condition (◯), the yield of **4a** slightly increased. However, the turn over frequency (TOF) decreased (1.2 → 0.8).

8. The investigation of reaction mechanism.

8-1. The investigation of the possibility via α,β-unsaturated oxime

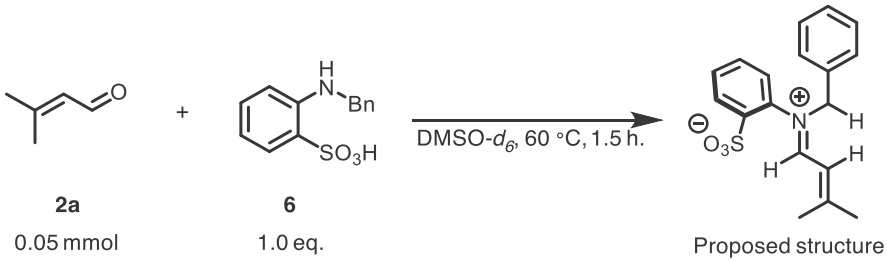


To a 15 mL test tube, α,β-unsaturated oxime **5** (99.1 mg, 1.0 mmol, 1.0 eq.), catalyst **C1** (68.2 mg, 0.05 mmol, 0.05 eq.) and toluene (2 mL) were added. Then, the reaction mixture was heated at 60 ℃ for 3 hours. The reaction mixture was analyzed GC-FID and the yield was determined by GC-internal standard method (biphenyl was used as an internal standard.).

4a : 12% (GC yield)

When the reaction of α,β-unsaturated aldehyde **2a** and acetoxime **3** with catalyst **C1** was carried out, the yield of **4a** was 76% (GC yield). Therefore, the reaction does not occur via α,β-unsaturated oxime.

8-2. The iminium formation of aldehyde 2a with *N*-benzylorthanilic acid 6



To a screw-cap NMR tube, 3-methyl-2-butenal (4.8 μL, 0.05 mmol, 1.0 eq.), *N*-benzylorthanilic acid (13.2 mg, 0.05 mmol, 1.0 eq.) and DMSO-d_6 (0.5 mL) were added and the reaction mixture was heated at 60 ℃ for 1.5 hours. Then, the ^{1}H, COSY, NOESY analyses were conducted.

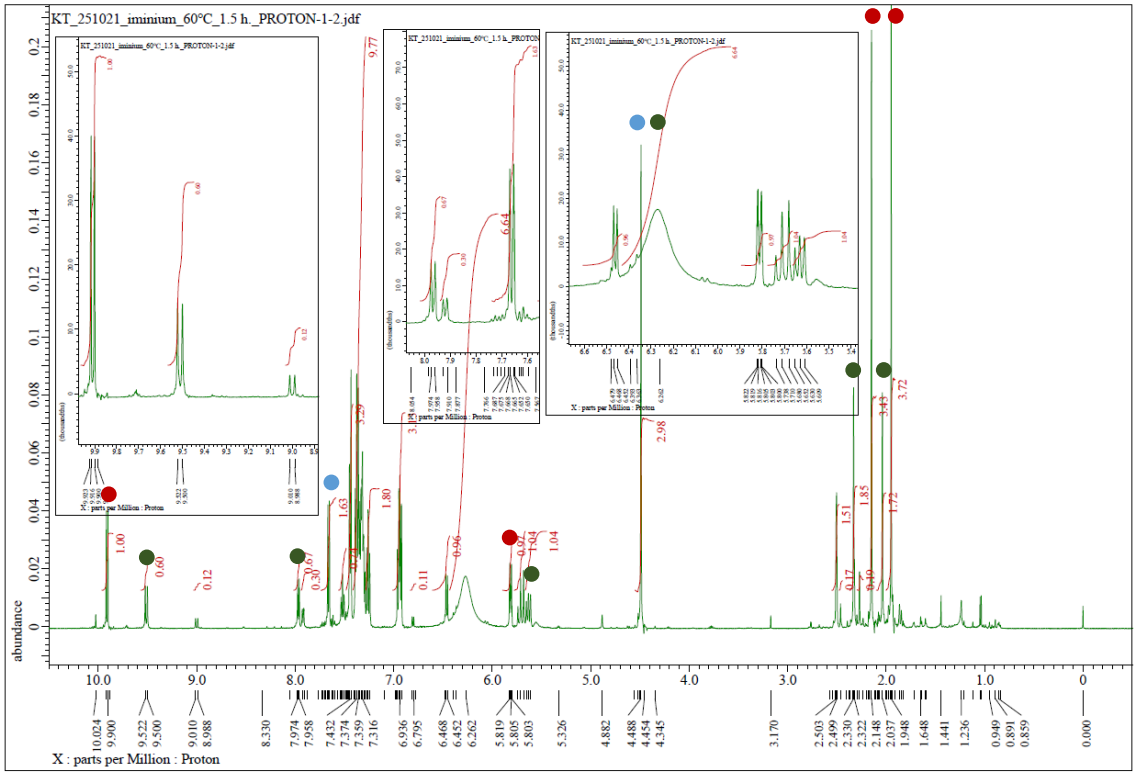


Figure S-15 ^{1}H-NMR spectra in the reaction of aldehyde **2a** with *N*-benzylorthanilic acid **6** at 60 ℃ for 1.5 h. (**2a** : ●, **5** : ●, proposed iminium cation : ●)

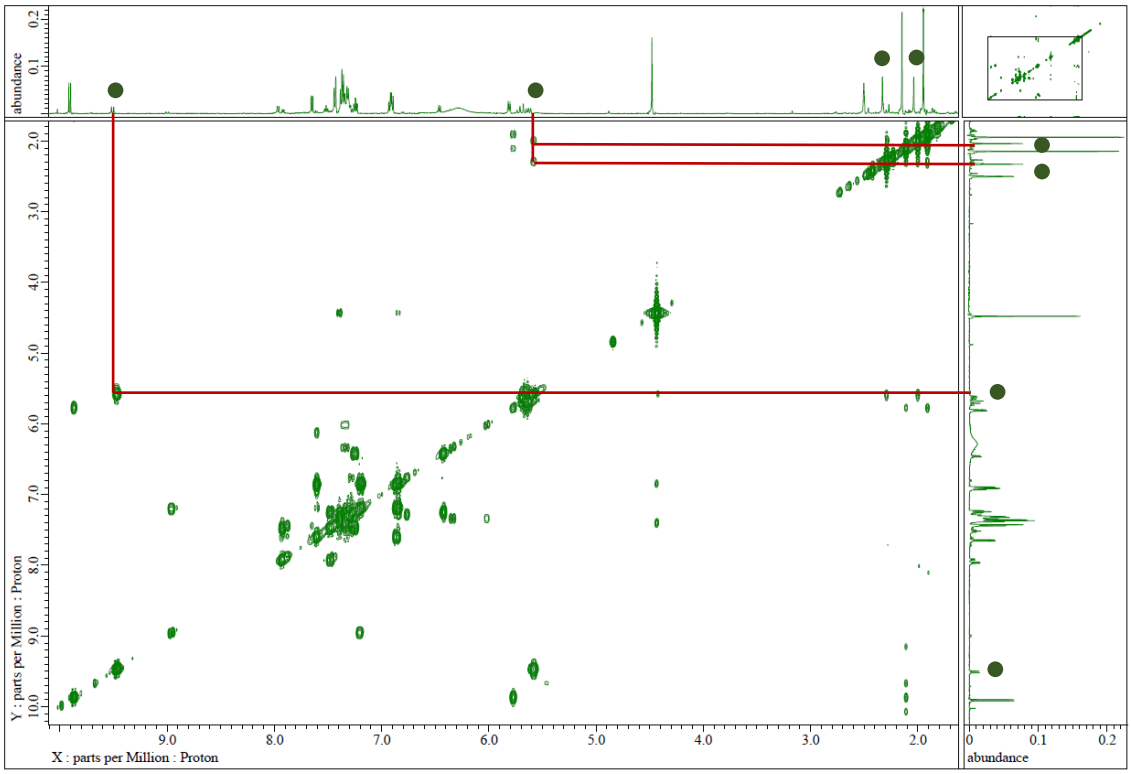


Figure S-16 COSY spectra in the reaction of aldehyde **2a** with *N*-benzylorthanilic acid **6** at 60 ℃ for 1.5 h.

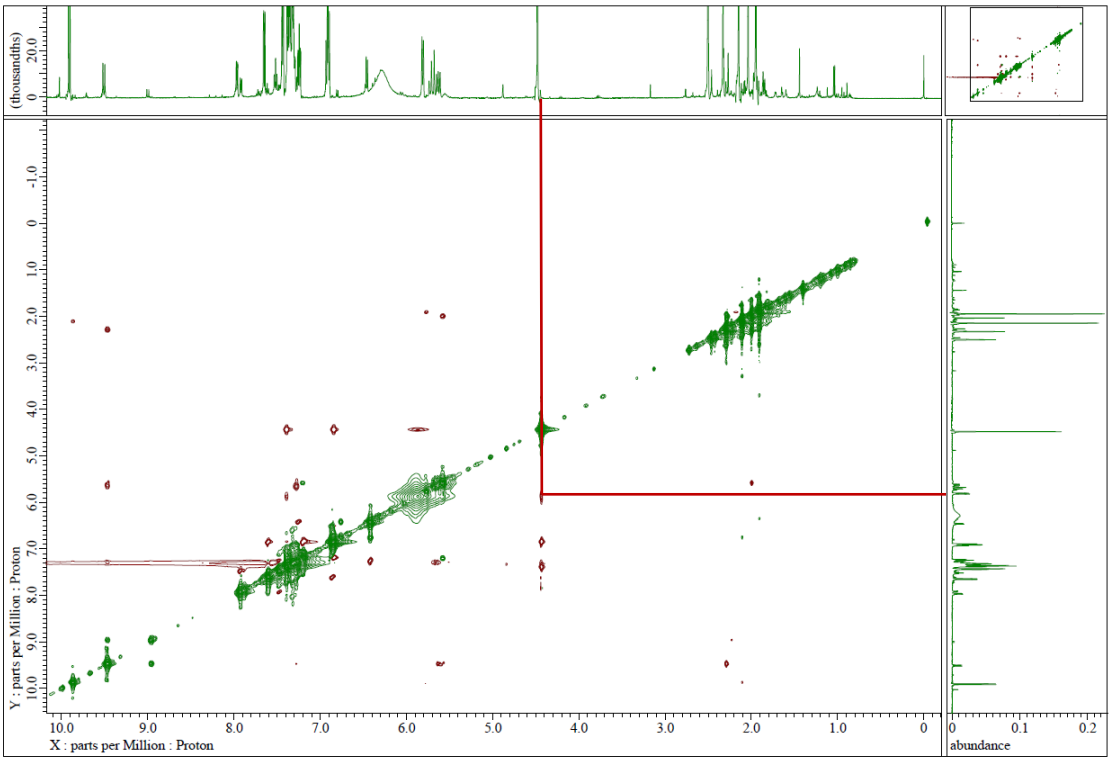
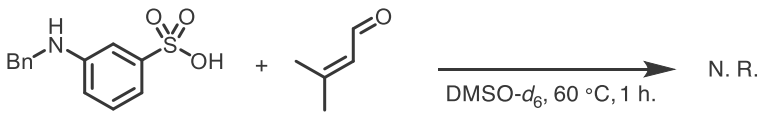


Figure S-17 NOESY spectra in the reaction of aldehyde **2a** with *N*-benzylorthanilic acid **6** at 60 ℃ for 1.5 h.

In the ^{1}H-NMR spectrum, the peaks at 9.51 (d, 1H), 5.63 (m, 1H), 2.33 (s, 3H), and 2.04 (s, 3H) were observed in close to the starting material **2a** (●). We assigned these peaks to the proposed iminium cation (●). It is likely that the PhCH2- peak was overlapped by the starting material **6** (●).

In the COSY spectrum, the alkene proton signal at 5.63 ppm correlated with signals at 9.51, 2.33, and 2.04 ppm. This correlation suggests that the generated compound is similar to the starting material **2a**. Additionally, the PhCH2- peak showed correlation with the alkene peak in the NOESY spectra. Therefore, it is inferred that the proposed iminium cation is formed in the catalytic cycle by **C1** catalyst.

8-3. The iminium formation of aldehyde 2a with *N*-benzylorthanilic acid 7



7 0.05 mmol

2a 1.0 eq.

To a screw-cap NMR tube, 3-methyl-2-butenal (4.8 μL, 0.05 mmol, 1.0 eq.), *N*-benzylmetanilic acid **7** (13.2 mg, 0.05 mmol, 1.0 eq.) and DMSO-d_6 (0.5 mL) were added and the reaction mixture was heated at 60 ℃ for 1.0 hours. Then, the ^{1}H-NMR was conducted.

In **Figure S-15**, the ^{1}H-NMR spectra of **2a**, **7** and the reaction mixture with **2a** and **7** at 60 ℃ for 1.0 hour. As a result, the iminium cation formation was not occurred. This result suggests that the iminium-cation-mediated mechanism, observed in **C1** would not work in **C2**. We conducted the computational investigation and see **11. DFT calculation.**

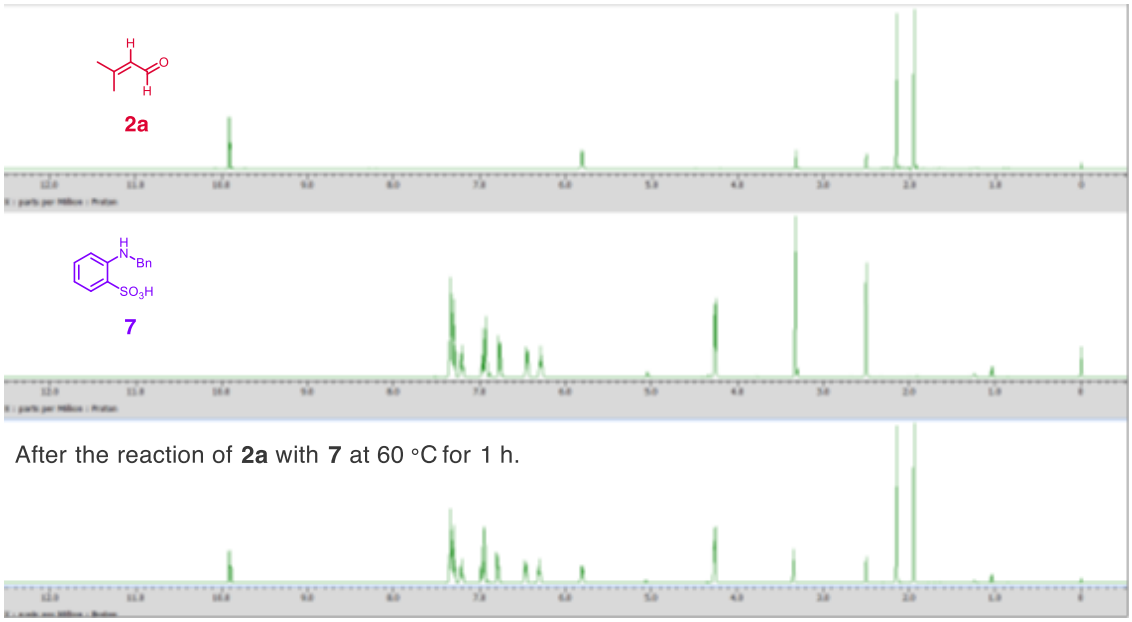
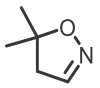


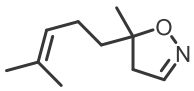
Figure S-18 The ^{1}H-NMR spectra of **2a**, **7** and the reaction mixture of **2a** with **7** at 60 ℃ for 1.0 hour.

9. Substrate scope



4a

To a 15 mL test tube, 3-methyl-2-butenal **2a** (84.1 mg, 1.0 mmol, 1.0 eq.), acetoxime **3** (95.0 mg, 1.3 mmol, 1.3 eq.), catalyst **C2** (228.3 mg, 0.05 mmol, 0.05 eq.) and toluene (2 mL) were added and the reaction mixture was heated at 60 ℃ for 3 hours. The yield of **4a** was evaluated by gas chromatography analysis (biphenyl was used as an internal standard).



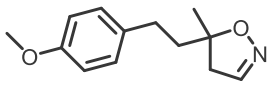
4b

To a 15 mL test tube, citral **2b** (152.2 mg, 1.0 mmol, 1.0 eq.), acetoxime **3** (95.0 mg, 1.3 mmol, 1.3 eq.), catalyst **C2** (260.0 mg, 0.05 mmol, 0.05 eq.) and toluene (2 mL) were added and the reaction mixture was heated at 60 ℃ for 5 hours. The catalyst was filtered and washed with $CHCl_3$. The filtrate was concentrated under reduced pressure. The resulting crude mixture was purified by column chromatography (Hexane : AcOEt = 10 : 1) to afford **4b** as a pale yellow oil (134.7 mg, 81%).

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm): 7.02 (t, *J* = 1.6 Hz, 1H), 5.09 (m, 1H), 2.82 (dd, *J* = 1.8, 17.4 Hz, 1H), 2.66 (dd, *J* = 1.8, 17.5 Hz, 1H), 2.01-2.07 (m, 2H), 1.68 (s, 3H), 1.64-1.67 (m, 2H), 1.61 (s, 3H), 1.35 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$): δ (ppm): 145.83, 132.23, 123.74, 84.71, 45.76, 40.11, 25.80, 25.57, 23.14, 17.78

Spectroscopic data of ^{1}H and ^{13}C were identical to that of reference[1].



4c

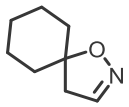
To a 15 mL test tube, **2c** (204.3 mg, 1.0 mmol, 1.0 eq., E/Z = 62/38), acetoxime **3** (95.0 mg, 1.3 mmol, 1.3 eq.), catalyst **C2** (260.0 mg, 0.05 mmol, 0.05 eq.) and toluene (2 mL) were added and the reaction mixture was heated at 60 ℃ for 5.5 hours. The catalyst was filtered and washed with $CHCl_3$. The filtrate was concentrated under reduced pressure. The resulting crude mixture was purified by column chromatography ($CHCl_3$: Hexane = 3 : 1) to afford **4c** as a pale yellow oil (163.0 mg, 74%).

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm): 7.09-7.12 (m, 2H), 7.05 (t, *J* = 1.8 Hz, 1H), 6.81-6.85 (m, 2H), 3.78 (s, 3H), 2.83 (dd, *J* = 1.83, 17.6 Hz, 1H), 2.70 (dd, *J* = 1.83, 17.4 Hz, 1H), 2.61-2.66 (m, 2H),

1.91-1.95 (m, 2H), 1.41 (s, 3H)

^{13}C NMR (125 MHz, $CDCl_3$): δ (ppm): 158.01, 145.89, 133.86, 129.32, 114.04, 84.49, 55.42, 45.88, 42.35, 29.81, 25.74

Spectroscopic data of ^{1}H and ^{13}C were identical to that of reference[1].



4d

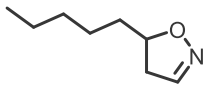
To a 15 mL test tube, **2d** (124.2 mg, 1.0 mmol, 1.0 eq.), acetoxime **3** (95.0 mg, 1.3 mmol, 1.3 eq.), catalyst **C2** (260.0 mg, 0.05 mmol, 0.05 eq.) and Chloroform (2 mL) were added and the reaction mixture was heated at 60 ℃ for 4.0 hours. The catalyst was filtered and washed with $CHCl_3$. The filtrate was concentrated under reduced pressure. The resulting crude mixture was purified by column chromatography ($CHCl_3$ 100%) to afford **4d** as a pale yellow oil (112.1 mg, 81%).

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm): 7.05 (t, *J* = 1.8 Hz, 1H), 2.69 (t, *J* = 1.8, 2H), 1.72-1.78 (m, 4H), 1.54-1.61 (m, 2H), 1.41-1.47 (m, 4H)

^{13}C NMR (125 MHz, $CDCl_3$): δ (ppm): 145.86, 84.70, 45.69, 36.40, 25.18, 23.59

IR (neat) ν = 770, 802, 848, 881, 1435, 1448, 1601, 2856, 2929 cm^{-1}

HRMS (ESI-Q-TOF) m/z : $[M+H]^+$ Calcd for $C_8H_{14}NO^+$ 140.1070; Found 140.1072



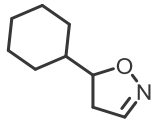
4e

To a 15 mL test tube, 2-octenal **2e** (124.2 mg, 1.0 mmol, 1.0 eq.), acetoxime **3** (365.5 mg, 5.0 mmol, 5.0 eq.), catalyst **C2** (260.0 mg, 0.05 mmol, 0.05 eq.) and Chloroform (2 mL) were added and the reaction mixture was heated at 30 ℃ for 7.0 hours. The catalyst was filtered and washed with $CHCl_3$. The filtrate was concentrated under reduced pressure. The resulting crude mixture was purified by column chromatography ($CHCl_3$ 100%) to afford **4e** as a pale yellow oil (84.0 mg, 60%).

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm): 7.11 (t, *J* = 1.6 Hz, 1H), 4.47-4.55 (m, 1H), 3.03 (ddd, *J* = 1.8, 10.5, 17.2), 2.61 (ddd, *J* = 1.8, 8.0, 17.4), 1.67-1.70 (m, 1H), 1.25-1.58 (m, 7H), 0.89 (t, *J* = 6.9 Hz)

^{13}C NMR (125 MHz, $CDCl_3$): δ (ppm): 146.02, 78.96, 40.58, 35.22, 31.76, 35.35, 22.68, 14.12

Spectroscopic data of ^{1}H and ^{13}C were identical to that of reference[7].



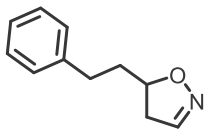
4f

To a 15 mL test tube, **2f** (138.2 mg, 1.0 mmol, 1.0 eq.), acetoxime **3** (365.5 mg, 5.0 mmol, 5.0 eq.), catalyst **C2** (260.0 mg, 0.05 mmol, 0.05 eq.) and Chloroform (2 mL) were added and the reaction mixture was heated at 30 ℃ for 5.0 hours. The catalyst was filtered and washed with $CHCl_3$. The filtrate was concentrated under reduced pressure. The resulting crude mixture was purified by column chromatography ($CHCl_3$ 100%) to afford **4f** as a pale yellow oil (58.9 mg, 38%).

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm): 7.09 (t, *J* = 1.6 Hz, 1H), 4.25 (ddd, *J* = 7.0, 8.7, 10.7 Hz, 1H), 2.93 (ddd, *J* = 1.8, 10.8, 17.4 Hz, 1H), 2.70 (ddd, *J* = 1.8, 8.7, 17.4 Hz, 1H), 1.86-1.90 (m, 1H), 1.75-1.79 (m, 2H), 1.60-1.70 (m, 2H), 1.44-1.54 (m, 1H), 1.15-1.27 (m, 3H), 0.96-1.07 (m, 2H).

^{13}C NMR (125 MHz, $CDCl_3$): δ (ppm): 145.97, 83.25, 42.37, 38.05, 28.74, 28.63, 26.45, 25.98, 25.81

Spectroscopic data of ^{1}H and ^{13}C were identical to that of reference[8].



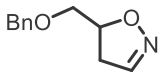
4g

To a 15 mL test tube, **2g** (160.2 mg, 1.0 mmol, 1.0 eq.), acetoxime **3** (365.5 mg, 5.0 mmol, 5.0 eq.), catalyst **C2** (260.0 mg, 0.05 mmol, 0.05 eq.) and Chloroform (2 mL) were added and the reaction mixture was heated at 30 ℃ for 5.0 hours. The catalyst was filtered and washed with $CHCl_3$. The filtrate was concentrated under reduced pressure. The resulting crude mixture was purified by two rounds of column chromatography (Hexane/AcOEt = 4/1 and $CHCl_3$ 100%) to afford **4g** as a pale yellow oil (71.8 mg, 41%).

^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm): 7.27-7.32 (m, 2H), 7.18-7.21 (m, 3H), 7.12 (t, *J* = 1.6 Hz, 1H), 4.52 (ddt, *J* = 5.3, 7.8, 9.1 Hz), 3.04 (ddd, *J* = 1.8, 10.5, 17.4 Hz, 1H), 2.76 (ddd, *J* = 6.9, 9.4, 12.4 Hz, 1H), 2.62 (ddd, *J* = 1.8, 7.8, 17.4 Hz, 1H), 2.01 (dddd, *J* = 5.7, 7.8, 9.3, 13.7 Hz, 1H), 1.83 (dddd, *J* = 5.0, 6.9, 9.6, 14.0 Hz, 1H),

^{13}C NMR (125 MHz, $CDCl_3$): δ (ppm): 146.10, 145.97, 141.29, 128.64, 126.18, 77.91, 46.68, 37.03, 31.99

Spectroscopic data of ^{1}H and ^{13}C were identical to that of reference[1].



4h

To a 15 mL test tube, **2h** (176.2 mg, 1.0 mmol, 1.0 eq.), acetoxime **3** (365.5 mg, 5.0 mmol, 5.0 eq.), catalyst **C2** (260.0 mg, 0.05 mmol, 0.05 eq.) and Chloroform (2 mL) were added and the reaction mixture was heated at 30 ℃ for 6.0 hours. The catalyst was filtered and washed with $CHCl_3$. The filtrate was concentrated under reduced pressure. The resulting crude mixture was purified by column chromatography ($CHCl_3$/AcOEt = 30/1) to afford **4h** as a pale yellow oil (54.9 mg, 29%).

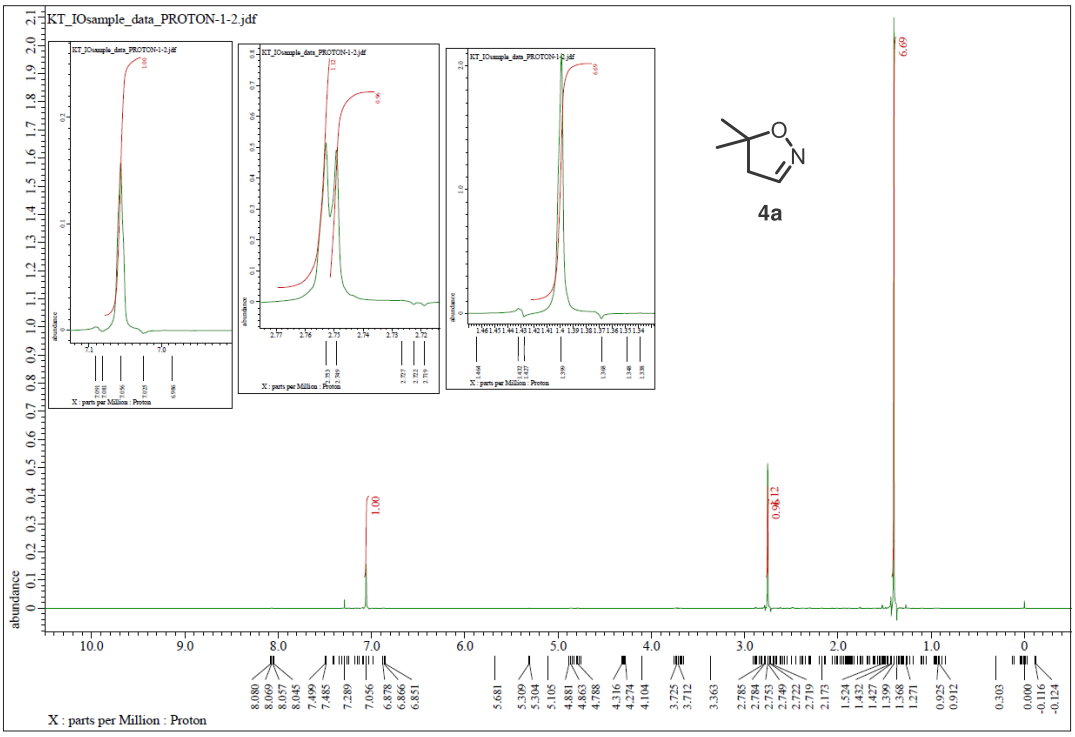
^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm): 7.27-7.38 (m, 5H), 7.12 (t, *J* = 1.6 Hz, 1H), 4.72 (dtdd, *J* = 0.5, 5.0, 7.2, 10.7 Hz, 1H), 4.59 (s, 2H), 3.59 (dd, *J* = 5.0, 10.3 Hz, 1H), 3.53 (dd, *J* = 5.0, 10.4 Hz, 1H), 3.04 (ddd, *J* = 1.8, 10.8, 17.5 Hz, 1H), 2.91 (ddd, *J* = 1.8, 7.3, 17.6 Hz, 1H)

^{13}C NMR (125 MHz, $CDCl_3$): δ (ppm): 146.02, 137.99, 128.58, 127.89, 77.34, 73.69, 70.93, 37.97

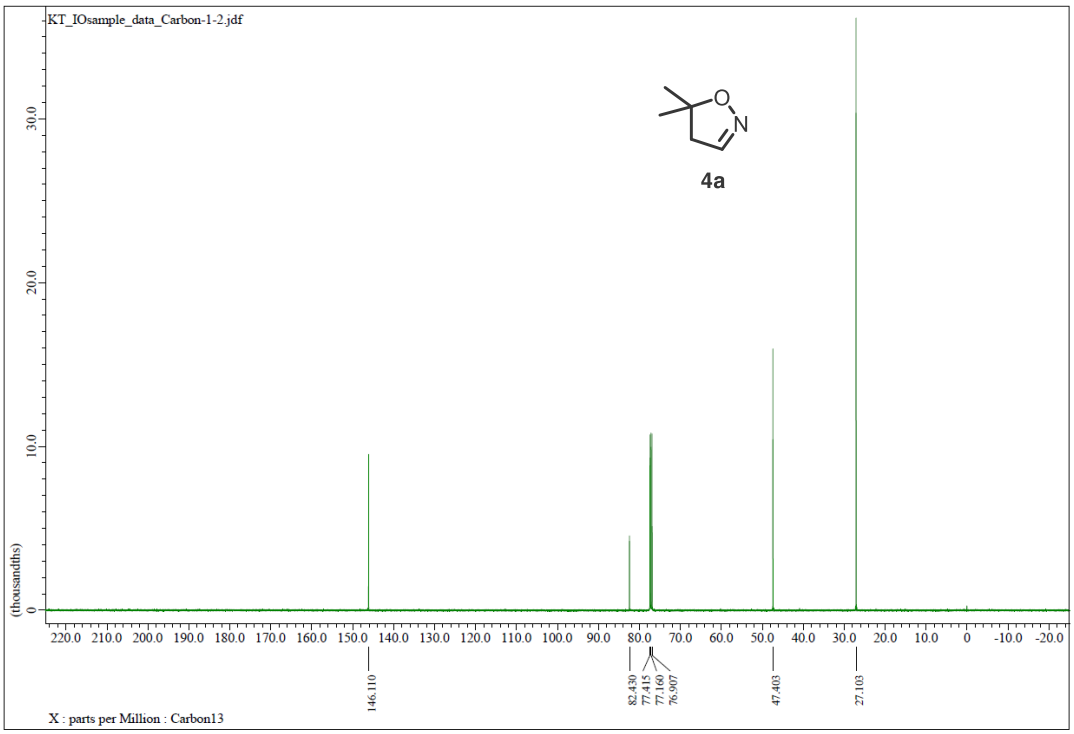
Spectroscopic data of ^{1}H and ^{13}C were identical to that of reference[8].

10. NMR spectra

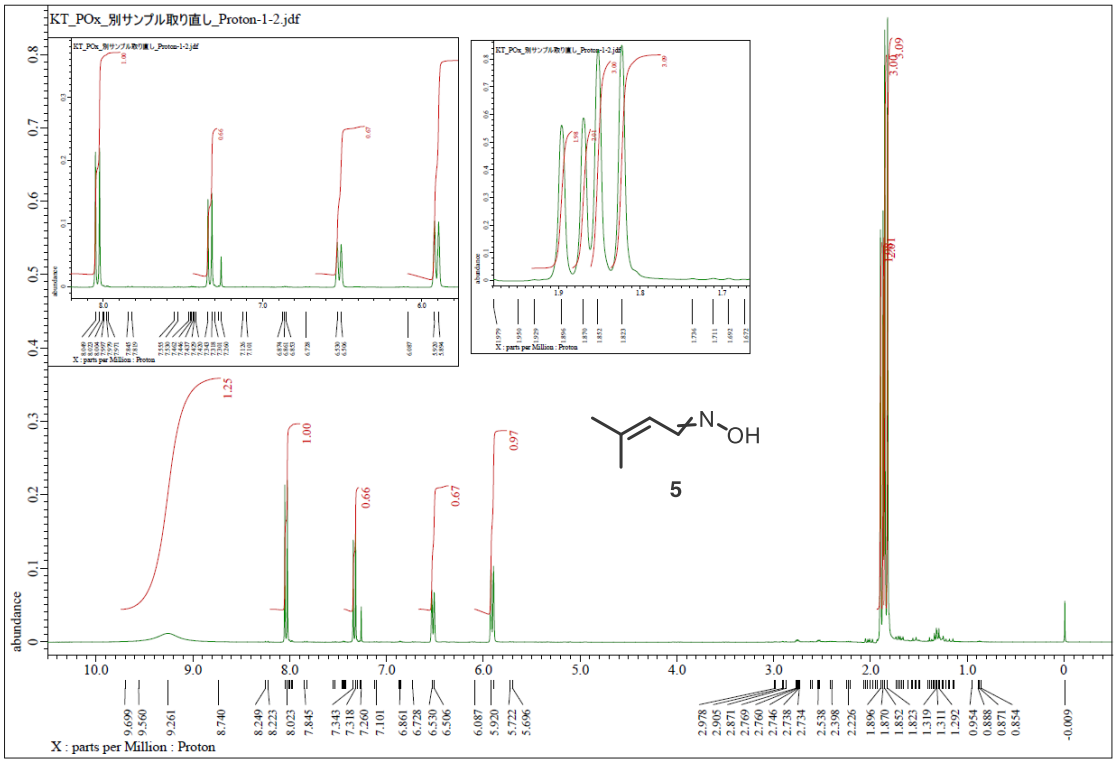
4a : ^{1}H-NMR (500 MHz, $CDCl_3$)



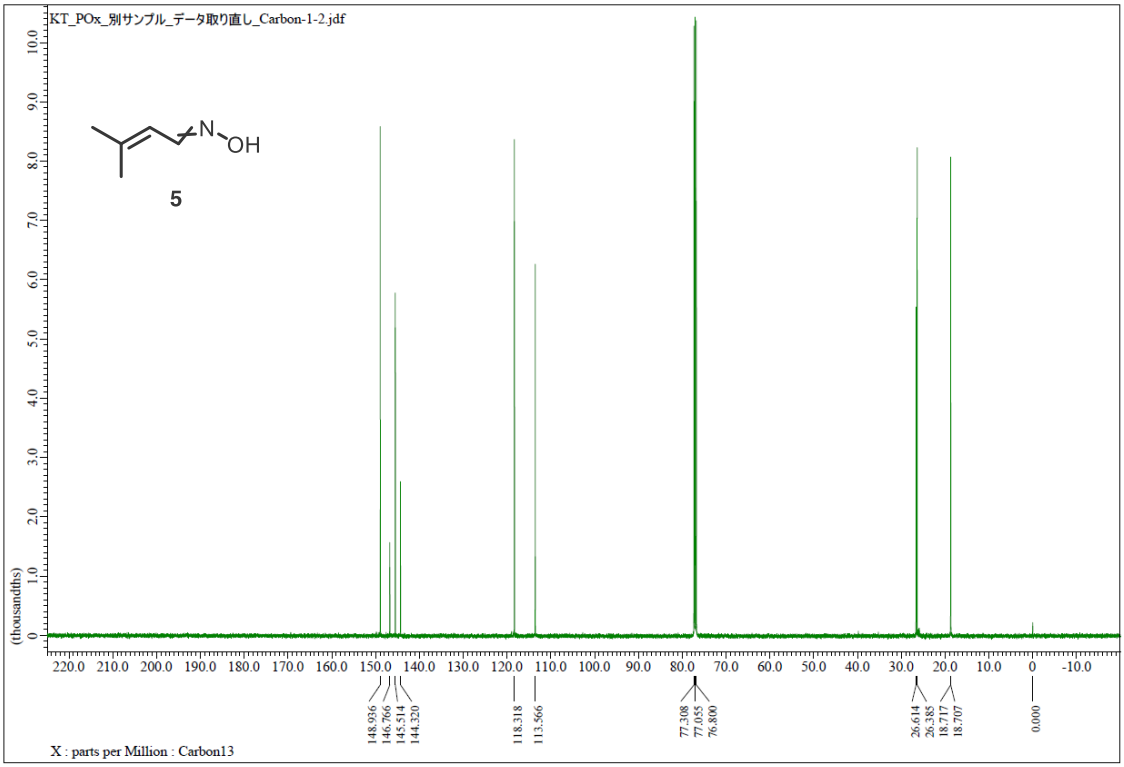
4a : ^{13}C-NMR (125 MHz, $CDCl_3$)



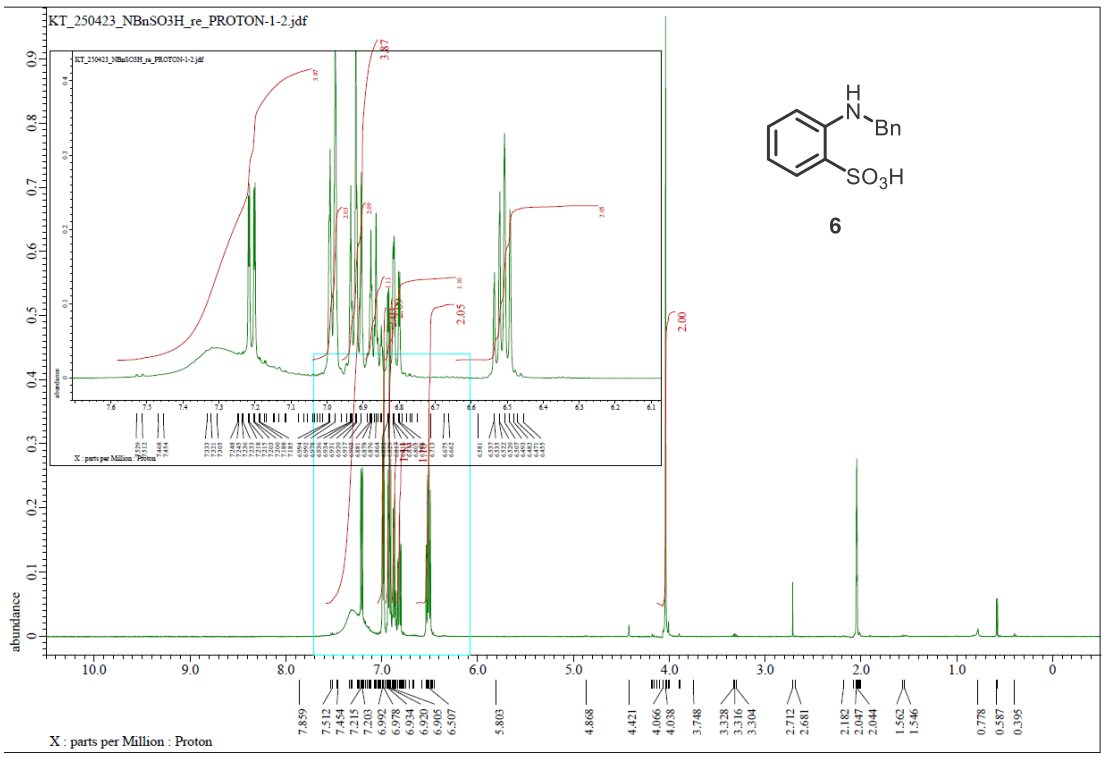
α,β-unsaturated oxime 5: ^{1}H-NMR (400 MHz, $CDCl_3$)



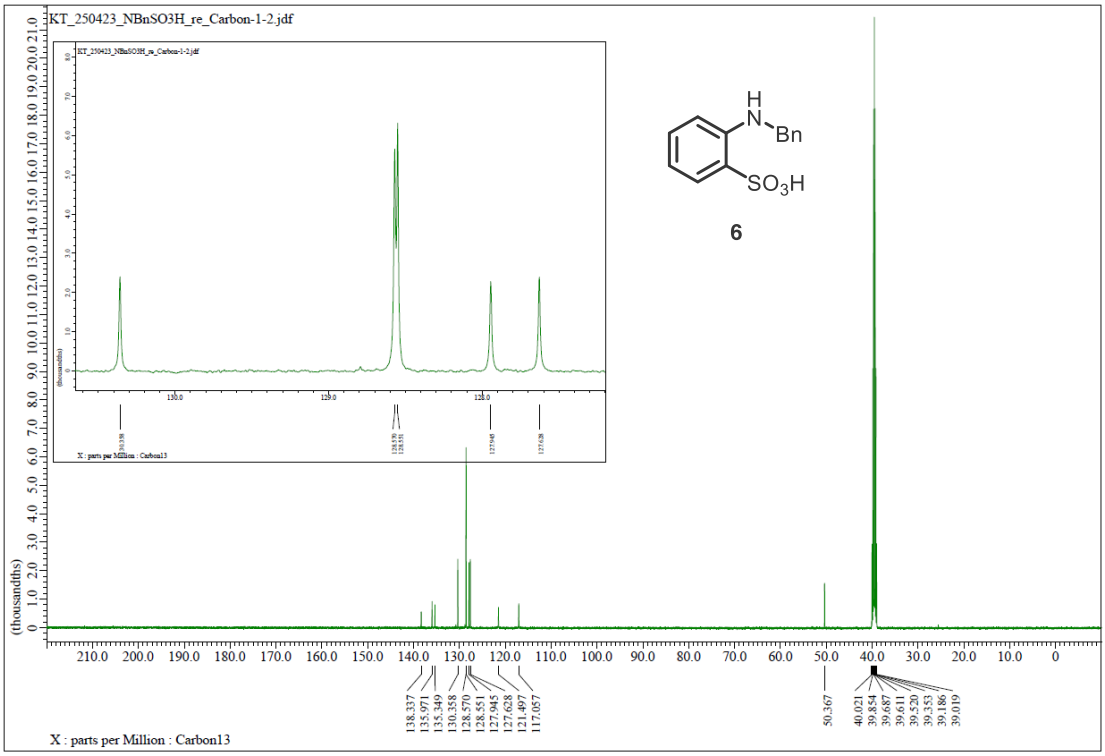
α,β-unsaturated oxime 5: ^{13}C-NMR (125 MHz, $CDCl_3$)



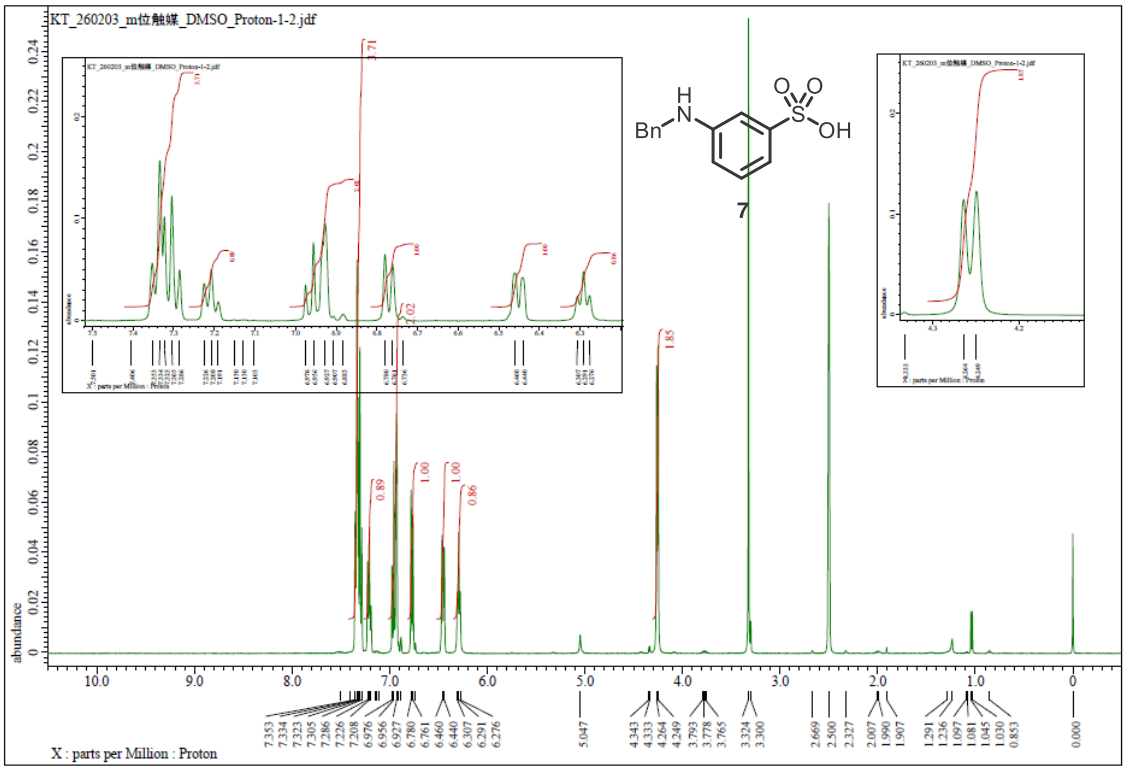
***N*-benzylorthanilic acid 6: ^{1}H-NMR (500 MHz, DMSO-d_6)**



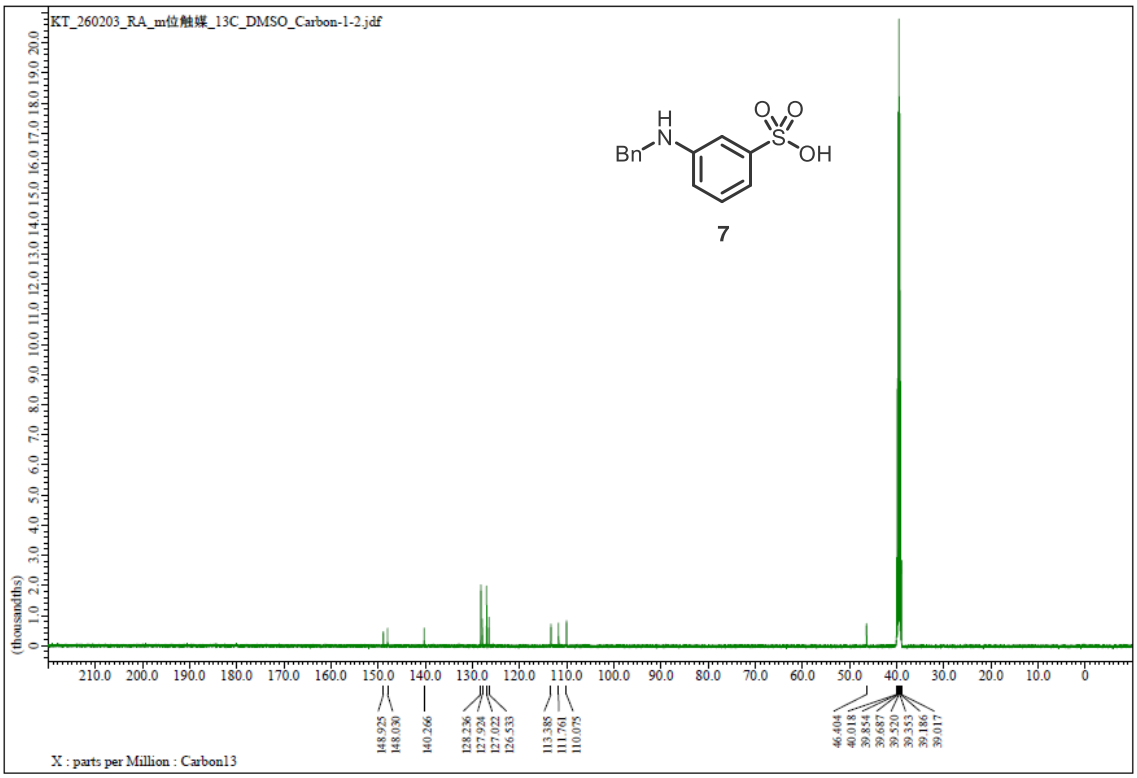
***N*-benzylorthanilic acid 6: ^{13}C-NMR (125 MHz, DMSO-d_6)**



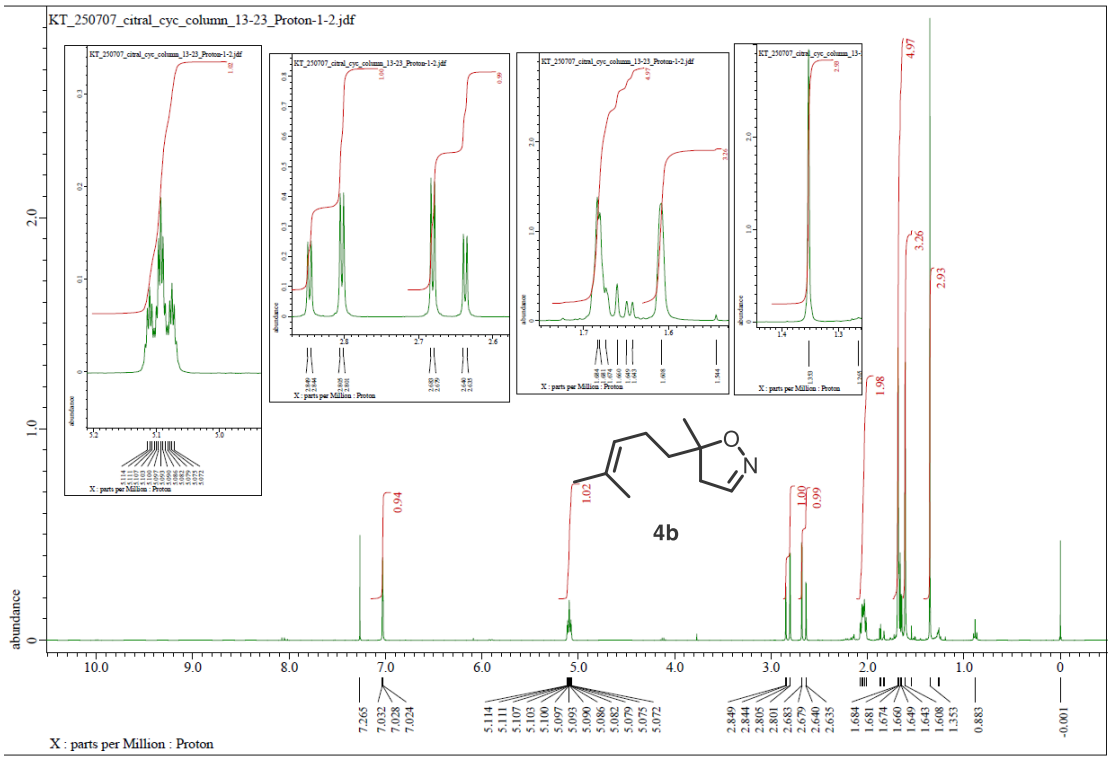
***N*-benzylmetanilic acid 7: ^{1}H-NMR (400 MHz, DMSO-d_6)**



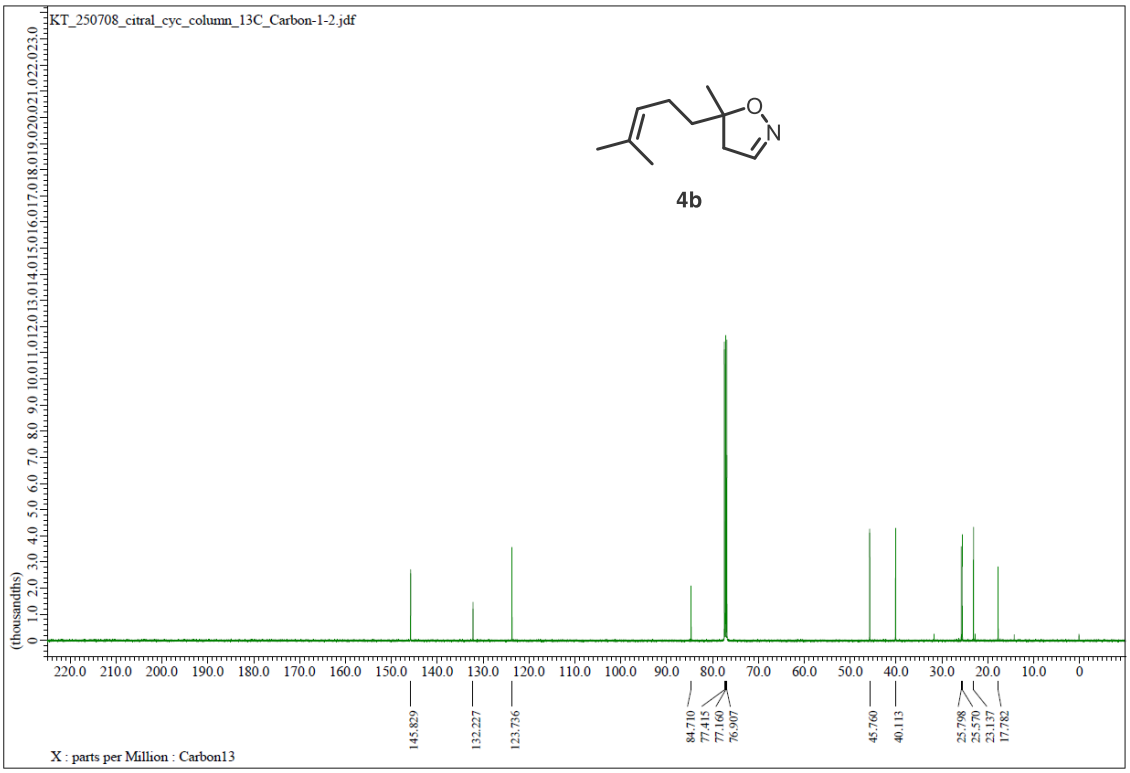
***N*-benzylmetanilic acid 7: ^{13}C-NMR (125 MHz, DMSO-d_6)**



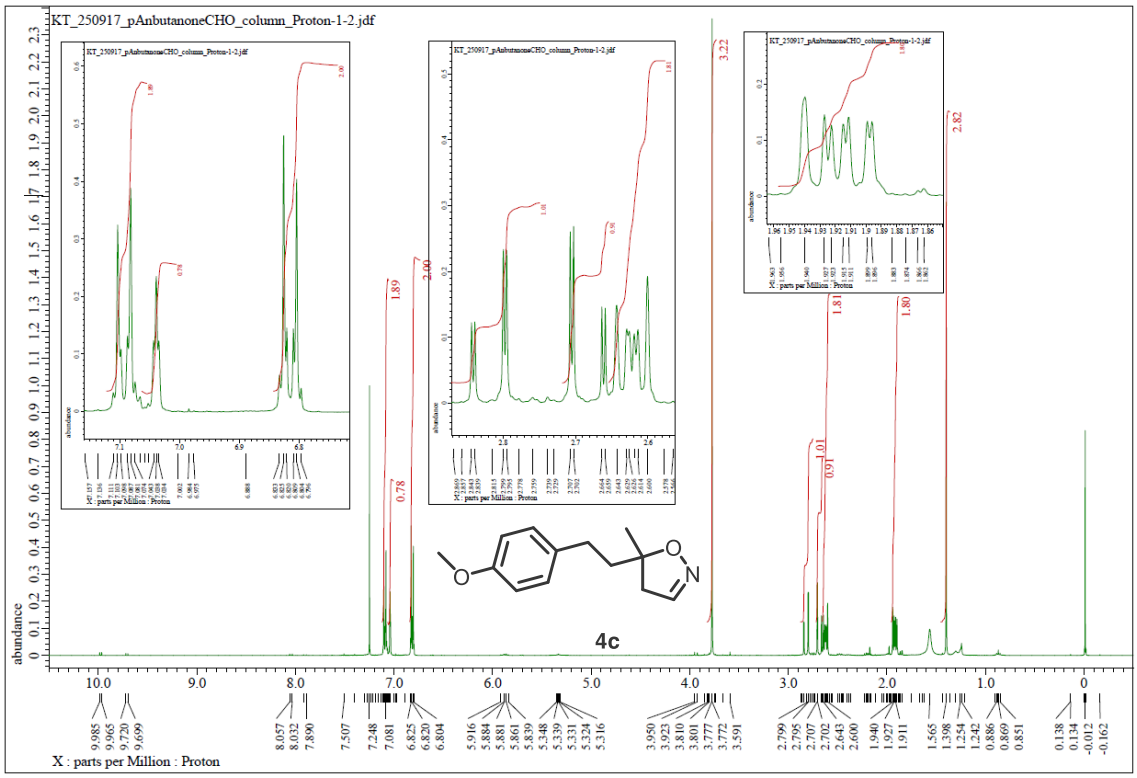
4b : ^{1}H-NMR (400 MHz, $CDCl_3$)



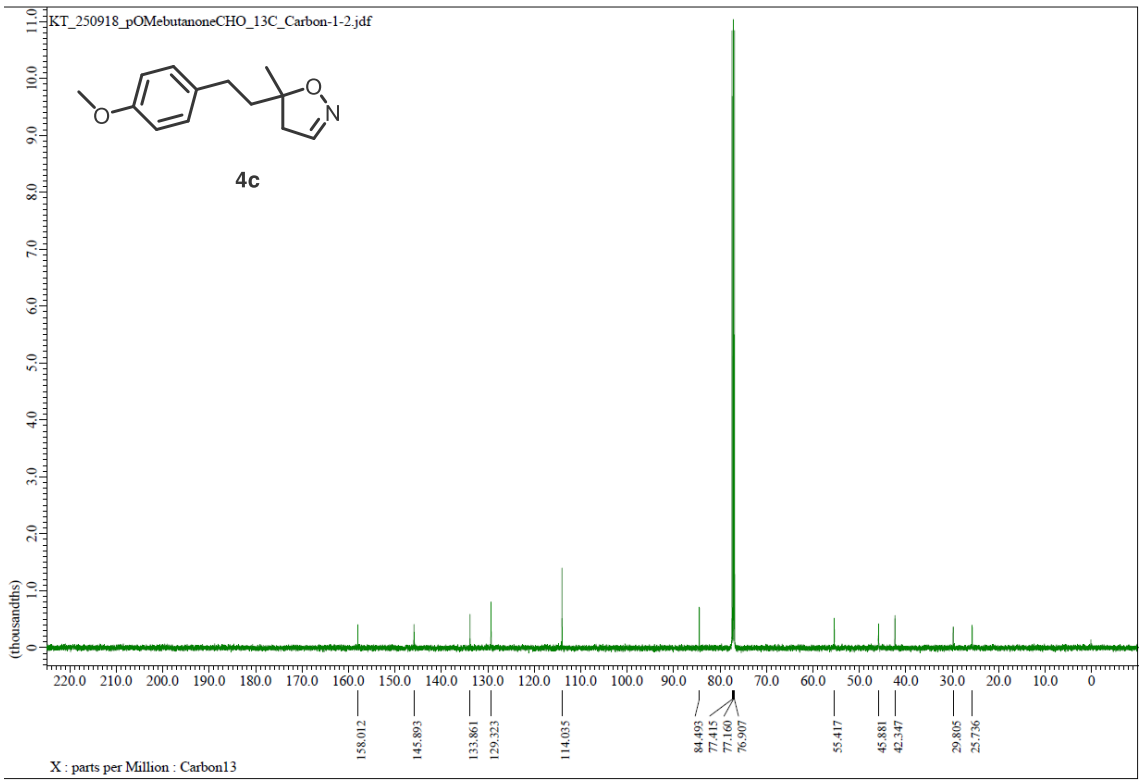
4b : ^{13}C-NMR (125 MHz, $CDCl_3$)



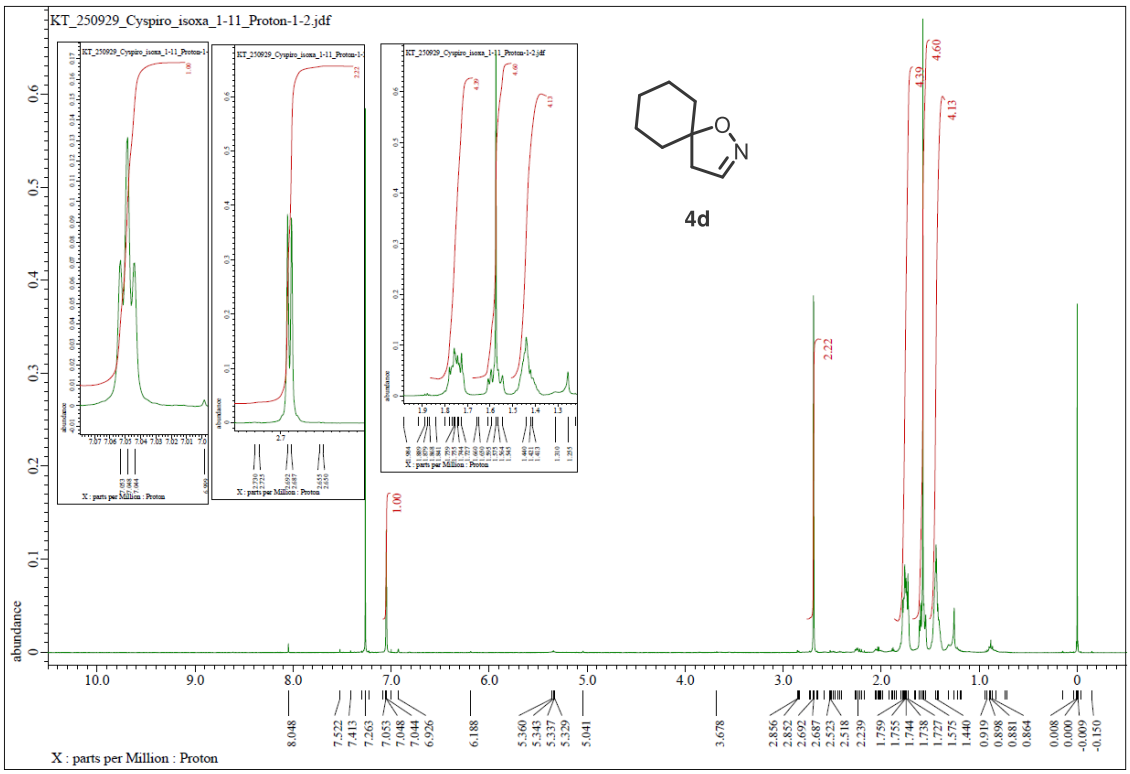
4c : ^{1}H-NMR (400 MHz, $CDCl_3$)



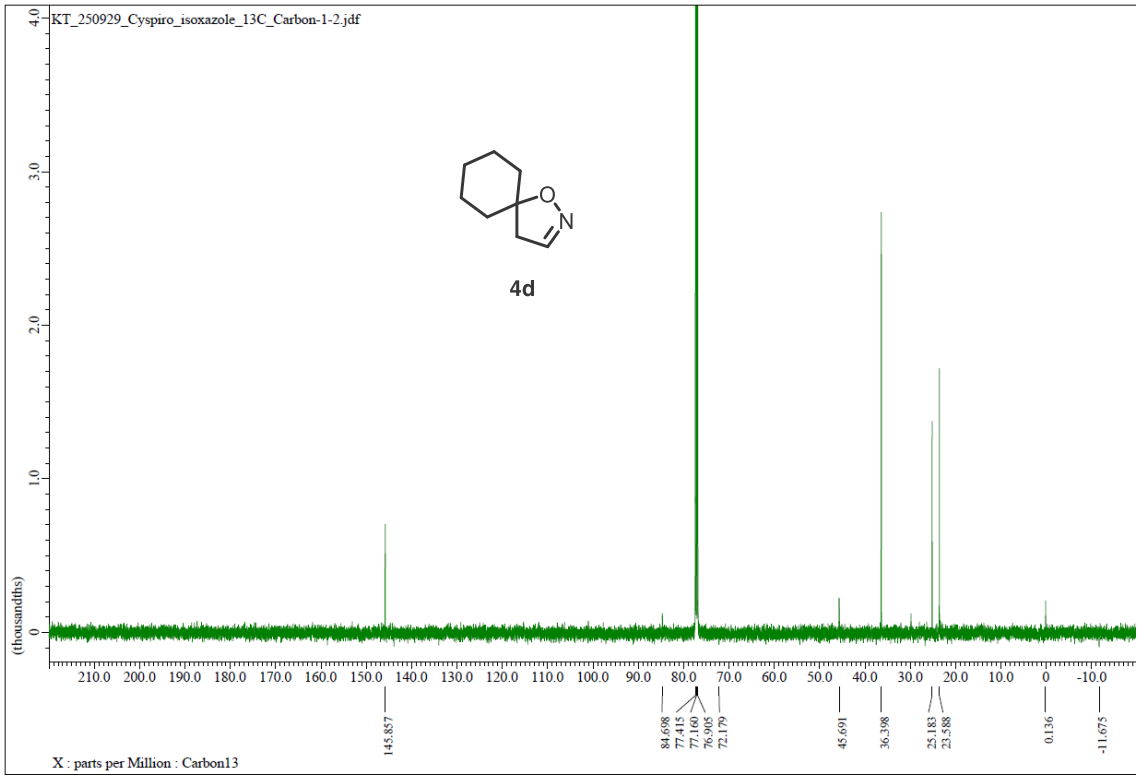
4c : ^{13}C-NMR (125 MHz, $CDCl_3$)



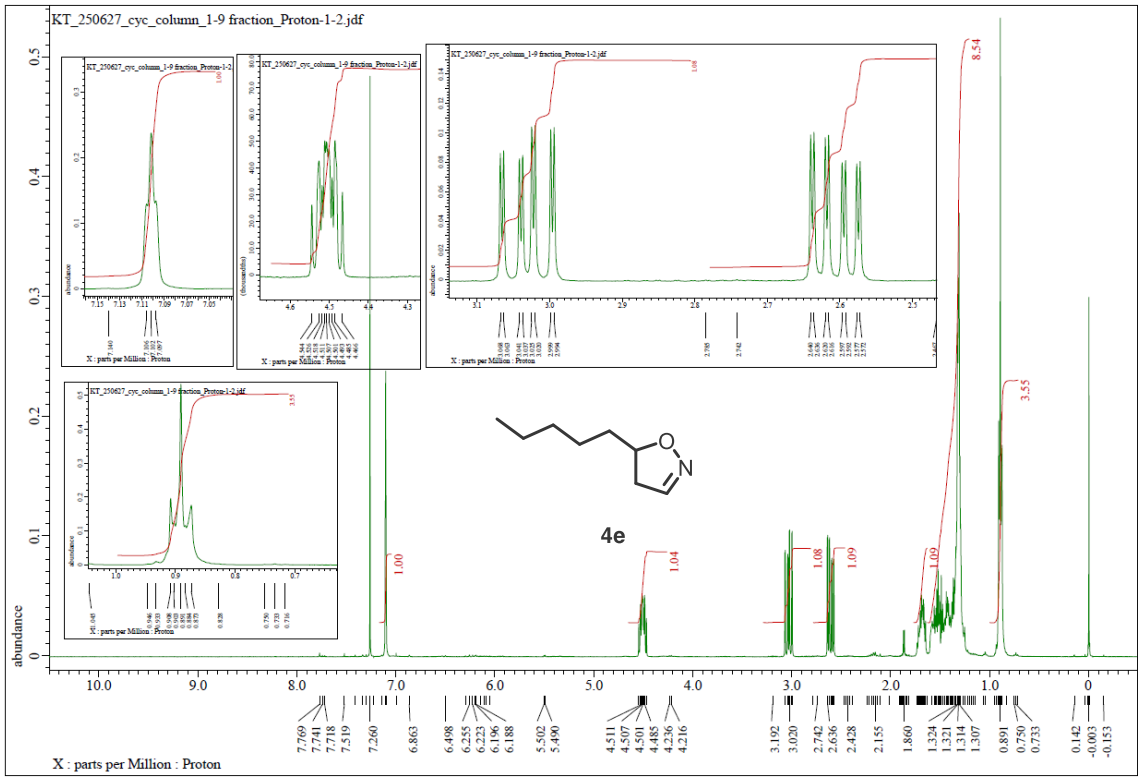
4d : ^{1}H-NMR (400 MHz, $CDCl_3$)



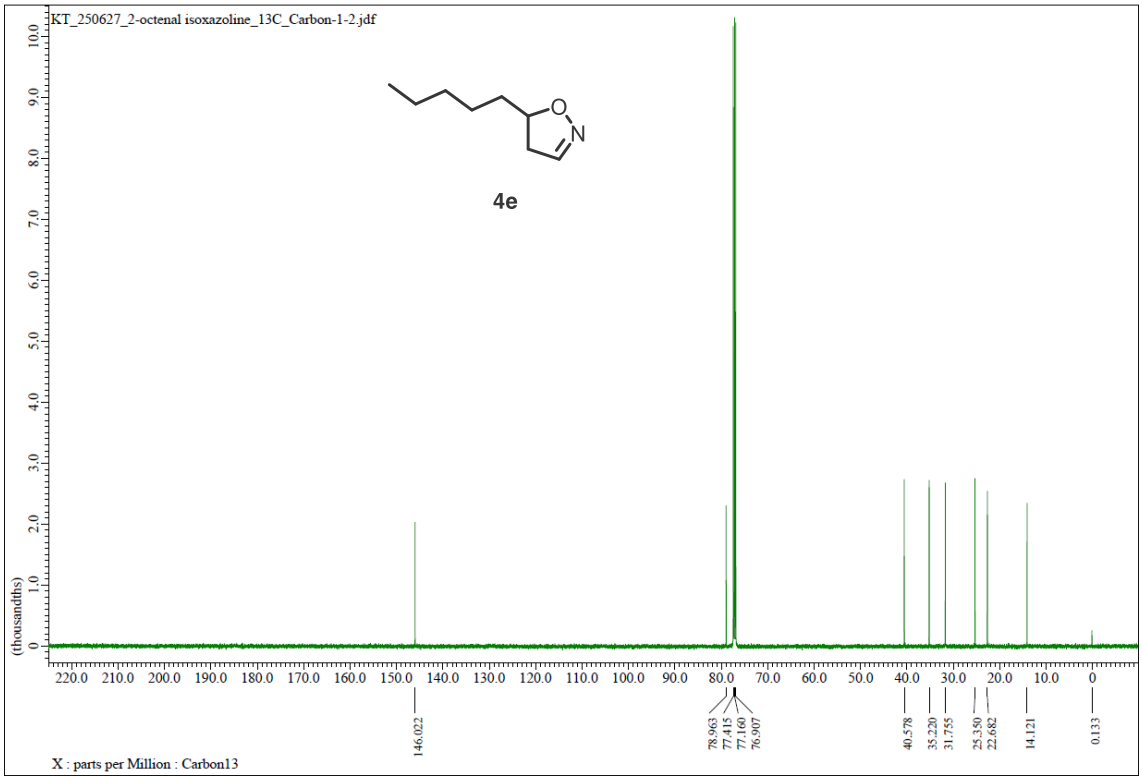
4d : ^{13}C-NMR (125 MHz, $CDCl_3$)



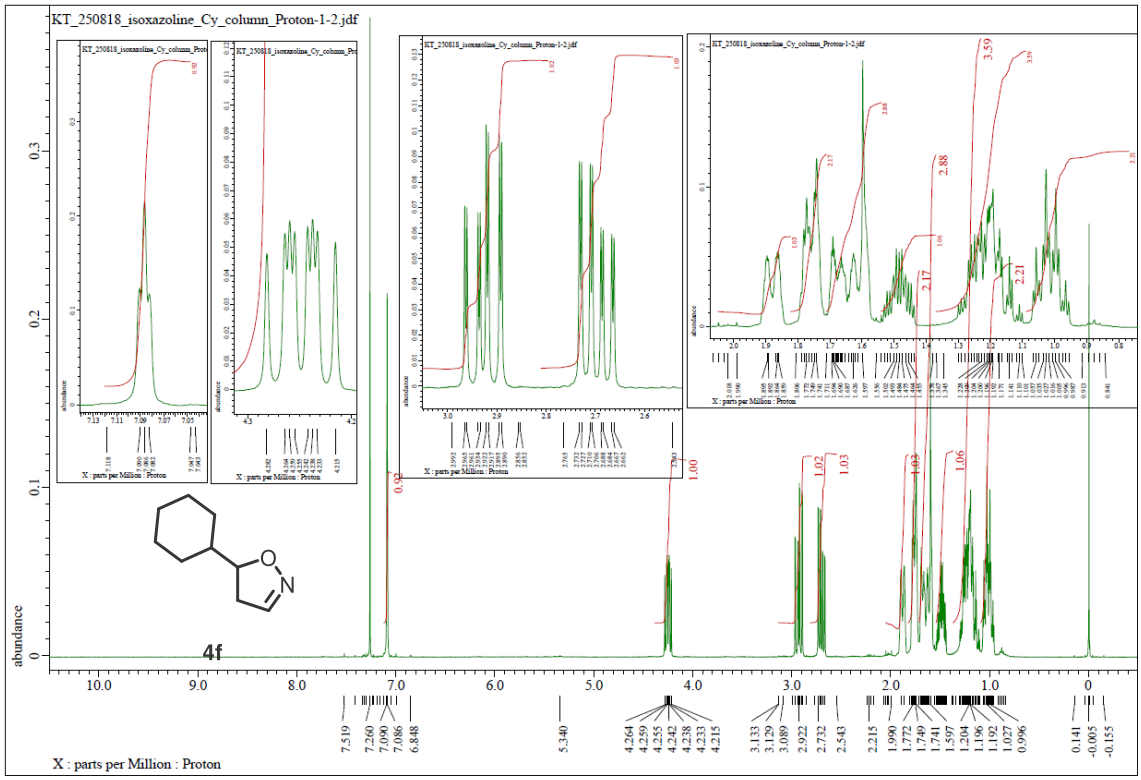
4e : ^{1}H-NMR (400 MHz, $CDCl_3$)



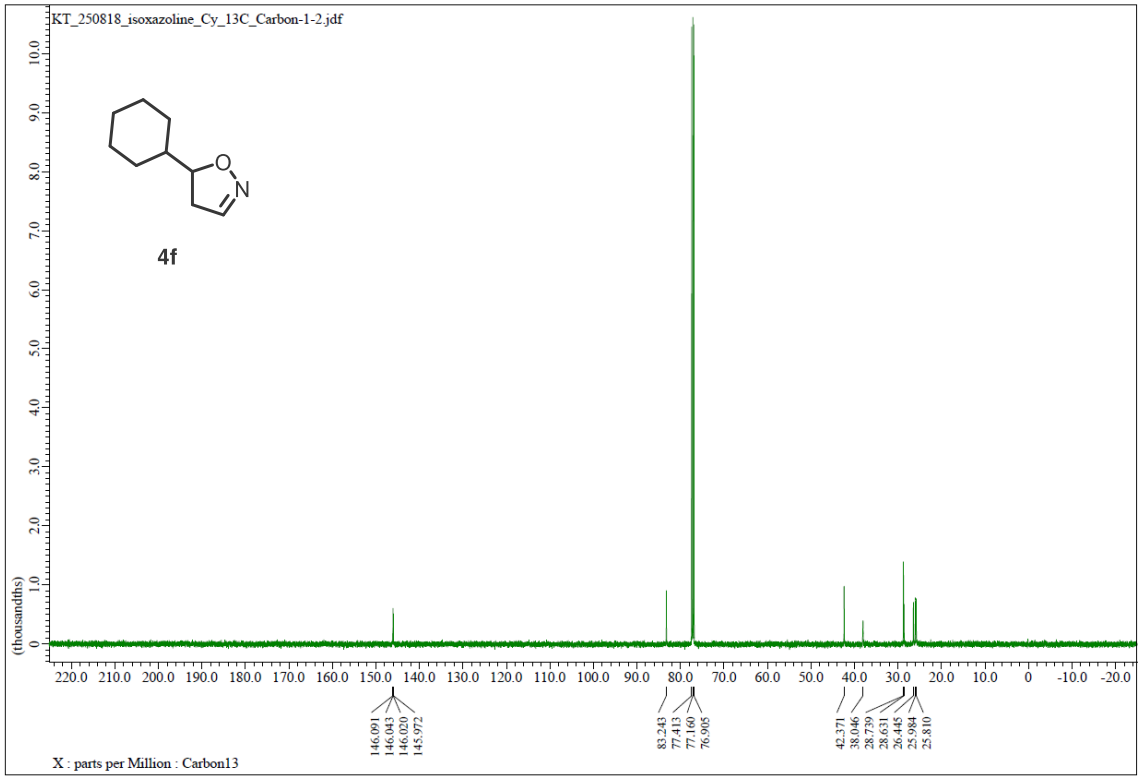
4e : ^{13}C-NMR (125 MHz, $CDCl_3$)



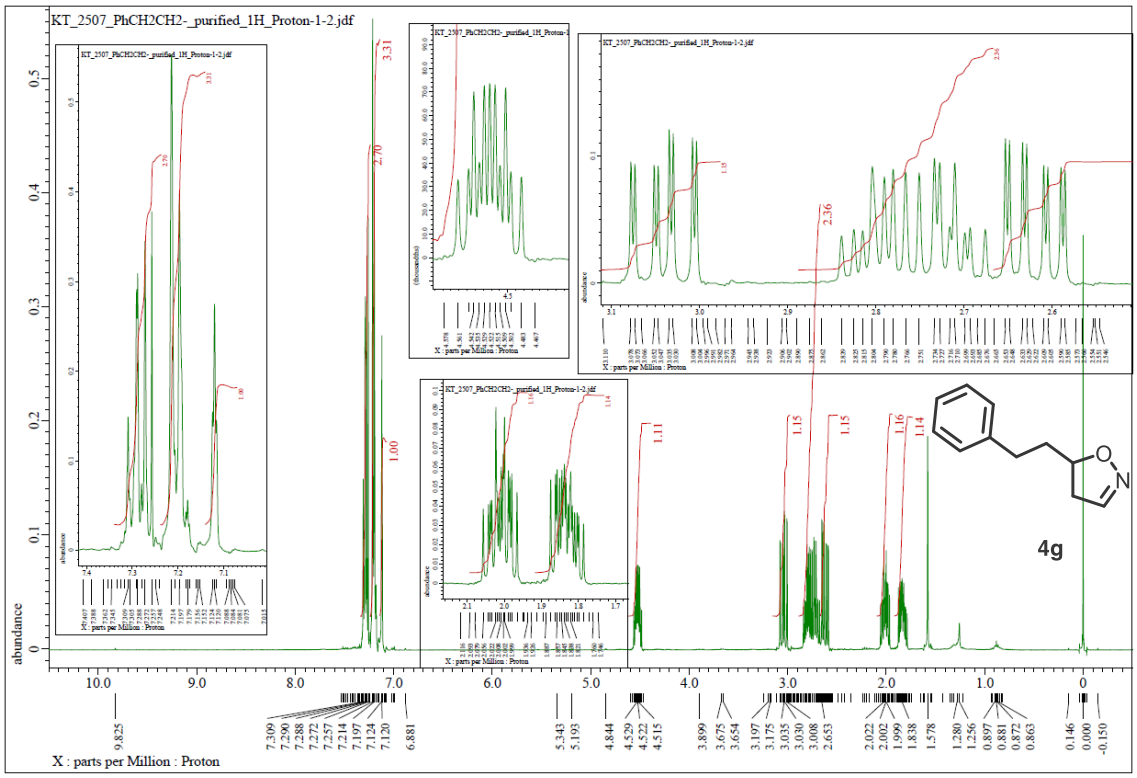
4f : ^{1}H-NMR (400 MHz, $CDCl_3$)



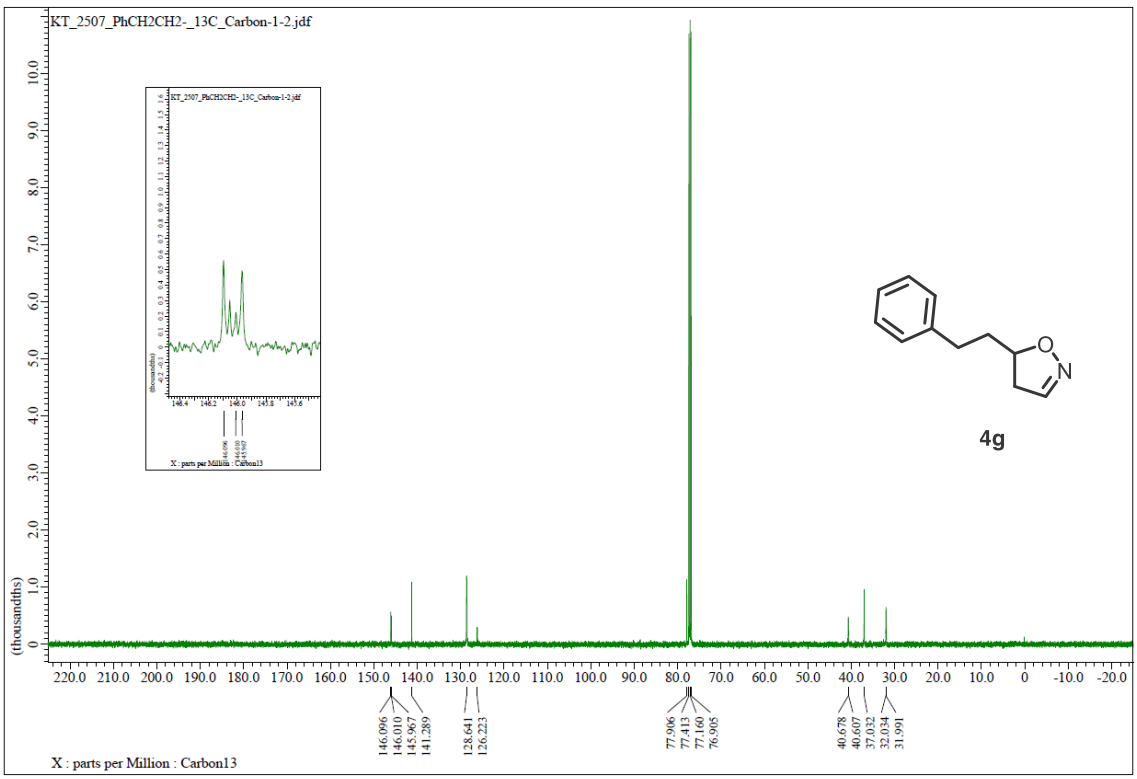
4f : ^{13}C-NMR (125 MHz, $CDCl_3$)



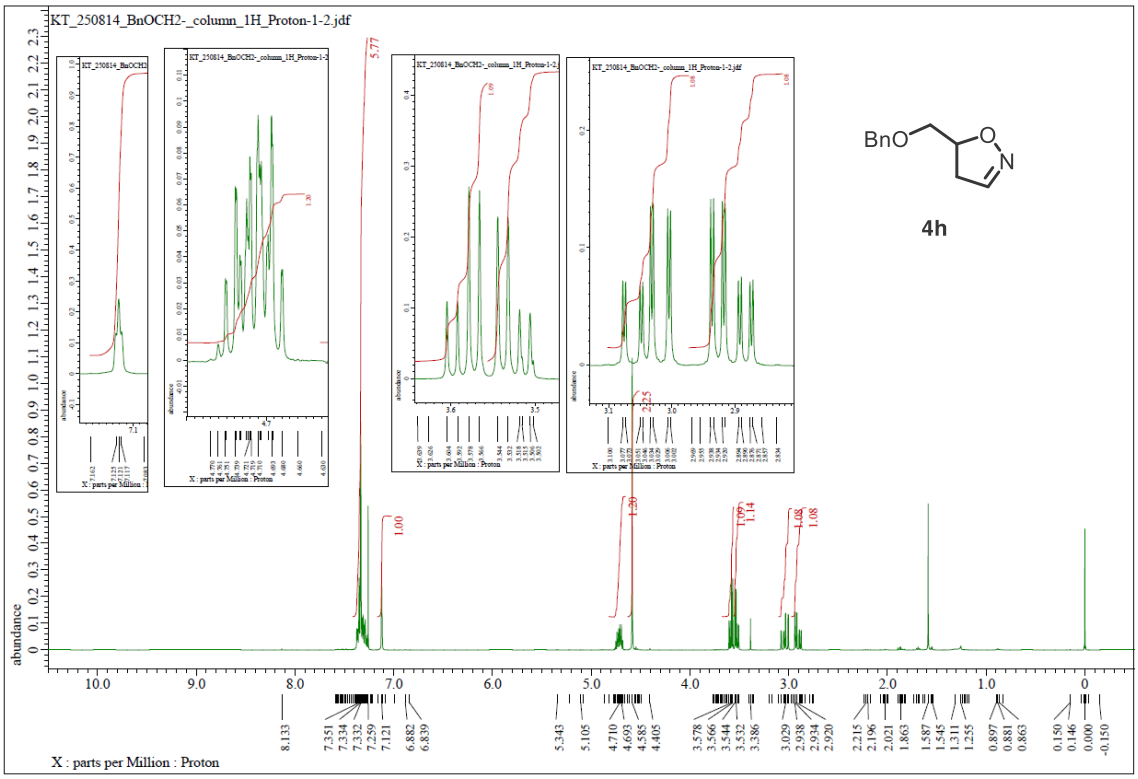
4g : ^{1}H-NMR (400 MHz, $CDCl_3$)



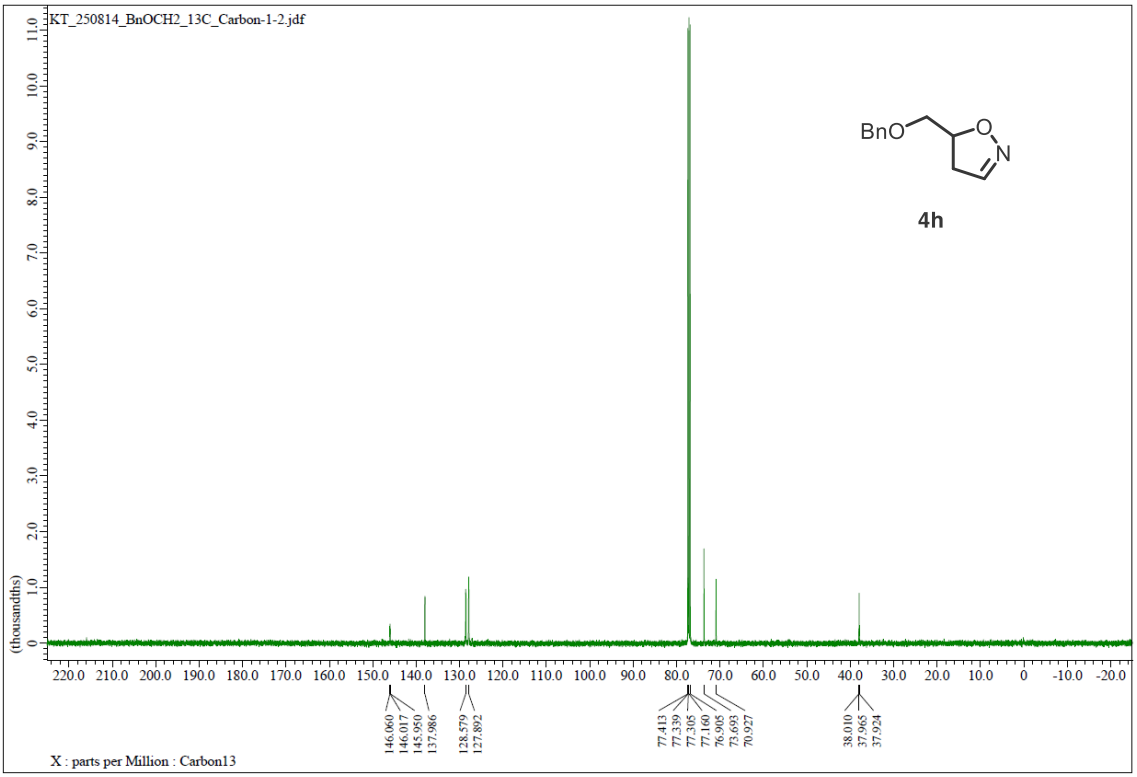
4g : ^{13}C-NMR (125 MHz, $CDCl_3$)



4h : ^{1}H-NMR (400 MHz, $CDCl_3$)



4h : ^{13}C-NMR (125 MHz, $CDCl_3$)



11. DFT calculation

Geometry optimizations and IRC calculations were carried out by using the program packages of Gaussian 16, Revision C.02[9] and Global Reaction Route Mapping (GRRM).[10] The DFT functional and the basis set employed in the present work were B3LYP[11] and the 6-31+G(d, p) bases, respectively.[12] The dispersion force was corrected applying the D3 version of Grimme's procedure.[13] To take butyl acetate (AcO^{n}Bu) solvent effect into account, the SMD method[14] was utilized. The free energy values given in this paper were derived by adjusting the raw harmonic entropy (Sharm, 1 atm and 298.15 K) to the standard state of 1 M and 298.15K.

We examined in detail the **C1** catalyst-promoted oxa-Michael addition of acetoxime **3** to 3-methyl-2-butenal **2a**. NMR experiments (**Scheme 3b**) show that the reaction of **2a** with aniline **6** generates an iminium intermediate, suggesting that iminium formation is an equilibrium process. Accordingly, transition-state searches were performed for two plausible pathways: (a) oxa-Michael addition of **3** to the iminium intermediate formed from **2a** and **C1**, and (b) oxa-Michael addition of **3** to **2a** via acid–base cooperative activation by **C1**. The calculations reveal that the activation free energy for the oxa-Michael addition of **3** to the iminium intermediate is 16.5 kcal mol^{-1} at 25 °C (**Table S-4** and **Figure S-19**), whereas that for the oxa-Michael addition of **3** to **2a** via acid–base cooperative activation is 21.2 kcal mol^{-1} at 25 °C (**Table S-5** and **Figure S-19**). The 4.7 kcal mol^{-1} lower activation free energy for pathway (a) indicates that, under the **C1**-catalyzed conditions, the reaction preferentially proceeds via oxa-Michael addition of **3** to the iminium intermediate. In the oxa-Michael addition pathway, the Gibbs free energy associated with Reaction Coordinate 4 in **Table S-4** is 7.3 kcal mol^{-1} higher than that of the Starting point (Reaction coordinate 0, isolated acetoxime (**3**) + 3-methyl-2-butenal (**2**) + **C1**). This indicates that the oxa-Michael addition proceeds uphill and is in equilibrium with the iminium intermediate. The subsequent hydrolysis of the resulting oxa-Michael adduct that generates the aldehyde and the **C1** catalyst can also be regarded as an equilibrium process. However, because the generated aldehyde can further undergo an intramolecular cyclization to afford an isoxazoline, the equilibrium is expected to shift toward the product side.

Table S-4. The relative energies in kcal mol^{-1} of the stationary points along the reaction coordinate for the oxa-Michael addition process of acetoxime **3** to the iminium intermediate.

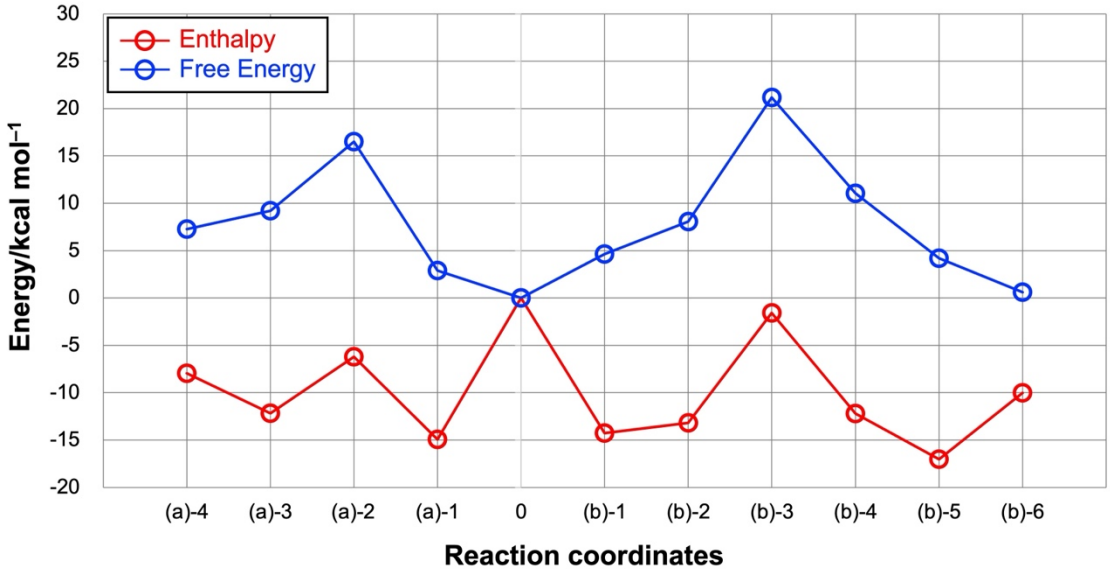
Stationary Point	Reaction Coordinate	*H*	*G* Standard State: T = 298.15 K 1.0 atm	*G* Standard State: T = 298.15 K 1.0 mol L^{-1}
Starting Point	0	0.00000	0.00000	0.00000
Reactant Side	1	-14.92529	6.67082	2.88214
Transition State	2	-6.21915	20.29970	16.51102
Product Side	3	-12.18740	12.98584	9.19716
Enamine Product	4	-7.96561	9.15348	7.25914

0	Starting point (isolated acetoxime (**3**) + 3-methyl-2-butenal (**2**) + **C1**)
1	Reactant side IRC terminal (oxa-Michael addition of **3** to the iminium intermediate)
2	Saddle point (oxa-Michael addition of **3** to the iminium intermediate)
3	Product side IRC terminal (oxa-Michael addition of **3** to the iminium intermediate)
4	Isolated oxa-Michael enamine intermediate and H_2O

Table S-5. The relative energies in kcal mol^{-1} of the stationary points along the reaction coordinate for the oxa-Michael addition process of acetoxime **3** to **2a** via acid–base cooperative activation by **C1**.

Stationary Point	Reaction Coordinate	*H*	*G* Standard State: T = 298.15 K 1.0 atm	*G* Standard State: T = 298.15 K 1.0 mol L^{-1}
Starting Point	0	0.00000	0.00000	0.00000
Reactant Association	1	-14.27710	8.41992	4.63124
Reactant Side	2	-13.18658	11.85344	8.06476
Transition State	3	-1.57938	24.96313	21.17445
Product Side-Enol	4	-12.20318	14.85189	11.06321
Product Side-Keto	5	-17.02684	7.97753	4.18885
Oxa-Michael-Product	6	-10.01505	2.51127	0.61693

0	Starting point (isolated acetoxime (**3**) + 3-methyl-2-butenal (**2**) + **C1**)
1	Association complex of **3**, **2a** and **C1**
2	Reactant side IRC terminal (acid–base cooperative activation by **C1**)
3	Saddle point (acid–base cooperative activation by **C1**)
4	Association complex of the enol form of the product and **C1**
5	Association complex of the keto form of the product and **C1**
6	Isolated oxa-Michael product and **C1**



Standard State: 1.0 M at 298.15 K

0: Starting point (isolated acetoxime (**3**) + 3-methyl-2-butenal (**2a**) + **C1**)

(a)-1: Reactant side IRC terminal (oxa-Michael addition of **3** to the iminium intermediate)

(a)-2: Saddle point (oxa-Michael addition of **3** to the iminium intermediate)

(a)-3: Product side IRC terminal (oxa-Michael addition of **3** to the iminium intermediate)

(a)-4: Isolated oxa-Michael enamine intermediate and H_2O

(b)-1: Association complex of **3**, **2a** and **C1**

(b)-2: Reactant side IRC terminal (acid–base cooperative activation by **C1**)

(b)-3: Saddle point (acid–base cooperative activation by **C1**)

(b)-4: Association complex of the enol form of the product and **C1**

(b)-5: Association complex of the keto form of the product and **C1**

(b)-6: Isolated oxa-Michael product and **C1**

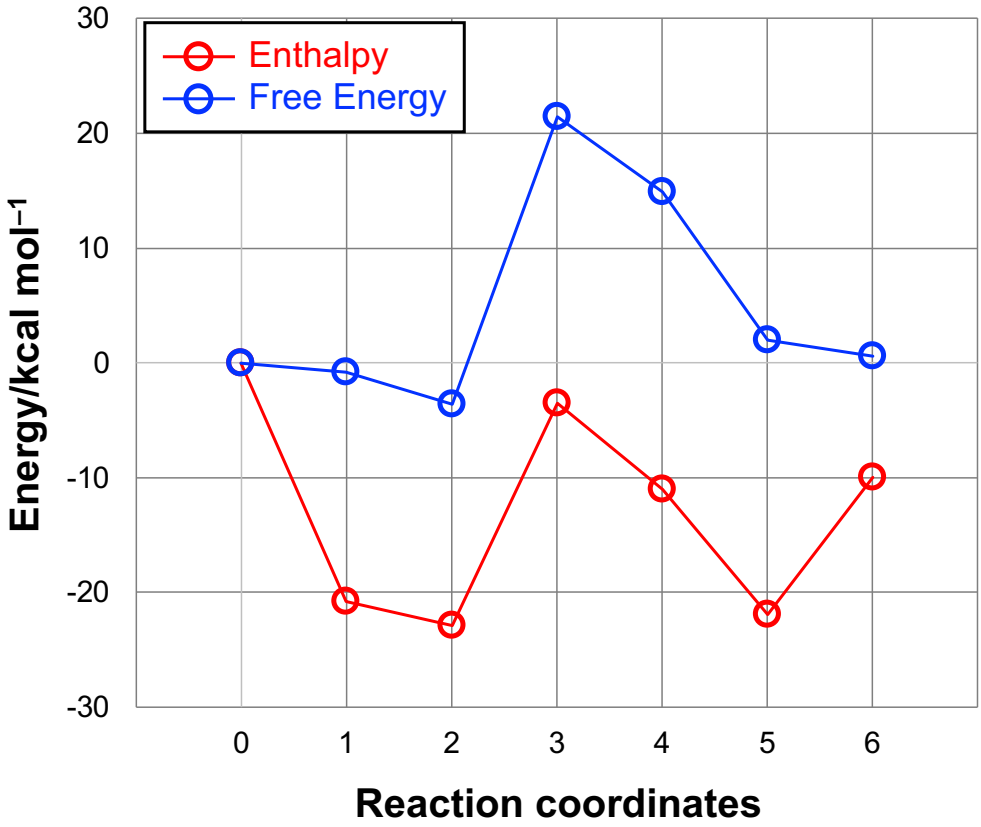
Figure S-19. **C1** catalyst-promoted Oxa-Michael addition process of acetoxime to 3-methyl-2-butenal: (a) oxa-Michael addition of **3** to the iminium cation formed from **2a** and **C1**, and (b) oxa-Michael addition of **3** to **2a** via acid–base cooperative activation by **C1**.

We also examined the **C2** catalyst-promoted Oxa-Michael addition process of acetoxime **3** to 3-methyl-2-butenal **2a** in detail. **Table S-6** and **Figure S-20** given below show the relative energies of the stationary points and the energy diagram of this reaction process.

Table S-6. The relative energies in kcal mol^{-1} of the stationary points along the reaction coordinate for the oxa-Michael addition process of acetoxime **3** to **2a** via acid–base cooperative activation by **C2**.

Stationary Point	Reaction Coordinate	*H*	*G*	*G*
			Standard State: T = 298.15 K 1.0 atm	Standard State: T = 298.15 K 1.0 mol L^{-1}
Starting Point	0	0.00000	0.00000	0.00000
Reactant Association	1	-20.77056	2.98381	-0.80487
Reactant Side	2	-22.90096	0.20331	-3.58537
Transition State	3	-3.53539	25.25977	21.47109
Product Side-Enol	4	-11.01833	18.63514	14.84646
Product Side-Keto	5	-21.95907	5.79944	2.01076
Oxa-Michael-Product	6	-10.01505	2.51127	0.61693

0	Starting point (isolated acetoxime (**3**) + 3-methyl-2-butenal (**2a**) + **C2**)
1	Association complex of **3**, **2a** and **C2**
2	Reactant side IRC terminal (acid–base cooperative activation by **C2**)
3	Saddle point (acid–base cooperative activation by **C2**)
4	Association complex of the enol form of the product and **C2**
5	Association complex of the keto form of the product and **C2**
6	Isolated oxa-Michael product and **C2**



Standard State: 1.0 M at 298.15 K

0: Starting point (isolated acetoxime (**3**) + 3-methyl-2-butenal (**2a**) + **C2**)

1: Association complex of the reactants and **C2**

2: Reactant side IRC terminal via acid–base cooperative activation by **C2**

3: Saddle Point via acid–base cooperative activation by **C2**

4: Association complex of the enol form of the product and **C2**

5: Association complex of the keto form of the product and **C2**

6: Isolated oxa-Michael product and **C2**

Figure S-20. **C2** catalyst-promoted oxa-Michael addition process of acetoxime to 3-methyl-2-butenal.

Cartesian coordinates

C1 Catalyst: SCF E = -950.795533804

C	-0.99727100	0.62569700	0.26814700
C	-0.23870100	-0.52923300	0.04678400
C	-0.90080800	-1.73286200	-0.19987700
C	-2.29689500	-1.77408300	-0.22408800
C	-3.04090700	-0.61260700	0.00184600
C	-2.38844700	0.59687900	0.25220400

H	-0.31456700	-2.63148200	-0.36005700
H	-2.80291300	-2.71557300	-0.41453000
H	-4.12577400	-0.64469500	-0.01019600
H	-2.95335200	1.50678400	0.43688300
N	-0.30623400	1.90168500	0.51582000
H	0.63823400	1.64403800	0.92230100
C	-0.08841700	2.73655200	-0.71589500
H	-1.05641500	2.97396200	-1.15696900
H	0.43639700	3.64539500	-0.41803700
H	0.52137100	2.15431600	-1.40673500
S	1.58495600	-0.46905900	0.01812600
O	2.04999600	-1.83540700	0.33808300
O	1.92356600	0.02748500	-1.34292700
O	1.89777200	0.55218300	1.09432400
H	-0.82062900	2.44426400	1.21601900

3-Methyl-2-butenal (2a): SCF *E* = -270.594138003

C	0.72983800	-0.47557500	0.00000000
C	0.00000000	0.66890400	0.00000000
H	0.51409100	1.62858500	0.00000000
C	-1.45405700	0.75547700	0.00000000
H	-2.02365700	-0.19239700	0.00000000
O	-2.06695300	1.82349100	0.00000000
C	2.23229500	-0.41531900	0.00000000
H	2.63262900	-0.93673800	0.87944200
H	2.63262900	-0.93673800	-0.87944200
H	2.60865100	0.61100700	0.00000000
C	0.16420100	-1.86981100	0.00000000
H	0.53138300	-2.41464900	-0.87912100
H	0.53138300	-2.41464900	0.87912100
H	-0.92514500	-1.91440700	0.00000000

Acetoxime (3): SCF *E* = -248.493493072

C	0.00000000	0.39433800	0.00000000
N	-0.88959100	-0.53143400	0.00000000
O	-0.29532900	-1.82514100	0.00000000

H	-1.06745400	-2.40965600	0.00000000
C	-0.49704800	1.81151700	0.00000000
H	-0.11833800	2.34256700	0.88232400
H	-0.11833800	2.34256700	-0.88232400
H	-1.58927300	1.85272900	0.00000000
C	1.48152400	0.13305400	0.00000000
H	2.04337200	1.06978200	0.00000000
H	1.76647400	-0.45513700	0.87961900
H	1.76647400	-0.45513700	-0.87961900

Reactant side IRC terminal (oxa-Michael addition of 3 to the iminium intermediate): SCF *E* = -1469.910289373

C	-2.91456757	0.58350816	0.23625594
C	-4.08575033	1.07727652	0.81431518
C	-5.15331912	0.21780929	1.08637034
C	-5.05610409	-1.14214419	0.78270623
C	-3.88638587	-1.64501915	0.20799399
C	-2.82220577	-0.78299869	-0.05693739
N	-1.63434358	-1.33589775	-0.67231488
C	-1.68078852	-1.59964812	-2.12318763
C	-0.58469326	-1.60618631	0.06907668
C	0.57996459	-2.26666572	-0.39560080
C	1.68157168	-2.49278340	0.38884366
C	1.87483192	-1.96904372	1.77579184
C	2.82752425	-3.28840425	-0.14835025
O	3.74534001	-0.35369007	-1.09280820
S	-1.53780987	1.71707824	-0.11866814
O	-0.43367464	1.25968287	0.80094626
O	-2.05131173	3.07316489	0.18329442
O	-1.19437826	1.47441431	-1.55452245
O	1.69613560	1.41586511	-0.98046282
H	3.00778847	0.31113902	-1.09383757
H	1.13158413	1.32764297	-0.18174754
H	1.02060683	1.46253966	-1.67667552
H	-4.15080538	2.13609211	1.03899999
H	-6.05996909	0.61358066	1.53381081

H	-5.88343689	-1.81283001	0.99290286
H	-3.79104227	-2.69912026	-0.03505394
H	-1.73818700	-2.67694609	-2.30469299
H	-2.56276127	-1.11052036	-2.53022084
H	-0.79192647	-1.18123539	-2.59654577
H	-0.67252848	-1.30870513	1.10655735
H	0.59245205	-2.63520685	-1.41570186
H	2.67690023	-1.21914657	1.73075879
H	0.99534133	-1.50599460	2.22367802
H	2.23412307	-2.76895889	2.43326654
H	3.74737343	-2.69954570	-0.06556123
H	2.96286083	-4.18847991	0.46681687
H	2.68498152	-3.58592760	-1.18959836
C	4.92710332	0.91886464	0.40050376
N	4.42423619	-0.23977045	0.15389628
C	4.85228315	2.11488195	-0.50850523
H	3.88649858	2.62057086	-0.39523941
H	5.64548841	2.82748654	-0.26696055
H	4.93473032	1.81081711	-1.55609287
C	5.63774991	1.07172253	1.71668964
H	6.68308143	1.35976703	1.54968971
H	5.17292092	1.87456249	2.30270073
H	5.60853855	0.14494543	2.29555622

Saddle point (oxa Michael addition of 3 to the iminium intermediate): SCF *E* = -1469.893868061, Imaginary Frequency = 240.0166i cm^{-1}

C	-2.94070272	0.40806423	0.14699192
C	-4.20237277	0.73988201	0.65319766
C	-5.20462161	-0.22564788	0.75380102
C	-4.95045342	-1.53698450	0.34429531
C	-3.68997658	-1.87709242	-0.14623018
C	-2.67391021	-0.91741065	-0.24095209
N	-1.40868519	-1.33252757	-0.76562471
C	-1.34295030	-1.78186385	-2.15599650
C	-0.30948378	-1.35263999	0.01821408
C	0.91999484	-1.84130740	-0.33959573

C	2.07768236	-1.80038739	0.53470684
C	1.90491393	-1.40149178	1.98431334
C	3.09011882	-2.90058441	0.31399680
O	2.98367561	-0.44128857	-0.15904628
S	-1.71441834	1.74714366	0.01453233
O	-0.75387680	1.51740689	1.16128460
O	-2.48840018	3.00382391	0.13894356
O	-1.02910990	1.56666173	-1.30760587
O	1.53929319	1.56772820	-0.22122379
H	2.32660353	0.40550492	-0.17440729
H	0.87608658	1.59295288	0.51743940
H	0.91784977	1.55404136	-0.98021375
H	-4.39471889	1.76628777	0.94445895
H	-6.18026977	0.04988770	1.14267965
H	-5.72464369	-2.29538444	0.41453247
H	-3.47445800	-2.89565213	-0.45578203
H	-1.11698254	-2.85342316	-2.21568092
H	-2.30041890	-1.58968070	-2.63827999
H	-0.56525244	-1.22209694	-2.68664000
H	-0.47283918	-0.94280758	1.00796005
H	1.07679238	-2.26878070	-1.32422879
H	2.87718027	-1.25676425	2.45737233
H	1.32103742	-0.48674158	2.10655973
H	1.38524724	-2.21324549	2.50480544
H	4.04391837	-2.66721149	0.79357786
H	2.69515850	-3.81870635	0.76395311
H	3.25447547	-3.08169101	-0.75164009
C	4.94117739	0.70174310	-0.10580517
N	4.17545019	-0.06861529	0.58166015
C	4.67963265	1.19765595	-1.49902753
H	4.06725975	2.10644349	-1.45177459
H	5.62075501	1.45258840	-1.99250440
H	4.13689657	0.45962580	-2.09386987
C	6.19282597	1.15761143	0.58777309
H	7.07045452	0.82138663	0.02311978
H	6.22034676	2.25362995	0.60932045

H	6.24924052	0.77548187	1.60951246

Product side IRC terminal (oxa-Michael addition of 3 to the iminium intermediate): SCF *E* = -1469.905080675

C	-2.98038275	0.28928180	0.21115335
C	-4.22816210	0.48658118	0.81264323
C	-5.12322622	-0.57779356	0.91980399
C	-4.77329496	-1.83361338	0.41710668
C	-3.52009988	-2.03059974	-0.16374220
C	-2.59761172	-0.98115096	-0.26449232
N	-1.32723471	-1.22476182	-0.85111003
C	-1.24692263	-1.53984742	-2.27150990
C	-0.19906084	-1.27225241	-0.06350522
C	1.05042989	-1.57139161	-0.48262138
C	2.26846683	-1.58205314	0.40283820
C	1.98814801	-1.39508010	1.89461244
C	3.11032450	-2.83646527	0.14785979
O	3.03245956	-0.40094945	-0.09812883
S	-1.94846871	1.74673554	-0.03169075
O	-0.78533321	1.56153522	1.05244225
O	-2.75286701	2.91459871	0.34248350
O	-1.34449456	1.71430812	-1.37688274
O	1.40061741	1.78232363	-0.23680037
H	1.99042716	0.98919801	-0.18294120
H	0.13822982	1.62670139	0.58547546
H	1.01277036	1.76452753	-1.12681132
H	-4.49901473	1.47273141	1.17169229
H	-6.09139045	-0.42034117	1.38464091
H	-5.46875779	-2.66454518	0.49009327
H	-3.23007111	-3.00861246	-0.53596842
H	-0.87926154	-2.56211235	-2.43262964
H	-2.23557625	-1.44094885	-2.71991781
H	-0.56825077	-0.83930536	-2.77348409
H	-0.39602634	-1.04644265	0.97830721
H	1.24552422	-1.79131558	-1.52831442
H	2.92674815	-1.39546489	2.45250879

H	1.47889857	-0.44723817	2.09209323
H	1.36437384	-2.21324300	2.26697200
H	4.05006532	-2.79862446	0.70584755
H	2.55069806	-3.72263631	0.46404886
H	3.33959044	-2.93373844	-0.91855035
C	5.02311217	0.63481216	0.00348239
N	4.27309337	-0.23534340	0.57807060
C	4.67568590	1.39307570	-1.24890361
H	4.05181669	2.26094087	-1.00180993
H	5.58290030	1.76029094	-1.73600925
H	4.11175778	0.76897746	-1.94714241
C	6.34231072	0.91882887	0.66544475
H	7.16608751	0.68401351	-0.01991832
H	6.41804495	1.98675292	0.90612734
H	6.46208098	0.33778015	1.58324344

Enamine intermediate: SCF *E* = -1393.45425543

C	-2.39853100	0.51623500	-0.17674000
C	-3.51828700	1.15505200	-0.72289500
C	-4.72465400	0.46690100	-0.84621300
C	-4.81543800	-0.85807700	-0.40952400
C	-3.69313600	-1.50069200	0.11090800
C	-2.46271200	-0.83787600	0.22015500
N	-1.34343500	-1.55960900	0.71557900
C	-1.27102000	-1.84039000	2.14649200
C	-0.19749200	-1.60680600	-0.05706600
C	1.05379100	-1.86086300	0.36814200
C	2.26639300	-1.84069200	-0.52222800
C	3.17801400	-3.03731100	-0.23441800
C	1.98922500	-1.72557600	-2.02324000
O	3.13359800	-0.70730200	-0.11212100
S	-0.95094900	1.55238200	0.14680600
O	0.09823000	1.13446000	-0.97791100
O	-0.41236600	1.22044800	1.47442400
O	-1.35346700	2.94109600	-0.11658100
H	1.03121500	0.80515400	-0.60025000

H	-3.44523500	2.19448400	-1.02138900
H	-5.58932000	0.96886000	-1.26895400
H	-5.75407500	-1.39801300	-0.49251300
H	-3.74307700	-2.53999700	0.42179100
H	-0.80270900	-2.81702900	2.30855700
H	-0.68923300	-1.06891200	2.66757300
H	-2.28026200	-1.86095100	2.56049000
H	-0.39393000	-1.41265900	-1.10536900
H	1.26452100	-2.00371200	1.42419400
H	4.11636600	-2.95580600	-0.79310400
H	3.41088500	-3.09712800	0.83347300
H	2.67165900	-3.96070700	-0.53122600
H	2.94011200	-1.68373800	-2.56278500
H	1.42912800	-2.59689900	-2.37568300
H	1.42018400	-0.82690000	-2.27305900
C	3.28017300	1.50690200	0.14584300
N	2.51158000	0.54009900	-0.21696800
C	4.68049900	1.28274000	0.63882900
H	5.28787400	0.80908700	-0.14082900
H	5.14478300	2.22664400	0.93160400
H	4.67705900	0.59855500	1.49444000
C	2.75073700	2.90919800	0.08134000
H	2.71351300	3.33353300	1.09224400
H	3.43811400	3.53157800	-0.50383800
H	1.75725600	2.97093800	-0.36333700

Water: SCF *E* = -76.440776134

O	0.00000000	0.00000000	0.11755800
H	0.00000000	0.76839600	-0.47023300
H	0.00000000	-0.76839600	-0.47023300

Association complex of 3, 2a and C1: SCF *E* = -1469.908484612

C	1.50152029	-0.44471998	-1.22512112
C	2.12676498	0.61328443	-0.49404464
C	3.50323303	0.60368249	-0.21931551
C	4.31320892	-0.43841752	-0.65023780

C	3.72412866	-1.48424294	-1.37588663
C	2.36627533	-1.48936706	-1.65804850
H	3.93167673	1.43116707	0.33637743
H	5.37597230	-0.43377017	-0.43354488
H	4.33504289	-2.31087559	-1.72874651
H	1.94843049	-2.31426575	-2.22181952
N	0.17319586	-0.49938651	-1.50819561
H	-1.89478639	2.04996573	-0.23573308
C	-0.44791847	-1.56234970	-2.27187436
H	-0.37656061	-2.53240439	-1.76257039
H	-1.50132099	-1.31026518	-2.39101871
H	-0.00165060	-1.66036877	-3.26958457
S	1.23970868	1.99434419	0.19887587
O	-0.07440767	2.10807102	-0.47576710
O	0.99353609	1.61327608	1.73684502
O	2.11256384	3.16761187	0.22703748
H	0.18025314	1.01961499	1.88695790
C	0.11103200	-2.36543760	1.51529293
C	-1.16621368	-1.91770104	1.38480713
H	-1.88494943	-2.54285525	0.86026403
C	-1.73743551	-0.70591512	1.93813673
H	-2.83505360	-0.71171508	2.03287405
O	-1.13486938	0.30920498	2.32250051
C	1.19350255	-1.67058507	2.28748696
H	1.82463448	-1.09333701	1.60081272
H	0.80774793	-0.98466954	3.04245846
H	1.84425494	-2.40904772	2.76785753
C	0.51936988	-3.66060851	0.87556182
H	-0.27362083	-4.10000875	0.26534273
H	0.81515259	-4.38500683	1.64584231
H	1.40414243	-3.49565960	0.24787714
C	-4.05244589	0.02971734	-0.76726489
N	-2.85927018	0.47573688	-0.59556939
O	-2.84660514	1.85929533	-0.33370892
H	-0.43473068	0.23627816	-1.17721444
C	-5.28058945	0.89537869	-0.70221036

H	-6.18122247	0.31510745	-0.91644860
H	-5.37538985	1.34810253	0.29186468
H	-5.20621903	1.72226777	-1.41702324
C	-4.20827961	-1.44199155	-1.02391193
H	-4.69579259	-1.61008922	-1.99251656
H	-3.24616621	-1.95776942	-1.01542709
H	-4.85722391	-1.88844003	-0.25937867

Reactant side IRC terminal (acid–base cooperative activation by C1): SCF *E* = -1469.907738113

C	-1.87103541	-1.34977976	0.21173241
C	-2.78582456	-0.32020178	-0.13276450
C	-3.84001475	-0.55249733	-1.02825004
C	-4.02104008	-1.80464887	-1.60319445
C	-3.13730321	-2.83592199	-1.26451623
C	-2.09196686	-2.61544242	-0.37507850
H	-4.52442192	0.25707462	-1.25853575
H	-4.84014278	-1.97505656	-2.29401798
H	-3.26313621	-3.82476907	-1.69634983
H	-1.42026478	-3.43115956	-0.13489512
N	-0.77131251	-1.15988752	1.05612651
H	0.80364933	-1.08426838	-0.02279719
C	-0.33419322	-2.27333456	1.91436751
H	0.17831444	-3.04253238	1.33208429
H	0.38247253	-1.87568181	2.63396954
H	-1.17577472	-2.73097293	2.45043529
S	-2.70368229	1.35355100	0.51418775
O	-1.80159625	1.37430325	1.68827332
O	-2.03630711	2.20466830	-0.65390733
O	-4.06806624	1.86257380	0.66943905
H	-0.99286312	2.11446725	-0.65345784
C	3.40345825	1.80974607	-0.57375830
C	2.54465323	2.08873932	0.44967022
H	2.94186643	2.24124470	1.44948344
C	1.11280900	2.14570218	0.34298017
H	0.55874014	2.30161168	1.28198957
O	0.46277209	2.02953624	-0.71853812

C	2.95292904	1.53512312	-1.97762058
H	3.79952004	1.29571362	-2.62618187
H	2.23726185	0.70544817	-1.98034247
H	2.41770808	2.39706238	-2.39077812
C	4.87705657	1.73275414	-0.32161045
H	5.14068024	1.90334596	0.72485709
H	5.39795773	2.46921275	-0.94840497
H	5.25163989	0.74917673	-0.63207688
C	3.74379338	-1.66207138	0.28711897
N	2.55475378	-1.32470717	0.63497362
O	1.66354530	-1.29230218	-0.45583010
H	-0.83723064	-0.28883951	1.57454712
C	4.14396798	-1.99337945	-1.12558951
H	5.22611406	-2.12291026	-1.20597334
H	3.65618157	-2.92096807	-1.44945598
H	3.82017638	-1.21061264	-1.81718702
C	4.77663923	-1.72861253	1.37612955
H	5.59855504	-1.03260694	1.16684984
H	4.34331057	-1.48262852	2.34916486
H	5.21391837	-2.73411181	1.42443836

Saddle point (acid–base cooperative activation by C1): SCF E = -1469.885274879, Imaginary Frequency = 540.5353i cm^{-1}

C	-0.98738963	-1.22430050	-0.01104552
C	-2.30419742	-0.73318023	-0.06678223
C	-3.21629821	-1.29203783	-0.97244361
C	-2.83708243	-2.33155125	-1.81745657
C	-1.52656330	-2.81885493	-1.76706733
C	-0.61375313	-2.26613774	-0.87287466
H	-4.23007244	-0.90626809	-1.00653991
H	-3.55668803	-2.75491783	-2.51141392
H	-1.21443041	-3.62329197	-2.42647074
H	0.40785814	-2.63296499	-0.83728733
N	0.02142306	-0.70882001	0.88384157
H	1.20748426	-0.40371904	0.23100556
C	0.37163152	-1.65120425	1.98422393

H	0.83898416	-2.54624159	1.56907312
H	1.08440370	-1.15155852	2.64237602
H	-0.52043229	-1.93561308	2.55099712
S	-2.93905221	0.66397514	0.91977560
O	-1.86987638	1.00535543	1.90961443
O	-3.11845571	1.77299152	-0.10114905
O	-4.22249356	0.22206244	1.50379666
H	-1.77424378	2.01231691	-0.85590978
C	2.10369837	1.38278500	-1.25380416
C	1.37818427	2.28313102	-0.39507581
H	1.95199895	2.81254261	0.35857372
C	0.03021319	2.49356433	-0.37101338
H	-0.38928535	3.14895243	0.39327581
O	-0.82887540	1.96554158	-1.22568589
C	1.44759414	0.72236291	-2.43547769
H	2.13352348	0.01534041	-2.90695462
H	0.52026065	0.21671419	-2.16865623
H	1.19141387	1.50188827	-3.16341740
C	3.56812536	1.67623871	-1.41752597
H	4.03200716	1.99571403	-0.48192254
H	3.65013634	2.50524382	-2.13298534
H	4.10816034	0.82119923	-1.82824345
C	4.17144013	-0.68593972	0.89980657
N	3.04569775	-0.06408640	0.95333703
O	2.24826404	-0.25064269	-0.21614990
H	-0.34657993	0.14193899	1.32483136
C	4.67454597	-1.54324007	-0.22538939
H	5.57531041	-1.08802177	-0.65437299
H	4.97267793	-2.52116104	0.17012612
H	3.93113922	-1.67833119	-1.00962665
C	5.06162382	-0.52857600	2.10034197
H	6.02819732	-0.10855692	1.79641974
H	4.60690398	0.12342428	2.84982258
H	5.26296943	-1.50870147	2.54913371

Association complex of the enol form of the product and C1: SCF *E* = -1469.910048788

C	-0.90718102	-1.19081298	0.07764383
C	-2.13975529	-0.68395269	-0.35104181
C	-2.72193483	-1.21361523	-1.50879847
C	-2.08555357	-2.22453903	-2.22566839
C	-0.84993532	-2.71590401	-1.79350021
C	-0.26442174	-2.20095221	-0.63912873
H	-3.67706334	-0.82425584	-1.84567179
H	-2.55049746	-2.62305520	-3.12197304
H	-0.34248144	-3.49591055	-2.35224645
H	0.69516838	-2.57168430	-0.29635381
N	-0.25686831	-0.70215396	1.30063741
H	0.75762782	-0.49068239	1.11005182
C	-0.37063117	-1.64695975	2.45955326
H	0.07270449	-2.60407337	2.18842221
H	0.15783178	-1.20626970	3.30625779
H	-1.42690678	-1.77326367	2.69758423
S	-3.02525916	0.70080668	0.44182261
O	-2.26700542	0.97083315	1.71339198
O	-2.88948993	1.82617538	-0.54354099
O	-4.41628918	0.24784628	0.64401422
H	-1.24210027	2.08798693	-1.02276514
C	2.68804987	1.77693679	-0.31641764
C	1.51770620	2.23799734	0.52381272
H	1.73093395	2.50251199	1.55599948
C	0.23259385	2.36731655	0.15184128
H	-0.50794475	2.70762568	0.87451631
O	-0.25585026	2.08511601	-1.07797039
C	2.72707477	2.40806709	-1.71060776
H	3.60008854	2.04481647	-2.26327565
H	1.82329968	2.16671036	-2.27121614
H	2.80027592	3.49582410	-1.61800774
C	4.00200175	2.03535790	0.42880698
H	4.00696007	1.53191533	1.40095147
H	4.13072991	3.10926691	0.60019512
H	4.85097380	1.67201415	-0.15875733
C	3.16216701	-1.56171682	0.42729830

N	2.49328219	-0.46441898	0.51836581
O	2.61720689	0.33211248	-0.63309872
H	-0.74444386	0.17683414	1.57835056
C	4.01747097	-1.92465865	-0.75230141
H	4.62018965	-2.81046328	-0.53906524
H	3.38588368	-2.13037194	-1.62511253
H	4.66816415	-1.08963312	-1.02689801
C	3.04107635	-2.53423636	1.56374865
H	4.03958511	-2.77838819	1.94522781
H	2.44109203	-2.13073038	2.38177856
H	2.59767738	-3.47626191	1.21604737

Association complex of the keto form of the product and C1: SCF *E* = -1469.91369669

C	2.02031100	1.06941100	0.72496700
C	3.07961700	0.44819100	0.00030700
C	3.80939700	1.14530400	-0.97330600
C	3.51794400	2.47162200	-1.26671500
C	2.48237300	3.10193300	-0.56476600
C	1.75618000	2.42456300	0.40643100
H	4.61290600	0.63498500	-1.49409500
H	4.08804100	3.00387200	-2.02068100
H	2.23889300	4.14006500	-0.77332200
H	0.96496300	2.94534900	0.93153400
N	1.25404500	0.40776800	1.65874300
H	-1.67345900	-0.41134400	1.23198200
C	0.38369600	1.11460700	2.58776300
H	-0.45088800	1.59202800	2.06509500
H	-0.02917900	0.38255600	3.28476300
H	0.91846400	1.88298600	3.16374700
S	3.55429700	-1.26440000	0.21708300
O	2.96847100	-1.77264800	1.47546000
O	2.85844800	-2.02872600	-1.01778500
O	4.99347700	-1.41698100	0.00011400
H	1.85673600	-1.86435100	-1.00253900
C	-2.28201800	-0.03135700	-0.82179400
C	-1.68543000	-0.93973000	0.26961800

H	-2.34021800	-1.80885000	0.43283900
C	-0.31750100	-1.49774600	0.06365100
H	0.09030600	-2.06367400	0.91792500
O	0.33611400	-1.41411100	-0.97637700
C	-1.45484000	1.23954800	-1.01002900
H	-1.93425900	1.89197300	-1.74629700
H	-1.37032500	1.78717500	-0.06700900
H	-0.45142900	0.99335600	-1.36232000
C	-2.49597700	-0.76275800	-2.14843900
H	-3.08112900	-1.67501900	-2.00509400
H	-1.53300200	-1.02881000	-2.59034400
H	-3.03495000	-0.11023100	-2.84298000
C	-5.62465300	-0.10447900	0.26457300
N	-4.47850100	-0.56286300	-0.09148200
O	-3.55332100	0.47821500	-0.32092000
H	1.67078200	-0.44217600	2.01923200
C	-5.93777600	1.36075200	0.40439600
H	-6.98389400	1.51303400	0.68021800
H	-5.29804900	1.81819300	1.16798600
H	-5.73269400	1.88743000	-0.53421600
C	-6.70006600	-1.11307700	0.55178300
H	-7.55925200	-0.94684400	-0.11034200
H	-6.33656700	-2.13471600	0.41397500
H	-7.06240200	-0.99762400	1.58122100

oxa-Michael product: SCF *E* = -519.106206835

C	-2.32181078	-0.31141400	-0.00485150
C	-2.64484563	-0.26277771	1.46394398
H	-3.65465116	-0.63310312	1.65546083
H	-1.92821092	-0.86528539	2.03361873
H	-2.56177485	0.76311576	1.84015925
C	-3.35376102	-0.82929814	-0.96542367
H	-2.98648586	-0.81002957	-1.99476458
H	-3.63071037	-1.85827857	-0.70313159
H	-4.26752632	-0.22518315	-0.90004644
N	-1.20038777	0.06635629	-0.50536594

O	-0.31710716	0.52268742	0.49770100
C	0.94954507	0.96894973	-0.06306023
C	1.75455319	1.37659466	1.17137427
H	2.75572233	1.70383126	0.87425262
H	1.25846903	2.20041880	1.69370707
H	1.85865254	0.54007298	1.87064910
C	0.72868874	2.16050702	-0.99658529
H	1.69020048	2.54539620	-1.35204595
H	0.12667917	1.87374590	-1.86275101
H	0.21017250	2.96241598	-0.46064875
C	1.63785229	-0.19249933	-0.82008900
H	1.00229205	-0.47098103	-1.67159664
H	2.60864509	0.13231547	-1.20560489
C	1.81844523	-1.43419045	0.00812283
H	0.92245080	-1.77496804	0.56391640
O	2.85746481	-2.07135091	0.07569019

C2_catalyst: SCF *E* = -950.786254645

C	-1.92535400	-0.19336500	-0.03636200
C	-0.58575500	-0.63864100	0.03590000
C	0.44075800	0.29679900	0.08516100
C	0.22126100	1.67856100	0.06520100
C	-1.10532000	2.10813200	-0.00397100
C	-2.16417900	1.20055400	-0.05267200
H	-0.36567500	-1.70136000	0.05876100
H	1.04451100	2.38057100	0.12170300
H	-1.32122300	3.17259900	-0.01108900
H	-3.17983600	1.57626200	-0.09936200
N	-2.94509200	-1.11349900	-0.11089300
H	-2.69937400	-2.06653000	0.11904700
C	-4.34481100	-0.75509300	0.04176800
H	-4.67449500	-0.10515300	-0.77692000
H	-4.94069500	-1.66918400	0.00675200
H	-4.54578500	-0.24139500	0.99365900
S	2.12479600	-0.30455600	0.13742900
O	2.99496000	0.73595400	0.69594800

O	2.15157100	-1.67024500	0.65545900
O	2.51556600	-0.47280200	-1.45594900
H	2.78510200	0.39664300	-1.80898000

Association complex of 3, 2a and C2: SCF *E* = -1469.91251398

C	0.96858300	-2.12153100	-0.62118700
C	1.49161700	-0.81623700	-0.64348900
C	2.74194100	-0.57191200	-0.08855300
C	3.51869900	-1.58049600	0.48941700
C	2.99652800	-2.87362700	0.49351700
C	1.73774400	-3.15006800	-0.04963000
H	0.91505600	-0.00868700	-1.08176200
H	4.49122100	-1.35964700	0.91384400
H	3.57616400	-3.68361200	0.92624600
H	1.36185500	-4.16635700	-0.02514100
N	-0.33400000	-2.32544700	-1.10629700
H	-0.57221600	-1.67407400	-1.84844100
C	-0.81141900	-3.68123200	-1.38468400
H	-0.90170200	-4.24662200	-0.45270300
H	-1.80571100	-3.60458300	-1.82885100
H	-0.15020400	-4.22982000	-2.06966100
S	3.32040500	1.12493800	-0.02484200
O	4.78454900	1.14804400	0.00793300
O	2.60758400	1.89536900	-1.05739200
O	2.84231600	1.61641700	1.42665100
H	1.82809800	1.53847400	1.54148100
C	-1.71471000	2.56154100	-0.78425300
C	-0.63100600	2.19327500	-0.04735400
H	0.36435500	2.34444500	-0.45812300
C	-0.68392400	1.61089200	1.27093300
H	-1.66312000	1.40545600	1.72122700
O	0.32725200	1.32584200	1.93833400
C	-1.51825800	3.15192600	-2.15062300
H	-2.03043000	2.53542900	-2.90124400
H	-1.97782000	4.14753700	-2.20236100
H	-0.46311300	3.23604000	-2.42210500

C	-3.14803700	2.44402400	-0.35314000
H	-3.29063900	1.99234600	0.62762700
H	-3.60323700	3.44274000	-0.34684600
H	-3.70143600	1.85060200	-1.08952200
C	-4.30323600	-0.71034200	0.49562000
N	-3.23943900	-1.09686000	-0.11166500
O	-2.16367500	-1.30008000	0.77478800
H	-1.46329800	-1.65269900	0.17296700
C	-4.38388800	-0.50360500	1.98379200
H	-5.36590100	-0.12347000	2.27533800
H	-4.19626800	-1.44623600	2.51103800
H	-3.61275200	0.19798100	2.32027700
C	-5.51558300	-0.44000700	-0.34800600
H	-6.35331900	-1.07053300	-0.02404000
H	-5.83620100	0.60272900	-0.22679400
H	-5.31630400	-0.63063400	-1.40592400

Reactant side IRC terminal (acid–base cooperative activation by C2): SCF *E* = -1469.90809041

C	0.50853942	2.03262761	-0.10618251
C	1.31497508	1.02160668	0.45027387
C	2.61588170	0.85274560	-0.01143153
C	3.16422751	1.64809026	-1.02221310
C	2.35573551	2.64269056	-1.57110728
C	1.04636004	2.84139515	-1.12354561
H	0.92777638	0.38887199	1.24221898
H	4.18377080	1.49921518	-1.35909826
H	2.75069299	3.28204353	-2.35509696
H	0.45040332	3.63028810	-1.56790304
N	-0.81204553	2.17826048	0.34680256
H	-2.12888172	1.10297255	-0.45859631
C	-1.48155660	3.47741826	0.21477076
H	-1.70756240	3.68577466	-0.83465223
H	-2.42726511	3.42662477	0.75733675
H	-0.87635740	4.30125184	0.61718855
S	3.61486493	-0.46325826	0.69370079
O	2.92645765	-0.96740835	1.89393514

O	3.58693580	-1.59508726	-0.44178476
O	5.00843478	-0.02090875	0.79119520
H	2.62291525	-1.94427513	-0.55518244
C	-1.80315809	-2.47100997	-0.72717413
C	-0.95863053	-2.62900366	0.33400864
H	-1.37571882	-2.86050097	1.31084695
C	0.47363851	-2.48841400	0.29706683
H	0.99007108	-2.53796139	1.26908475
O	1.15795244	-2.31636480	-0.73298392
C	-1.34474105	-2.10567129	-2.10908156
H	-2.19426141	-1.87171469	-2.75525339
H	-0.65738912	-1.25482395	-2.08681410
H	-0.78074341	-2.93516817	-2.55279943
C	-3.27649054	-2.66149517	-0.55450154
H	-3.55838445	-2.91508572	0.47026056
H	-3.62341877	-3.45546180	-1.23014125
H	-3.79236528	-1.74524755	-0.85793892
C	-4.83934983	0.44111487	0.67369227
N	-3.58041057	0.69665317	0.65366490
O	-3.02538157	0.73482721	-0.64235916
H	-0.94029602	1.78322080	1.27391072
C	-5.71786512	0.21876195	-0.52655598
H	-6.13270490	-0.79651016	-0.50127023
H	-6.56953294	0.90886313	-0.48902943
H	-5.18317382	0.36266798	-1.46528952
C	-5.48376612	0.35474119	2.03012102
H	-6.29577943	1.08770675	2.11478290
H	-5.93022447	-0.63712320	2.17573503
H	-4.75746610	0.53499048	2.82693110

Saddle point (acid–base cooperative activation by C2): SCF E = -1469.88280474, Imaginary Frequency = 303.8199i cm^{-1}

C	-0.51747700	1.67779200	0.00793200
C	-1.49680400	0.89111100	-0.60729600
C	-2.73777100	0.73257900	0.00354500
C	-3.03662100	1.37035500	1.20922000

C	-2.06042000	2.17088400	1.80506300
C	-0.79945400	2.32112300	1.21933400
H	-1.28859600	0.38831200	-1.54648700
H	-4.01134600	1.24018200	1.66651100
H	-2.27677500	2.67954400	2.74004000
H	-0.05047100	2.93462800	1.70787900
N	0.78746200	1.73535300	-0.58792200
H	1.68976800	0.70165600	-0.03526400
C	1.53211300	3.01023700	-0.47534900
H	1.88512600	3.14777000	0.54885600
H	2.40122900	2.95291900	-1.13349100
H	0.91152800	3.86591200	-0.76173500
S	-3.91255400	-0.45147800	-0.70998000
O	-3.60568700	-0.51024800	-2.16375600
O	-3.55962000	-1.74921500	0.00470300
O	-5.27143200	0.02625400	-0.35548400
H	-2.11086200	-1.91570500	0.55239500
C	1.85370400	-1.53457300	0.84009200
C	0.99069500	-1.99056400	-0.23947400
H	1.48447300	-2.28330600	-1.16061400
C	-0.36203800	-2.13057300	-0.21382000
H	-0.86666100	-2.47534300	-1.11851400
O	-1.13804400	-1.93082500	0.84129100
C	1.24648600	-1.04994900	2.13131000
H	2.01730600	-0.62442700	2.77848200
H	0.45254800	-0.32096400	1.96335900
H	0.79349100	-1.90718000	2.64010700
C	3.14324200	-2.30013500	0.99802800
H	3.61524400	-2.51151700	0.03592000
H	2.88698200	-3.26036600	1.46140500
H	3.84598200	-1.78155500	1.65394400
C	4.53420800	0.18668600	-0.74950000
N	3.28040300	-0.03356900	-0.93826200
O	2.51594900	0.06720900	0.28928500
H	0.71804100	1.47297000	-1.57073700
C	5.21628300	0.51892900	0.54399300

H	5.89325600	-0.30077400	0.81188100
H	5.83805400	1.40988200	0.40249800
H	4.51507100	0.68660100	1.35959300
C	5.39122000	0.08979300	-1.97976500
H	5.89928200	1.04523200	-2.15444400
H	6.16901900	-0.66774800	-1.82675000
H	4.80059700	-0.17314300	-2.86004900

Association complex of the enol form of the product and C2: SCF *E* = -1469.90076473

C	-0.28090805	-1.45700298	-0.17378166
C	-1.37030868	-0.91329823	0.48998711
C	-2.57496556	-0.78180171	-0.20046318
C	-2.69783313	-1.23675833	-1.51246247
C	-1.59429541	-1.81623345	-2.14815350
C	-0.36759889	-1.91321115	-1.48844863
H	-1.28383002	-0.55549411	1.51039310
H	-3.64401765	-1.12508585	-2.03079816
H	-1.68251749	-2.17009750	-3.17046402
H	0.50297976	-2.32239010	-1.99132148
N	1.02139597	-1.46638693	0.51350533
H	1.69454345	-0.86398799	-0.02163141
C	1.61343967	-2.81993690	0.77208923
H	1.77949892	-3.32008293	-0.18097618
H	2.55877826	-2.67889756	1.29651415
H	0.91410521	-3.39173531	1.38210994
S	-3.90518335	0.16486868	0.59481927
O	-3.87610381	-0.23674189	2.02705933
O	-3.46087768	1.59635101	0.38479497
O	-5.14949053	-0.17055966	-0.14131192
H	-1.91626021	1.99103868	-0.14167557
C	2.09921046	1.69563880	-0.59344628
C	1.18239606	1.86375981	0.59390139
H	1.68512735	1.88796867	1.55653664
C	-0.15319311	2.03620439	0.63124600
H	-0.64016037	2.14497098	1.60199283
O	-0.97405870	2.11851074	-0.43400938

C	1.40407950	1.53141660	-1.94240042
H	2.15396273	1.33958152	-2.71639069
H	0.68428586	0.71071532	-1.92586198
H	0.85793578	2.44232790	-2.19343978
C	3.14439168	2.81291640	-0.64759381
H	3.67540683	2.90470029	0.30347350
H	2.64473581	3.76397515	-0.85637084
H	3.87313220	2.61640253	-1.44195849
C	4.56577575	-0.54458985	0.59438387
N	3.63656075	0.33658086	0.70954781
O	2.83309617	0.39218236	-0.46924664
H	0.91968290	-0.97206136	1.40652532
C	4.81136208	-1.36616203	-0.64162068
H	5.74677311	-1.92337237	-0.55670199
H	3.99750122	-2.08275056	-0.80219378
H	4.84603441	-0.72304222	-1.52618043
C	5.45310928	-0.74442256	1.78883861
H	5.40927737	-1.78930433	2.12091442
H	6.49544041	-0.53989339	1.51561859
H	5.16427049	-0.09205502	2.61646384

Association complex of the keto form of the product and C2: SCF *E* = -1469.91323988

C	-0.78690100	2.06747400	-0.06202400
C	-1.50549400	0.95736700	-0.56635500
C	-2.79446100	0.71137500	-0.10664300
C	-3.43300800	1.52011000	0.83894200
C	-2.71963600	2.61679400	1.32644300
C	-1.42124600	2.89332000	0.89488800
H	-1.05259900	0.30192800	-1.30273700
H	-4.44061000	1.30349600	1.17378100
H	-3.18341100	3.27282600	2.05754400
H	-0.90063000	3.75387000	1.29914000
N	0.50355100	2.28599400	-0.47109700
H	1.61974600	-0.78910200	2.16367400
C	1.29340200	3.43191900	-0.06543200
H	1.45649400	3.43795300	1.01977800

H	2.26733100	3.36890500	-0.55189700
H	0.82150900	4.38320600	-0.34919200
S	-3.63846900	-0.76395400	-0.68536200
O	-2.91190500	-1.29720400	-1.84498300
O	-3.47299000	-1.78264600	0.56235300
O	-5.07734000	-0.50790200	-0.77609000
H	-2.49984400	-1.99641500	0.70691500
C	1.99817300	-1.75847500	0.24821800
C	1.16720100	-0.83883800	1.16143000
H	1.20272700	0.19494300	0.78673900
C	-0.27671900	-1.15454500	1.36334900
H	-0.82524900	-0.43904700	2.00207000
O	-0.87166200	-2.11881000	0.88490800
C	2.15845700	-3.15462500	0.84797100
H	2.81204900	-3.76217900	0.21449500
H	2.59993700	-3.09688300	1.84839200
H	1.18573900	-3.64656700	0.91993600
C	1.44921600	-1.82477900	-1.17939900
H	1.31559500	-0.82566400	-1.60092900
H	0.48730700	-2.34157400	-1.19003800
H	2.15123200	-2.37367300	-1.81512100
C	4.66143200	0.44919900	-0.39158900
N	3.45418200	0.00906000	-0.39606700
O	3.36297000	-1.24498500	0.24481800
H	0.85413900	1.72605800	-1.23469100
C	5.82011800	-0.28114900	0.23136500
H	6.73846000	0.30594900	0.15687600
H	5.61605200	-0.49943100	1.28536100
H	5.97326200	-1.24639700	-0.26538800
C	4.90865900	1.76855700	-1.06563000
H	5.28870400	2.50134500	-0.34238700
H	5.67714700	1.65548800	-1.84057100
H	3.99853100	2.15898300	-1.52705500

Acetone: SCF *E* = -193.187831082

C	0.00000000	0.00000000	0.18136800

O	0.00000000	0.00000000	1.40587600
C	0.00000000	1.28629900	-0.61413300
H	0.00000000	2.15153600	0.05187800
H	0.88050400	1.32117400	-1.26734300
H	-0.88050400	1.32117400	-1.26734300
C	0.00000000	-1.28629900	-0.61413300
H	-0.88050400	-1.32117400	-1.26734300
H	0.88050400	-1.32117400	-1.26734300
H	0.00000000	-2.15153600	0.05187800

Isoxazoline: SCF *E* = -325.917641381

C	1.73858600	0.15823300	-0.44127900
C	0.44035600	0.48554100	-1.11672900
C	-0.57459000	0.01697100	-0.04965100
H	0.37485300	1.56110900	-1.32545100
H	0.32409400	-0.04303500	-2.06873000
O	0.27485800	-0.23776200	1.14217300
N	1.62838400	-0.22071300	0.77603100
C	-1.58990000	1.08070200	0.34588200
H	-2.24442800	1.30876700	-0.50266100
H	-2.21226800	0.73099200	1.17590900
H	-1.08321100	2.00083600	0.65306200
C	-1.23091000	-1.31163600	-0.41894200
H	-1.83880500	-1.68193000	0.41252100
H	-1.87718300	-1.18468700	-1.29486400
H	-0.46960600	-2.06261900	-0.65488600
H	2.72775600	0.23877700	-0.88018900

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