Electronic Supporting Information (ESI)

Na^+/K^+ switch of enantioselectivity in G-quadruplex DNA-based catalysis

Changhao Wang,[a] Guoqing Jia,[a] Yinghao Li,[a] Sufang Zhang[b] and Can Li[*ab]

[a] *State Key Laboratory of Catalysis, Dalian Institute of Chemical Physics, Chinese Academy of Sciences, Dalian 116023, China*

[b] *Dalian National Laboratory for Clean Energy, Dalian 116023, China.*

[*] *E-mail: canli@dicp.ac.cn; Fax: +86 411-83694447; Tel: +86 411-84379070*

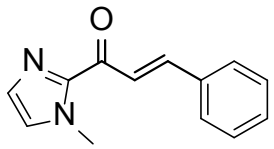
Table of Contents

General

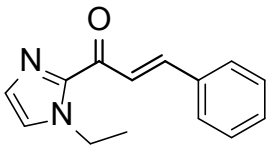
UV-Vis experiments were carried out on a Shimadzu 2450 spectrophotometer (Shimadzu, Japan) equipped with a Peltier temperature control accessory. All UV-Vis spectra were measured using a sealed quartz cell with a path length of 1.0 cm and UV-melting experiments were measured at 295 nm. The samples were first held at 15 ^{o}C for 5 min and then heated to 90 ^{o}C with the temperature gradient of 0.5 ^{o}C/min. The T_m values of the samples were calculated by analyzing their melting profiles according to the methods described previously.[1] Circular dichroism (CD) spectra were recorded on a dual beam DSM 1000 CD spectrophotometer (Olis, Bogart, GA) with a 10 mm quartz cell. Each measurement was recorded from 220 to 320 nm at 4 ^{o}C. The average scan for each sample was subtracted by a background CD spectrum of corresponding buffer solution. Nuclear magnetic resonance (NMR) spectra were recorded on a Bruker DRX 400 MHz type (^{1}H, 400 MHz; ^{13}C, 100 MHz) with an internal reference tetramethylsilane. Data for ^{1}H NMR spectra were recorded as follows: chemical shift (δ, ppm), multiplicity (s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet), integration, coupling constant (Hz). High-performance liquid chromatography (HPLC) analysis was performed on an Agilent 1100 Series instrument with the eluents of hexane and isopropanol (*i*-PrOH), using a chiral-phase Daicel Chiralcel OD column (250 × 4.6 mm), Daicel Chiralpak AD Column (250 × 4.6 mm) or ADH Column (250 × 4.6 mm).

Materials

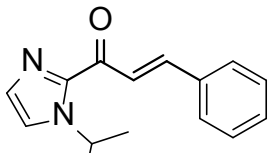
DNA oligodeoxynucleotide 5'-$G_3(TTAG_3)_3$-3' (**ODN**), d(TG_4T), d($T_2AG_3)_4$ and 3-(N-morpholino)propanesulfonic acid (MOPS) were purchased from Sangon (Shanghai, China), and the strand concentrations were determined by measuring the absorbance at 260 nm using the extinction coefficient values published in the literature.[2] $Cu(NO_3)_2 \cdot 3H_2O$ (>99%), LiCl (>99%), NaCl (>99%), KCl (>99%) and RbCl (>99%) were purchased from the Shanghai Chemical Reagent Company of the Chinese Medicine Group. CsCl (>99%) and cyclopetadiene dimer was purchased from Alfa Aesar (Tianjin, China). Water used was distilled and deionized using a Milli-Q A10 water purification system. All experiments were carried out in 20 mM MOPS buffer (pH 6.5) unless otherwise stated. Other reagents and solvents were obtained from commercial sources and used without further purification. 2-acylimidazoles (**1a-e**) were prepared according to the literature.[3]



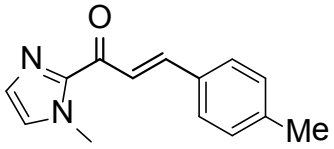
1a



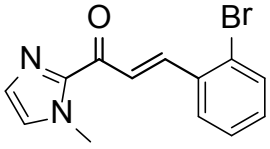
1b



1c



1d



1e

General procedure

An aqueous solution of **ODN** (5'-$G_3(TTAG_3)_3$-3', final conc. 50 μM) was added to a 3-(N-morpholino)propanesulfonic acid (MOPS) buffer (1 mL, 20 mM, pH 6.5) in the presence of NaCl (100 mM) or KCl (25 mM). After stirred for a half hour at 4 °C, a solution of $Cu(NO_3)_2$ (final conc. 150 μM) was added. Then, 2-acylimidazole (**1**) in CH_3CN (10 μL of a 0.1 M solution) was added. The reaction was initiated by the addition of freshly distilled cyclopentadiene (**2**, 10 μL) and the mixture was stirred for 3 days at 4 °C. The reaction mixture was extracted with ethyl acetate (3 × 5 mL), dried by anhydrous Na_2SO_4. After a short flash chromatography, the solvent was removed under reduced pressure. The residue was directly analyzed by chiral-phase high-performance liquid chromatography (HPLC) to determine the conversion, diastereoselectivity (*endo*:*exo*) and enantiomeric excess (ee).

HPLC conditions:

Product **3a:**[4] Daicel chiralcel-OD, hexane/*i*-PrOH 99:1, 1.0 mL/min, 254 nm.

Retention times: 13.7, 17.4 (*exo* isomer); 16.0 (-), 22.8 (+) mins (*endo* isomer).

Product **3b:** Daicel chiralpak-AD, hexane/*i*-PrOH 85:15, 1.0 mL/min, 254 nm.

Retention times: 9.9, 12.2 (*exo* isomer); 6.3, 11.5 mins (*endo* isomer).

Product **3c:** Daicel chiralpak-AD, hexane/*i*-PrOH 90:10, 1.0 mL/min, 254 nm.

Retention times: 9.4, 14.6 (*exo* isomer); 5.8, 16.1 mins (*endo* isomer).

Product **3d:** Daicel chiralpak-ADH, hexane/*i*-PrOH 97:3, 1.0 mL/min, 254 nm.

Retention times: 16.0, 18.9 (*exo* isomer); 20.0, 21.6 mins (*endo* isomer).

Product **3e:**[4] Daicel chiralpak-ADH, hexane/*i*-PrOH 97:3, 1.0 mL/min, 254 nm.

Retention times: 8.7, 12.4 (*exo* isomer); 10.8, 20.2 mins (*endo* isomer).

Determination of the 1a conversion

Conversions of **1a** were calculated using the following formula:[5]

Conversion of **1a** (%) = $PA_{3a}/(PA_{3a} + PA_{1a}/f)$ **Scheme S1**

Where PA_{1a} and PA_{3a} are the HPLC peak areas of **1a** and **3a**, respectively. And f is the correction factor determined to be 0.44 from a fitting curve (Figure S1).

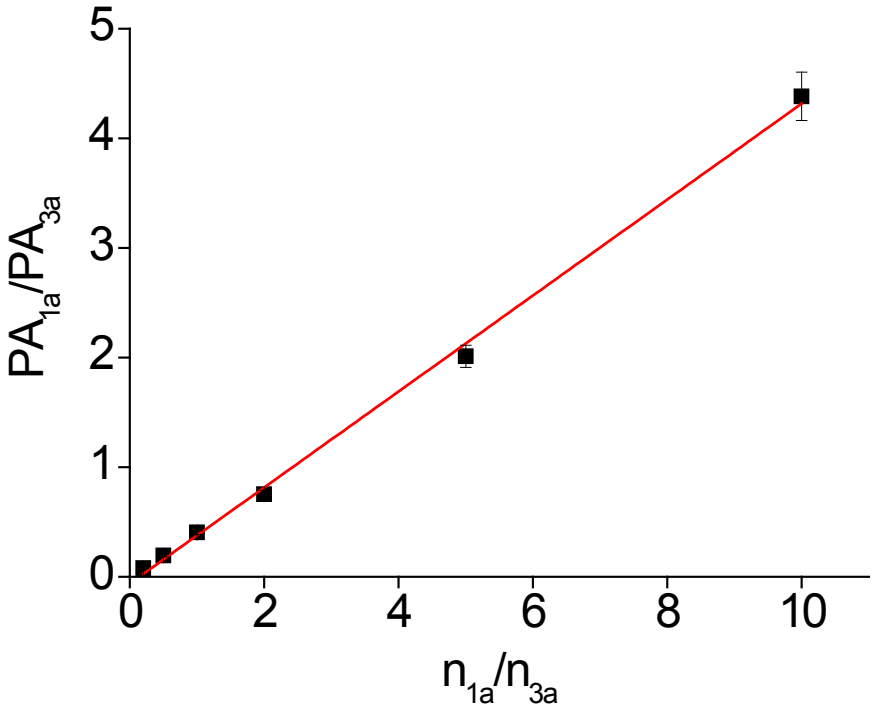


Fig. S1 Determination of the correction factor. The HPLC ratios of peak areas (PA_{1a}/PA_{3a}) were determined with the standard molar ratios (n_{1a}/n_{3a}) of 0.2, 0.5, 1, 2, 5 and 10. The correction factor (f=0.44) was estimated from the fitting curve (R^2 = 0.998).

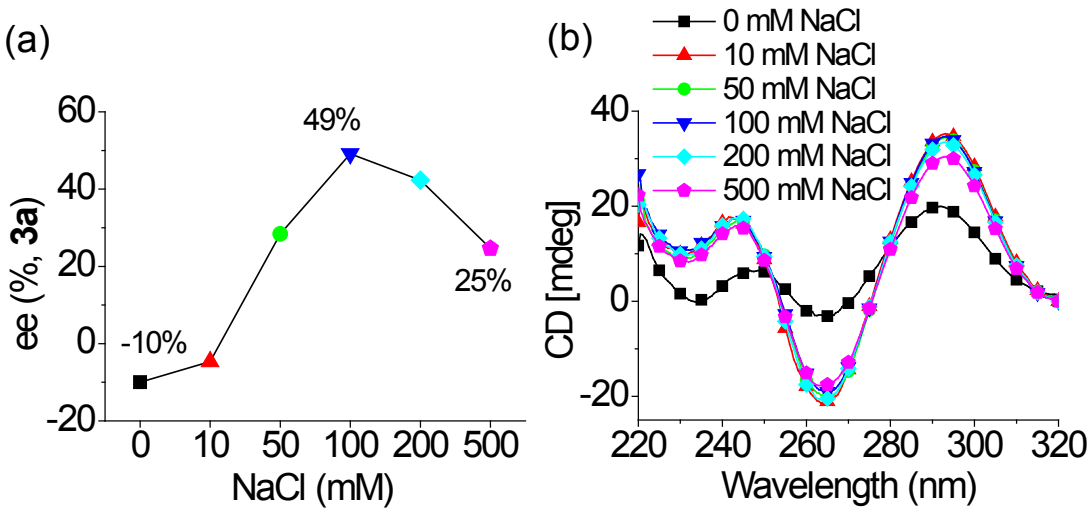


Fig. S2 The enantioselectivity of the Diels-Alder reactions and the G4DNA conformations with various concentrations of Na^+ ions. (a) The ee values of **3a** (*endo*) for the enantioselective Diels-Alder reactions catalyzed by **ODN**-Cu^{2+} and (b) CD spectra of **ODN**-Cu^{2+} in MOPS buffer within 0-500 mM Na^+ ions.

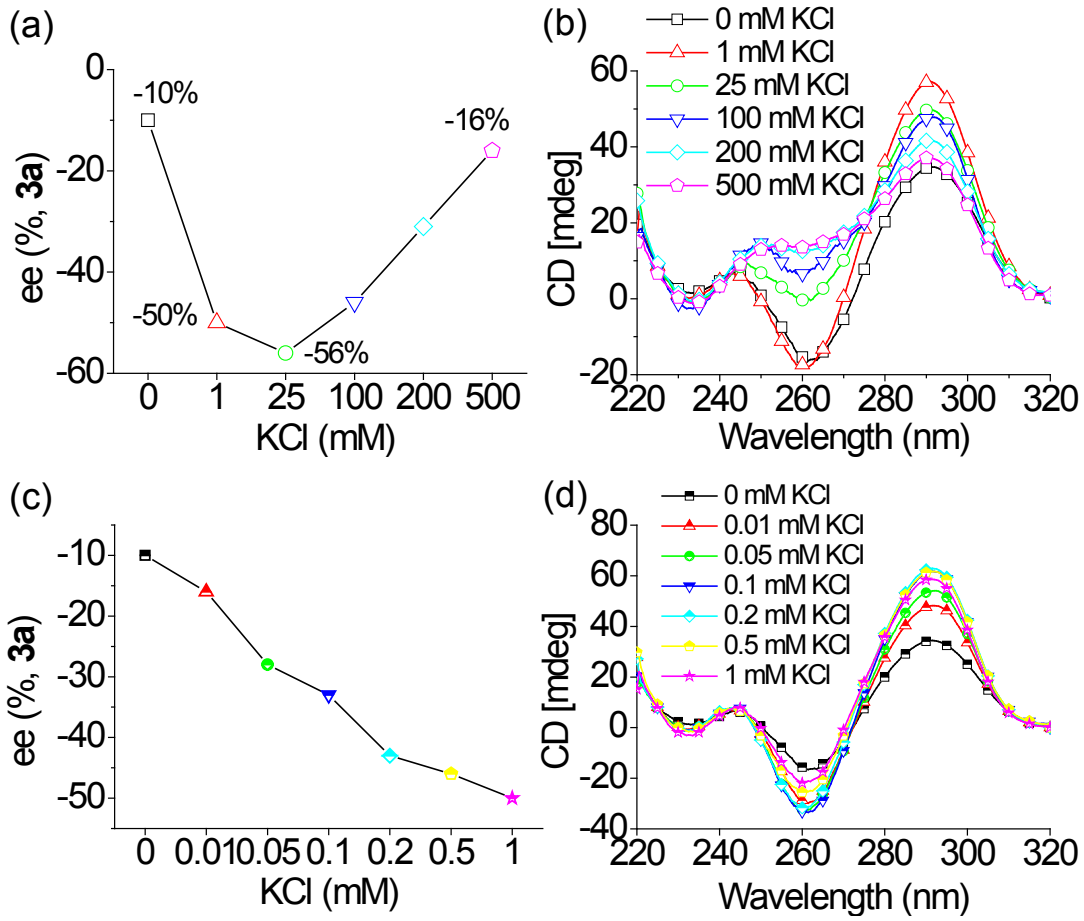


Fig. S3 The correlation of the enantioselectivity for the Diels-Alder reactions and the G4DNA conformations by varying the concentration of K^+ ions. (a) The ee values of **3a** (*endo*) for the enantioselective Diels-Alder reactions catalyzed by **ODN**-Cu^{2+} and (b) CD spectra of **ODN**-Cu^{2+} in MOPS buffer within 0-500 mM K^+ ions. (c) The ee values of **3a** (*endo*) for the enantioselective Diels-Alder reactions catalyzed by **ODN**-Cu^{2+} and (d) CD spectra of **ODN**-Cu^{2+} in MOPS buffer within 0-1 mM K^+ ions.

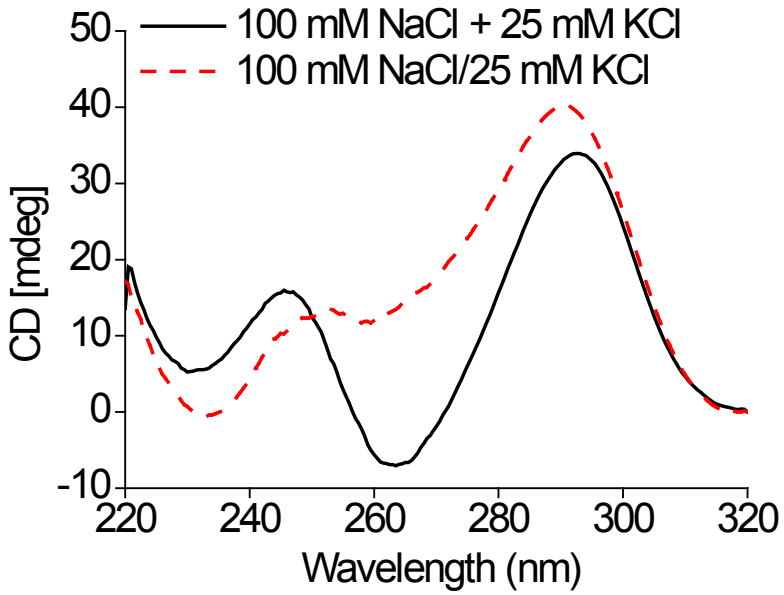


Fig. S4 CD spectra of **ODN**-Cu^{2+} in MOPS buffer (20 mM, pH 6.5) containing both 100 mM NaCl and 25 mM KCl (red, dash), and a simple sum (black, solid) of those obtained at 100 mM NaCl and 25 mM KCl, respectively.

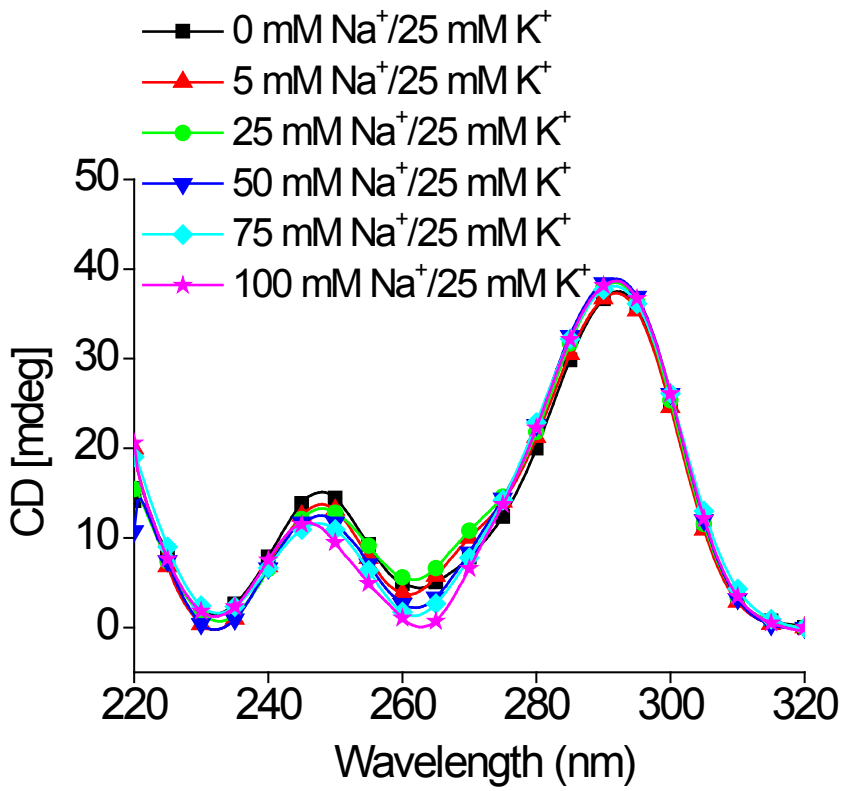


Fig. S5 CD spectra of **ODN**-Cu^{2+} in a fixed concentration of KCl with tuning the concentrations of NaCl. **ODN**-Cu^{2+} (50 μM **ODN** and 150 μM Cu^{2+}) in MOPS buffer (20 mM, pH 6.5) containing 25 mM KCl by addition of NaCl at 0 mM (■), 5 mM (▲), 25 mM (●), 50 mM (▼), 75 mM (◆), and 100 mM (★).

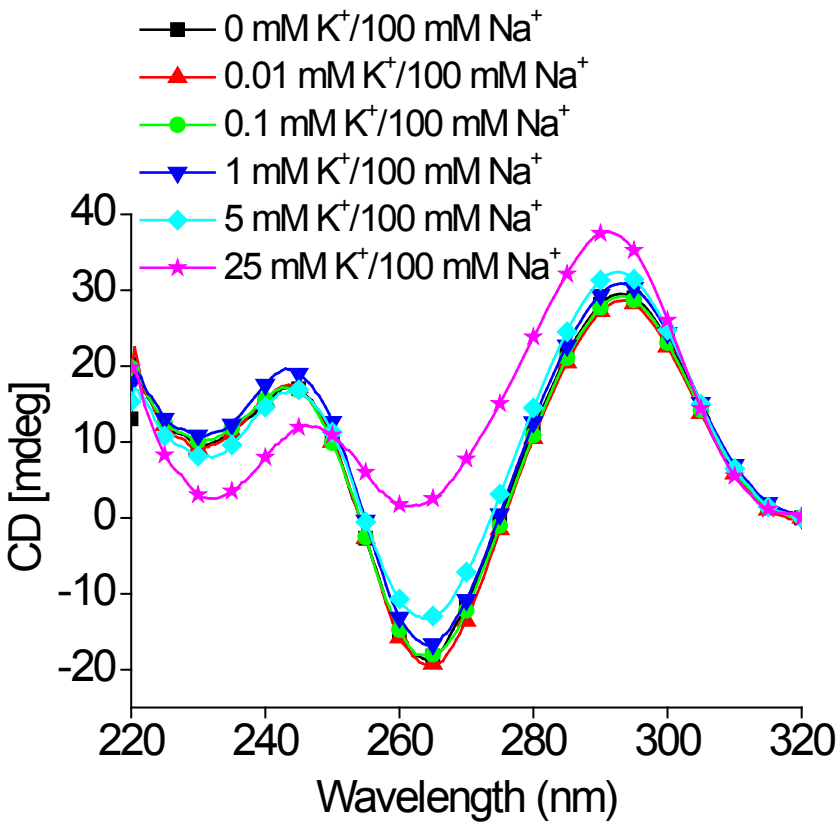
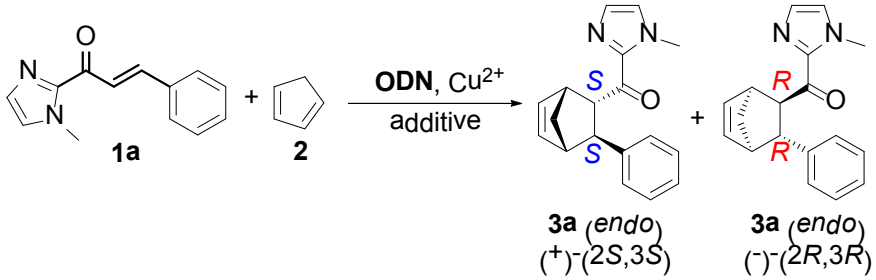


Fig. S6 CD spectra of **ODN**-Cu^{2+} in a fixed concentration of NaCl with tuning the concentrations of KCl. **ODN**-Cu^{2+} (50 μM **ODN** and 150 μM Cu^{2+}) in MOPS buffer (20 mM, pH 6.5) containing 100 mM NaCl by addition of KCl at 0 mM (■), 0.01 mM (▲), 0.1 mM (●), 1 mM (▼), 5 mM (◆), and 25 mM (★).

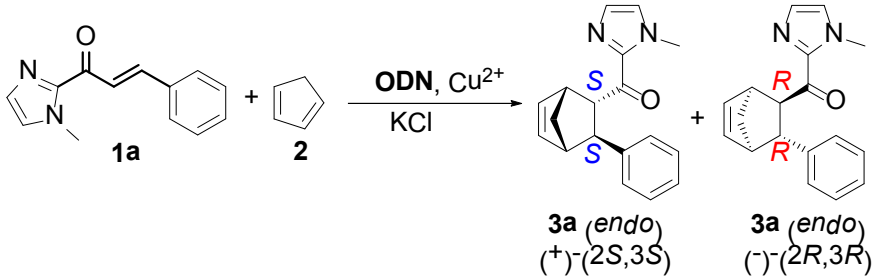
Table S1. Enantioselective Diels-Alder reaction catalyzed by G4DNA-based catalysts.



Entry[a]	Catalyst	Additive	Conversion[b] (%)	*Endo:exo*[b]	ee[c] (%)
1	none	KCl	2	77:23	0
2	**ODN**	KCl	5	79:21	-21
3	Cu^{2+}	KCl	14	87:13	0
4	**ODN**-Cu^{2+}	KCl	36	96:4	-56
5	**ODN**-Cu^{2+}	NaCl	17	96:4	49
6	**ODN**-Cu^{2+}	none	6	82:18	-10
7	**ODN**-Cu(dmbpy)[d]	KCl	16	91:9	16
8	**ODN**-Cu(dmbpy)[d]	NaCl	4	81:19	0

[a] Reaction condition: **1a** (1 μmol), **2** (15 μL, 180 μmol), **ODN** (5 mol%), $Cu(NO_3)_2$ (15 mol%), additive (25 mM KCl or 100 mM NaCl), MOPS buffer (20 mM, pH 6.5), 4 °C, 3 d. All data are averaged over two separated experiments. [b] Determined by chiral-phase HPLC for the crude product with reproducibility of ±5%. [c] Determined by chiral-phase HPLC for the *endo* isomer with reproducibility of ±5%. [d] Additional ligand 4,4'-dimethyl-2,2'-bipyridine (dmbpy) was added.

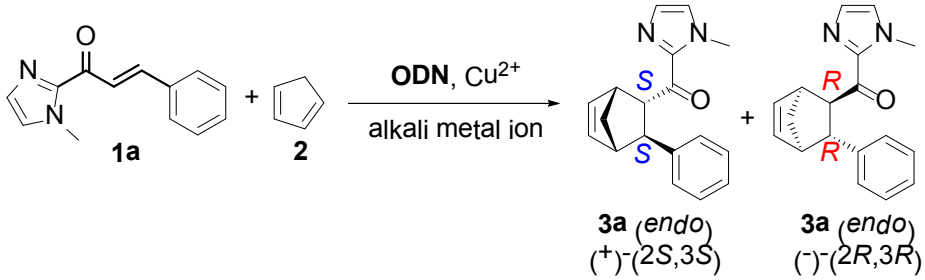
Table S2. Screening the optimized ratio of copper(II)/ODN.



Entry[a]	Copper(II)/**ODN**	Conversion[b] (%)	*Endo:exo*[b]	ee[c] (%)
1	0	6	82:18	-10
2	0.2	10	89:11	-30
3	0.5	21	89:11	-43
4	1	12	92:8	-49
5	2	20	94:6	-44
6	3	36	96:4	-56
7	6	40	94:6	-49
8	10	31	92:8	-30

[a] Reaction condition: **1a** (1 μmol), **2** (15 μL, 180 μmol), **ODN** (5 mol%), KCl (25 mM), MOPS buffer (20 mM, pH 6.5), 4 °C, 3 d. All data are averaged over two separated experiments. [b] Determined by chiral-phase HPLC for the crude product with reproducibility of ±5%. [c] Determined by chiral-phase HPLC for the *endo* isomer with reproducibility of ±5%.

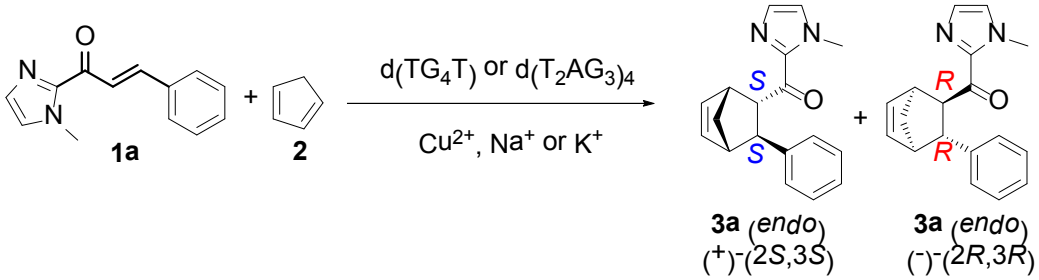
Table S3. The effect of different alkali metal ions.



Entry[a]	Alkali metal ion	Conversion[b] (%)	*Endo:exo*[b]	ee[c] (%)
1	none	6	82:18	-10
2	LiCl	6	81:19	-11
3	NaCl	7	88:12	31
4	KCl	16	95:5	-50
5	RbCl	16	95:5	-45
6	CsCl	9	91:9	-32

[a] Reaction condition: **1a** (1 μmol), **2** (15 μL, 180 μmol), **ODN** (5 mol%), $Cu(NO_3)_2$ (15 mol%), alkali metal ion (50 mM), MOPS buffer (20 mM, pH 6.5), 4 °C, 3 d. All data are averaged over two separated experiments. [b] Determined by chiral-phase HPLC for the crude product with reproducibility of ±5%. [c] Determined by chiral-phase HPLC for the *endo* isomer with reproducibility of ±5%.

Table S4. The effect of different sequences.



Entry[a]	5'-3' sequence	Alkali metal ion	Conversion[b] (%)	*Endo:exo*[b]	ee[c] (%)
1	$d(TG_4T)$	NaCl	8	87:13	0
2	$d(TG_4T)$	KCl	8	90:10	-15
3	$d(T_2AG_3)_4$	NaCl	6	89:11	0
4	$d(T_2AG_3)_4$	KCl	37	96:4	-3

[a] Reaction condition: **1a** (1 μmol), **2** (15 μL, 180 μmol), $d(TG_4T)$ or $d(T_2AG_3)_4$ (5 mol%), $Cu(NO_3)_2$ (15 mol%), NaCl (100 mM) or KCl (25 mM), MOPS buffer (20 mM, pH 6.5), 4 °C, 3 d. All data are averaged over two separated experiments. [b] Determined by chiral-phase HPLC for the crude product with reproducibility of ±5%. [c] Determined by chiral-phase HPLC for the *endo* isomer with reproducibility of ±5%.

References

1. (a) J. L. Mergny, A. T. Phan and L. Lacroix, *FEBS Lett.*, 1998, **435**, 74-78; (b) J. L. Mergny and L. Lacroix, *Oligonucleotides*, 2003, **13**, 515-537.

2. N. Kumar and S. Maiti, *Nucleic Acids Res.*, 2005, **33**, 6723-6732.

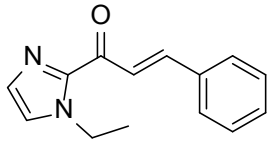
3. (a) D. A. Evans, K. R. Fandrick and H. J. Song, *J. Am. Chem. Soc.*, 2005, **127**, 8942-8943; (b) M. C. Myers, A. R. Bharadwaj, B. C. Milgram and K. A. Scheidt, *J. Am. Chem. Soc.*, 2005, **127**, 14675-14680.

4. A. J. Boersma, B. L. Feringa and G. Roelfes, *Org. Lett.*, 2007, **9**, 3647-3650.

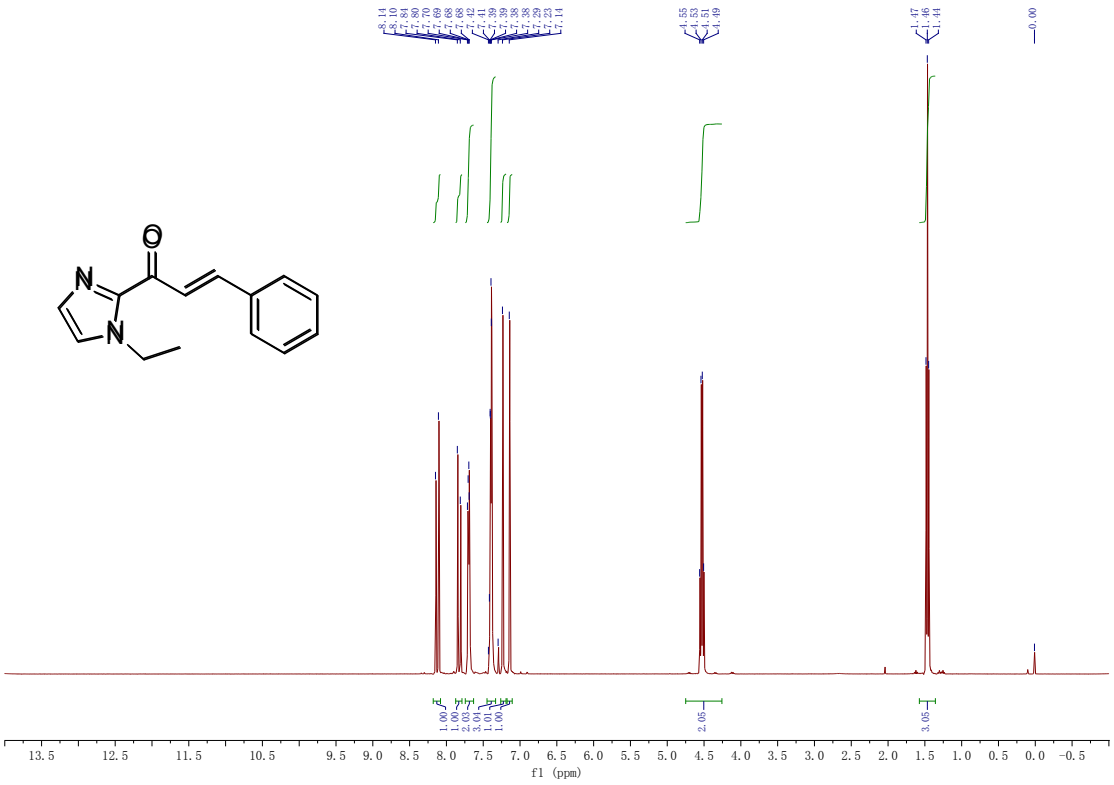
5. (a) C. Wang, G. Jia, J. Zhou, Y. Li, Y. Liu, S. Lu and C. Li, *Angew. Chem. Int. Ed.*, 2012, **51**, 9352-9355; (b) C. Wang, Y. Li, G. Jia, Y. Liu, S. Lu and C. Li, *Chem. Commun.*, 2012, **48**, 6232-6234.

NMR spectra and HPLC traces

(1) Synthesis the dienophile



(*E*)-1-(1-ethyl-1H-imidazol-2-yl)-3-phenylprop-2-en-1-one (1b). Synthesized directly from cinnamic acid and N-ethyl imidazole, using the methodology described by Evans et al.[3a] Starting from 2.7 g cinnamic acid (18.0 mmol). Purified by column chromatography (SiO_2, EtOAc:petroleum ether = 1:3), yielding 1.53 g (6.8 mmol, 38%) of **1b** as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.12 (d, *J*=16.0, 1H), 7.82 (d, *J*=16.0, 1H), 7.69 (dd, *J*=6.5, 2.8, 2H), 7.44 – 7.32 (m, 3H), 7.23 (s, 1H), 7.14 (s, 1H), 4.52 (q, *J*=7.2, 2H), 1.46 (t, *J*=7.2, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz) δ = 180.33 (s), 143.52 (s), 143.32 (s), 135.06 (s), 130.52 (s), 129.64 (s), 128.89 (d, *J*=11.9), 125.72 (s), 123.12 (s), 44.09 (s), 16.64 (s). HRMS (ESI) $[M+H]^+$ calcd for $C_{14}H_{14}N_2O$ 226.1106, found 226.1171.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8.10
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7.70
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7.41
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7.39
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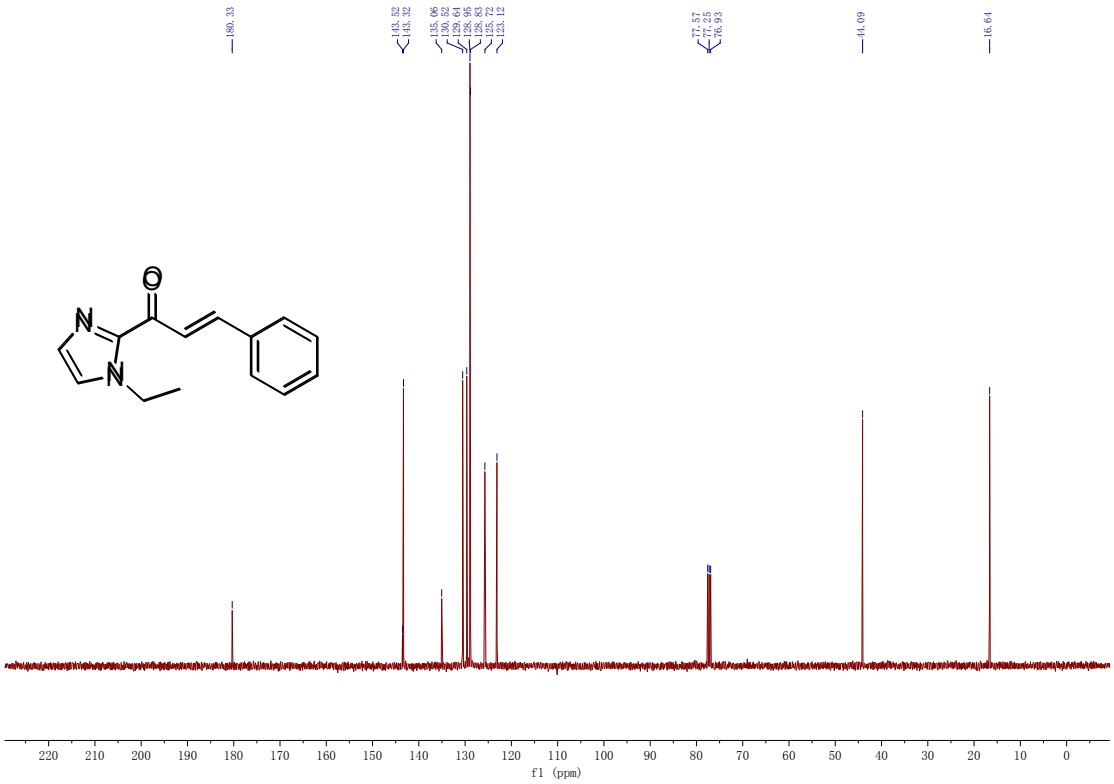
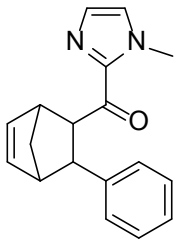
7.23
7.14
4.55
4.53
4.51
4.49
1.47
1.46
1.44
0.00
1.00
1.00
1.03
2.04
1.01
1.00
2.05
3.05
13.5 12.5 11.5 10.5 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

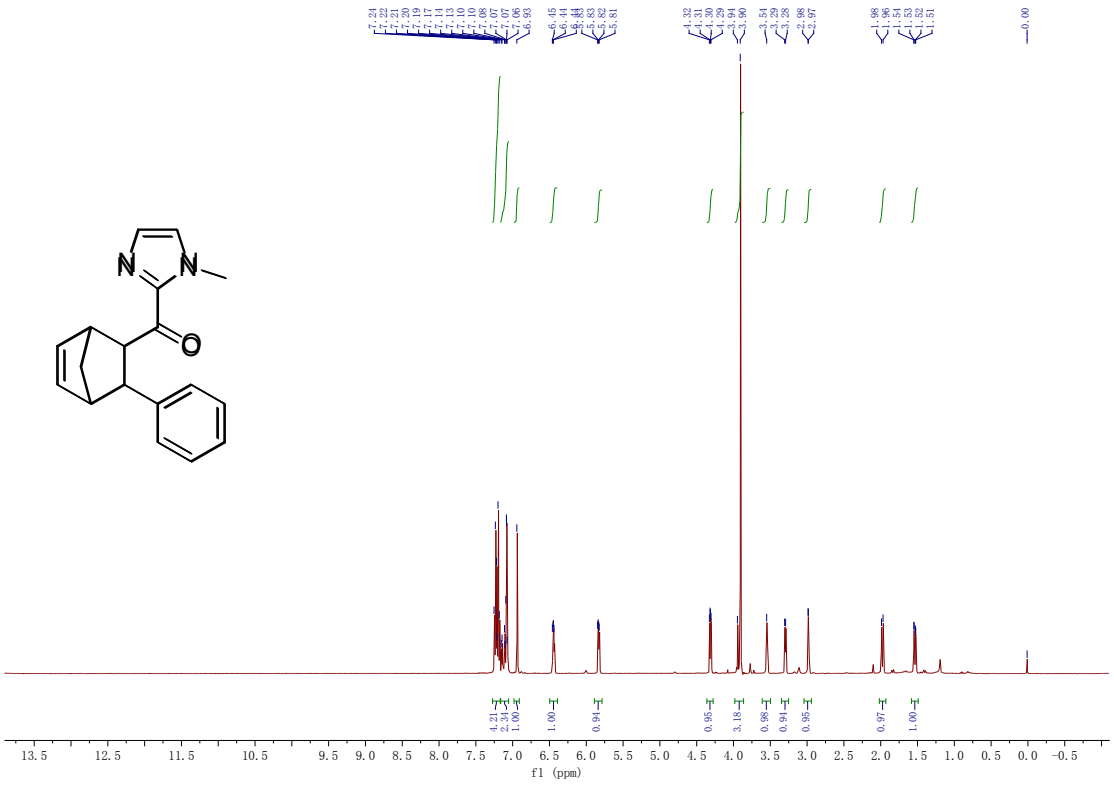

180.33
143.52
143.32
135.06
130.82
129.64
128.95
128.83
128.72
125.72
123.12
77.57
77.25
76.93
14.09
16.64
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

(2) Synthesis the Diels-Alder products

The Diels-Alder products were generally obtained as a mixture of *endo* and *exo* diastereomers, which were not separated. **3a** and **3e** were the known compounds[4] that presenting ^{1}H NMR and ^{13}C NMR. **3b, 3c** and **3d** were the new compounds that providing ^{1}H NMR, ^{13}C NMR and HRMS.



(1-methyl-1H-imidazol-2-yl)(-3-phenylbicyclo[2.2.1]hept-5-en-2-yl)methanone (3a). ^{1}H NMR (400 MHz, $CDCl_3$, *endo* isomer) δ = 7.21 (dt, *J*=13.0, 7.1, 4H), 7.11 – 7.04 (m, 2H), 6.93 (s, 1H), 6.44 (dd, *J*=5.5, 3.2, 1H), 5.82 (dd, *J*=5.6, 2.8, 1H), 4.31 (dd, *J*=5.3, 3.5, 1H), 3.92 (d, *J*=15.3, 3H), 3.54 (s, 1H), 3.29 (d, *J*=5.1, 1H), 2.97 (d, *J*=1.3, 1H), 1.97 (d, *J*=8.5, 1H), 1.53 (dd, *J*=8.6, 1.6, 1H). ^{13}C NMR (100 MHz, $CDCl_3$, *endo* isomer) δ = 192.64 (s), 144.47 (s), 139.68 (s), 132.99 (s), 129.18 (s), 128.59 (s), 127.87 (s), 126.99 (s), 126.10 (s), 55.30 (s), 49.90 (s), 49.68 (s), 48.49 (s), 45.90 (s), 36.48 (s). *Endo*/*exo* and ee were determined by chiral-phase HPLC (Daicel chiralcel-OD, hexane/*i*-PrOH 99:1, 1.0 mL/min, 254 nm). Retention times: 13.7, 17.4 (*exo* isomer); 16.0 (-), 22.8 (+) mins (*endo* isomer).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7.20
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7.13
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7.08
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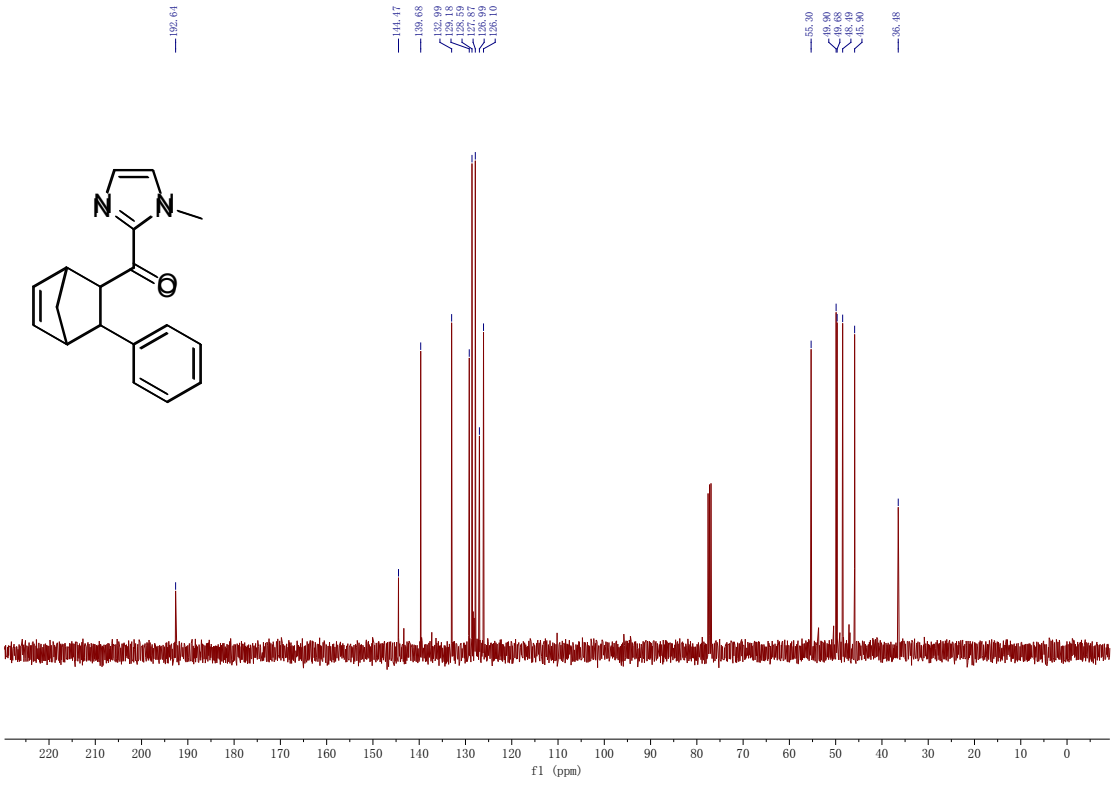
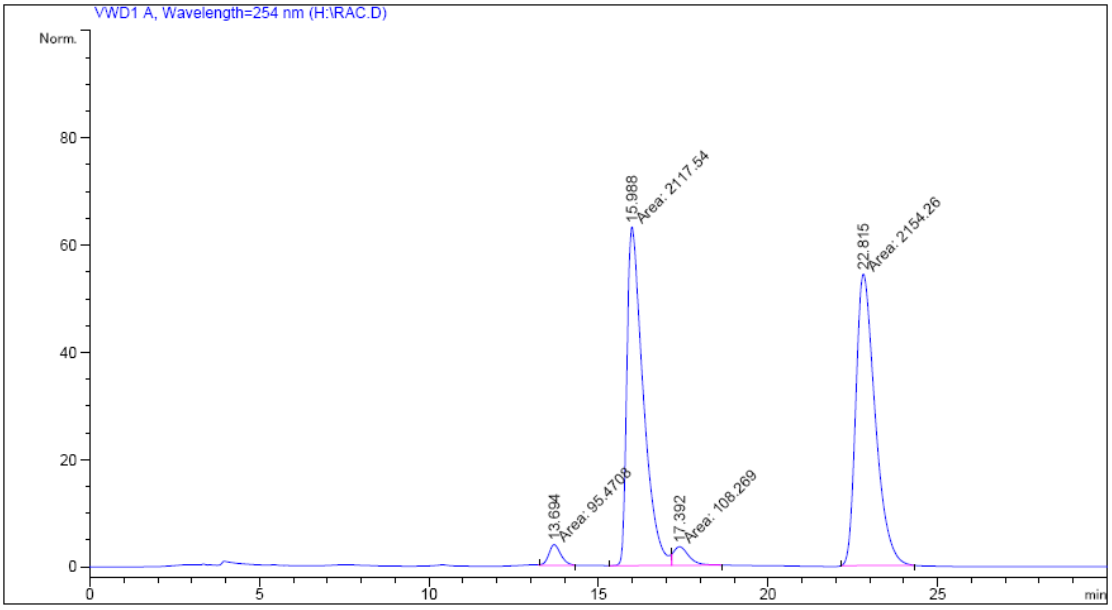
6.93
6.45
6.44
5.83
5.82
5.81
4.32
4.31
4.30
4.29
4.94
4.90
3.54
3.29
3.28
2.98
2.97
1.98
1.96
1.55
1.53
1.52
1.51
0.00
4.21
2.34
1.00
1.00
0.94
0.95
3.18
0.98
0.94
0.95
0.97
1.00
13.5 12.5 11.5 10.5 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 −0.5
f1 (ppm)


192.64
144.47
139.68
132.99
128.95
128.59
127.87
126.99
126.10
55.30
49.90
49.68
48.49
45.90
36.48
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

Racemic **3a**.

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================================================================================
                          Area Percent Report
================================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: VWD1 A, Wavelength=254 nm

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]  mAU   *s    [mAU   ]      %
----|-------|----|-------|----------|----------|--------|
   1  13.694 MM    0.4123   95.47079    3.85922   2.1332
   2  15.988 MF    0.5592 2117.54077   63.11161  47.3136
   3  17.392 FM    0.5184  108.26891    3.48110   2.4191
   4  22.815 MM    0.6608 2154.26440   54.33611  48.1341

Totals :                  4475.54488  124.78804

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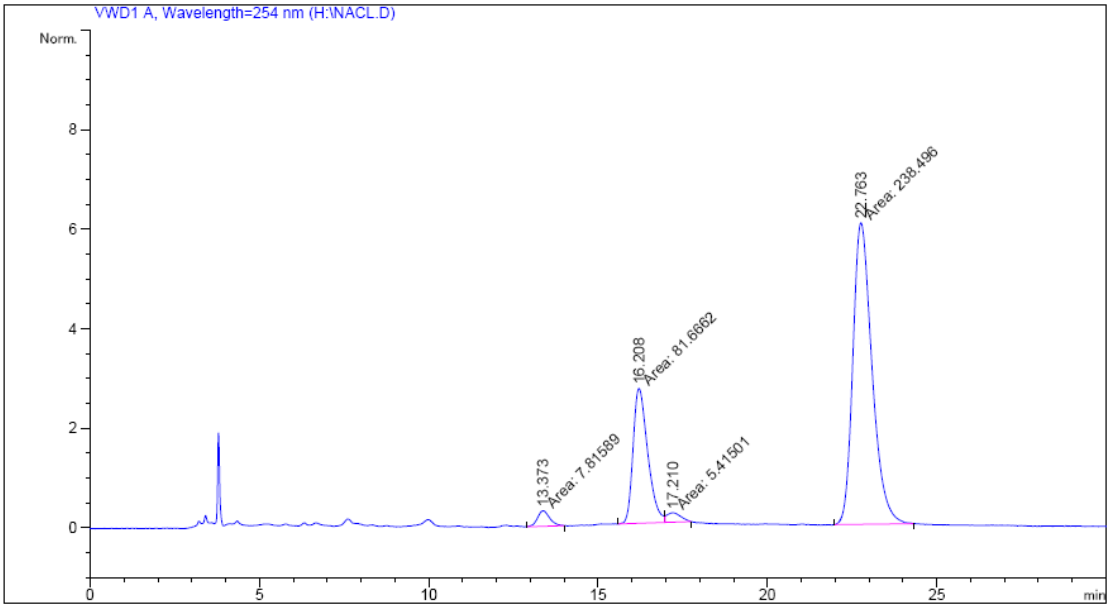
Product **3a** from the Diels-Alder reaction catalyzed by **ODN**-Cu^{2+} in the presence of 100 mM NaCl (49% ee).

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=====================================================================
                        Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: VWD1 A, Wavelength=254 nm

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]  mAU   *s    [mAU   ]      %
----|-------|----|-------|----------|----------|--------|
   1  13.373 MM    0.4158    7.81589 3.13256e-1   2.3443
   2  16.208 MF    0.5027   81.66620    2.70776  24.4954
   3  17.210 FM    0.4778    5.41501 1.88867e-1   1.6242
   4  22.763 MM    0.6559  238.49625    6.06012  71.5360

Totals :                   333.39334    9.27001


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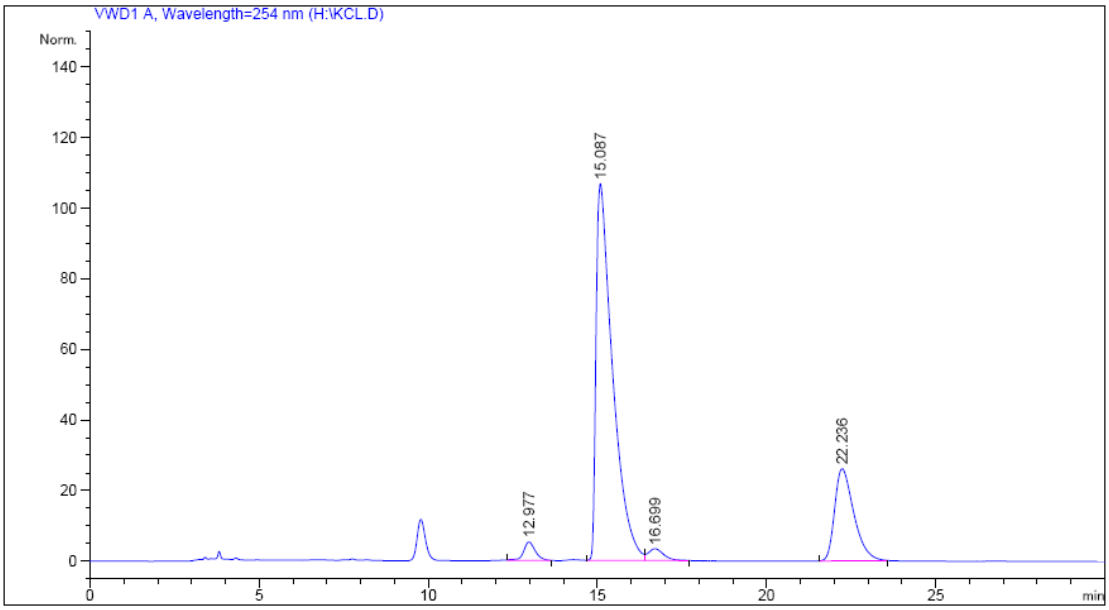
Product **3a** from the Diels-Alder reaction catalyzed by **ODN**-Cu^{2+} in the presence of 25 mM KCl (-56% ee).

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=====================================================================
                        Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: VWD1 A, Wavelength=254 nm

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]  mAU   *s    [mAU   ]      %
----|-------|----|-------|----------|----------|--------|
   1  12.977 BB    0.3648  126.41322    5.23346   2.5818
   2  15.087 BV    0.4905 3633.74609  106.70777  74.2132
   3  16.699 VB    0.4596  107.62764    3.36049   2.1981
   4  22.236 BB    0.5963 1028.57153   26.11782  21.0069

Totals :                  4896.35849  141.41954

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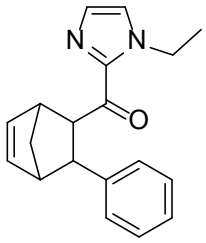
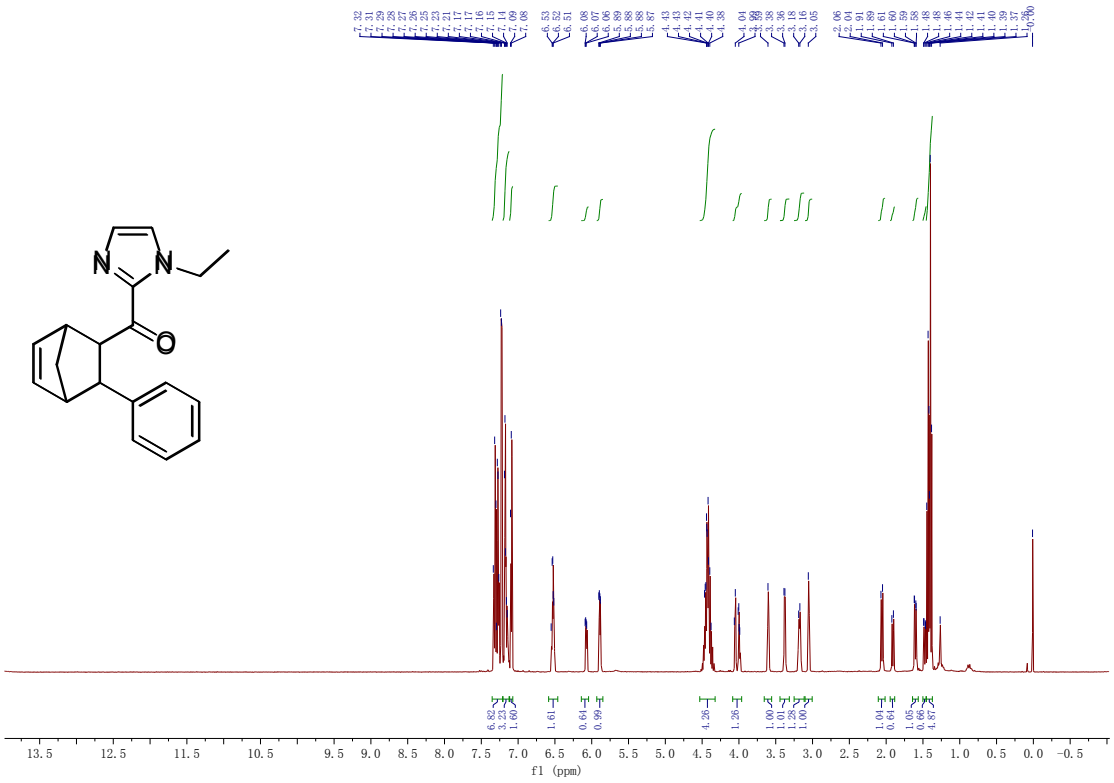
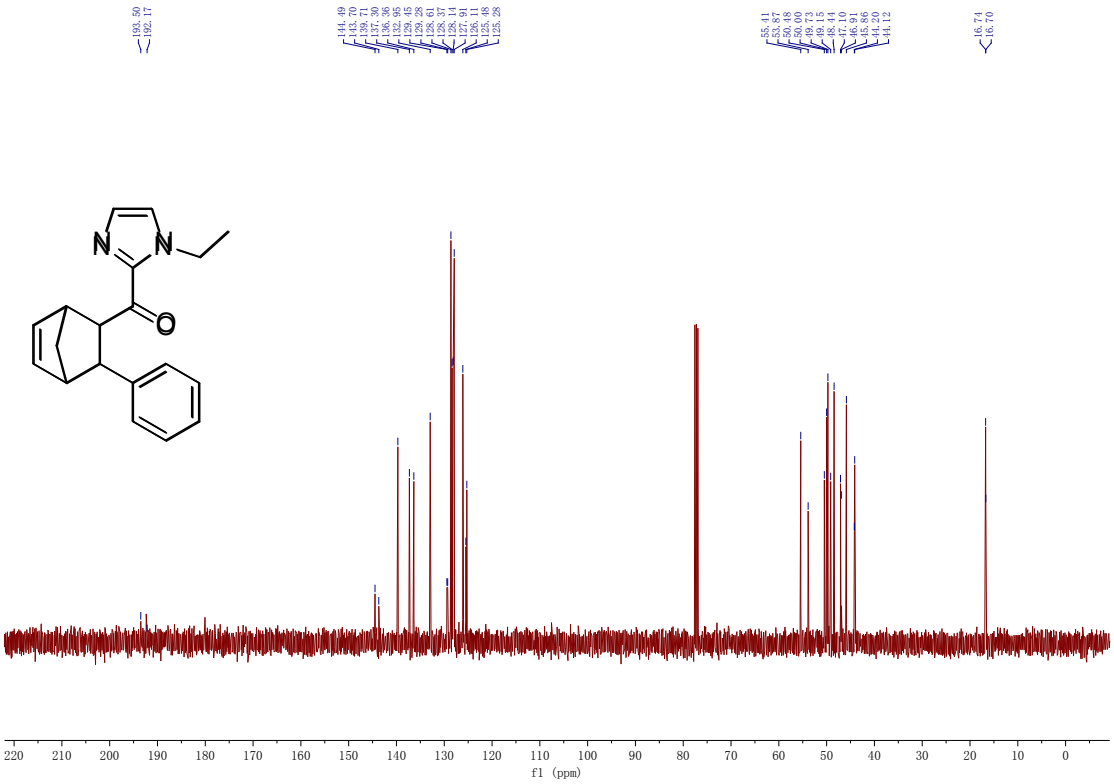
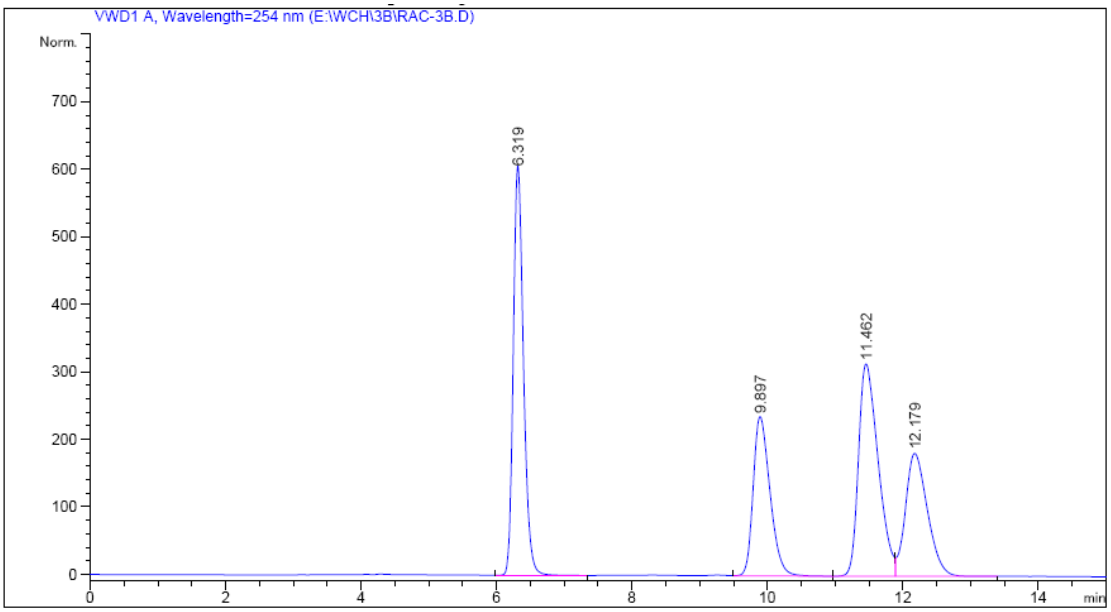


(1-ethyl-1H-imidazol-2-yl)(3-phenylbicyclo[2.2.1]hept-5-en-2-yl)methanone (3b). Purified by column chromatography (SiO_2, EtOAc:petroleum ether = 1:3) as a colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) *endo* isomer: δ = 7.34 – 7.20 (m, 3H), 7.20 – 7.11 (m, 3H), 7.09 (d, *J*=4.2, 1H), 6.58 – 6.45 (m, 1H), 5.88 (dd, *J*=5.6, 2.8, 1H), 4.52 – 4.31 (m, 3H), 3.59 (s, 1H), 3.37 (d, *J*=5.1, 1H), 3.05 (s, 1H), 2.05 (d, *J*=8.6, 1H), 1.59 (dd, *J*=8.6, 1.6, 1H), 1.39 (t, *J*=7.2, 3H). *exo* isomer: δ = 7.34 – 7.20 (m, 3H), 7.20 – 7.11 (m, 3H), 7.09 (d, *J*=4.2, 1H), 6.58 – 6.45 (m, 1H), 6.07 (dd, *J*=5.6, 2.8, 1H), 4.52 – 4.31 (m, 2H), 4.07 – 3.95 (m, 2H), 3.17 (d, *J*=6.5, 2H), 1.90 (d, *J*=8.5, 1H), 1.47 (dd, *J*=8.5, 1.4, 1H), 1.42 (t, *J*=8.0, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) *endo* isomer: δ = 192.17 (s), 144.49 (s), 139.71 (s), 132.95 (s), 129.28 (s), 128.61 (s), 127.91 (s), 126.11 (s), 125.28 (s), 55.41 (s), 50.00 (s), 49.73 (s), 48.44 (s), 45.86 (s), 44.12 (s), 16.74 (s). *exo* isomer: δ = 193.50 (s), 143.70 (s), 137.30 (s), 136.36 (s), 129.46 (s), 128.37 (s), 128.14 (s), 126.15 (s), 125.48 (s), 55.41 (s), 53.87 (s), 49.15 (s), 47.10 (s), 46.91 (s), 44.20 (s), 16.70 (s). HRMS (ESI) $[M+H]^+$ calcd for $C_{19}H_{20}N_2O$ 292.1576, found 292.1647. *Endo*/*exo* and ee were determined by chiral-phase HPLC (Daicel chiralpak-AD, hexane/*i*-PrOH 85:15, 1.0 mL/min, 254 nm). Retention times: 9.9, 12.2 (*exo* isomer); 6.3, 11.5 mins (*endo* isomer).


f1 (ppm)


f1 (ppm)

Racemic **3b**.

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======================================================================
                        Area Percent Report
======================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: VWD1 A, Wavelength=254 nm

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]    [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1   6.319 VB    0.1701 6363.61230  601.19275  30.4408
   2   9.897 VV    0.2666 4081.91992  235.26901  19.5262
   3  11.462 VV    0.3109 6338.94775  314.54272  30.3228
   4  12.179 VB    0.3517 4120.40234  181.95676  19.7102

Totals :                  2.09049e4  1332.96124

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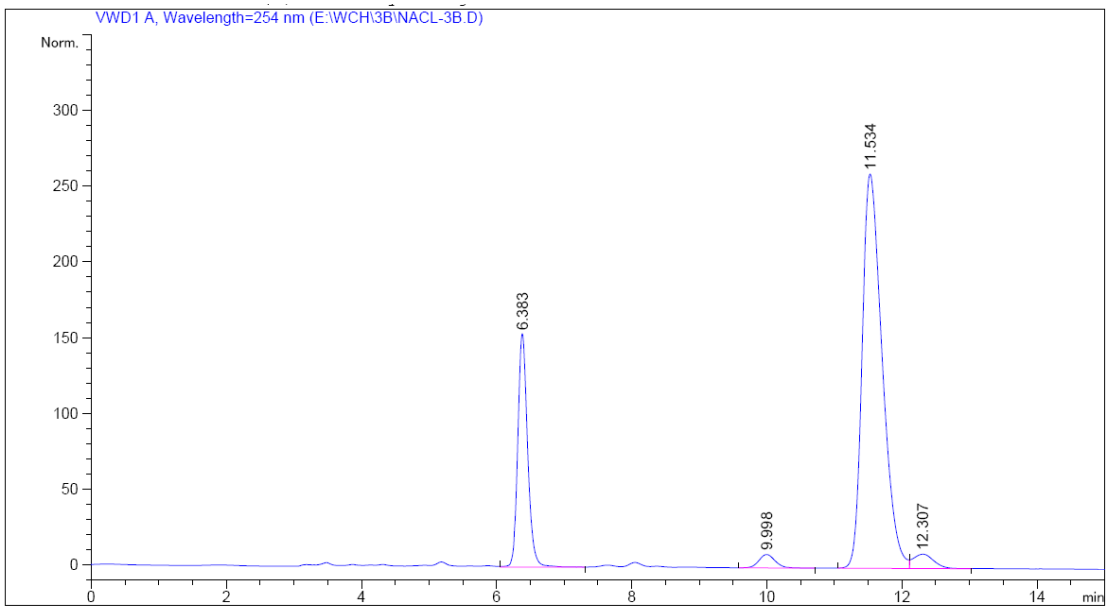
Product **3b** from the Diels-Alder reaction catalyzed by **ODN**-Cu^{2+} in the presence of 100 mM NaCl (55% ee).

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=====================================================================
                        Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: VWD1 A, Wavelength=254 nm

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]    [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1   6.383 VV    0.1594 1559.80518  153.46408  21.4493
   2   9.998 VB    0.2610  149.71092    8.87430   2.0587
   3  11.534 BV    0.3223 5361.51709  259.90738  73.7277
   4  12.307 VB    0.3228  201.02238    9.49527   2.7643

Totals :                  7272.05557  431.74103


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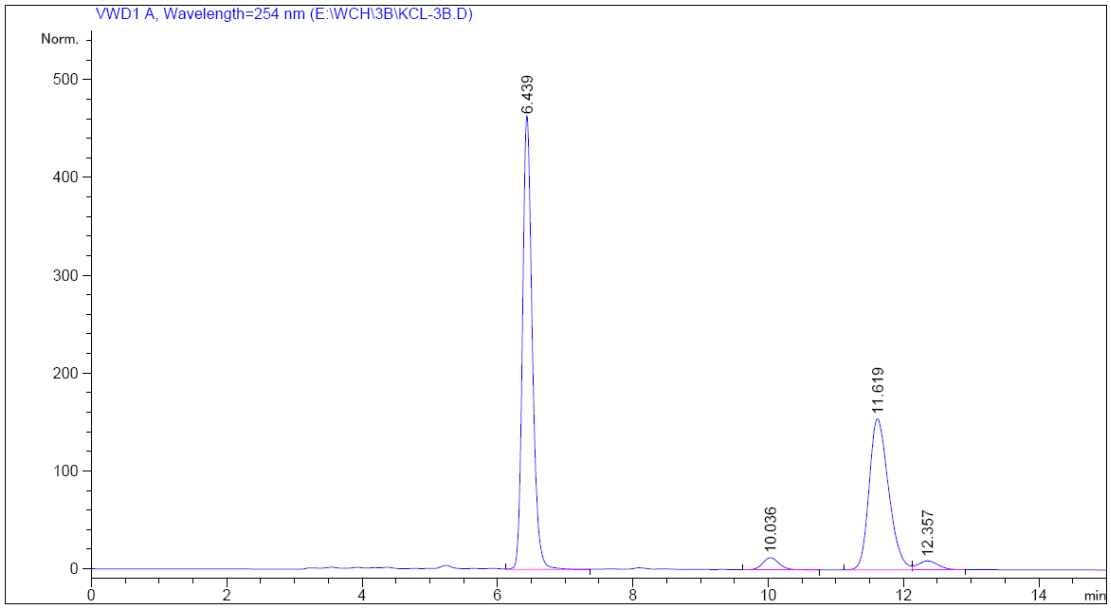
Product **3b** from the Diels-Alder reaction catalyzed by **ODN**-Cu^{2+} in the presence of 25 mM KCl (-20% ee).

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=====================================================================
                      Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: VWD1 A, Wavelength=254 nm

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1   6.439 VV    0.1584 4650.99854  461.63220  57.1317
   2  10.036 VB    0.2585  204.64111   12.28109   2.5138
   3  11.619 BV    0.3092 3091.48291  154.54012  37.9750
   4  12.357 VV    0.3236  193.71016    9.11863   2.3795

Totals :                  8140.83272  637.57204

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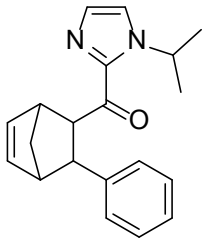
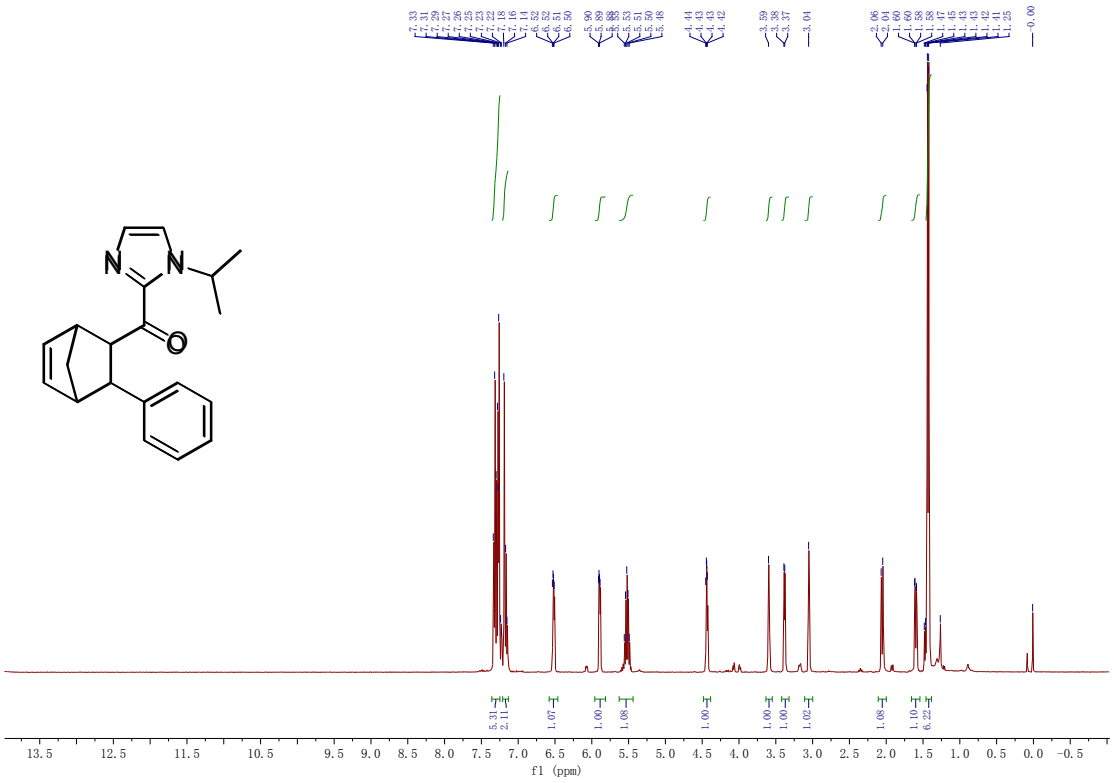
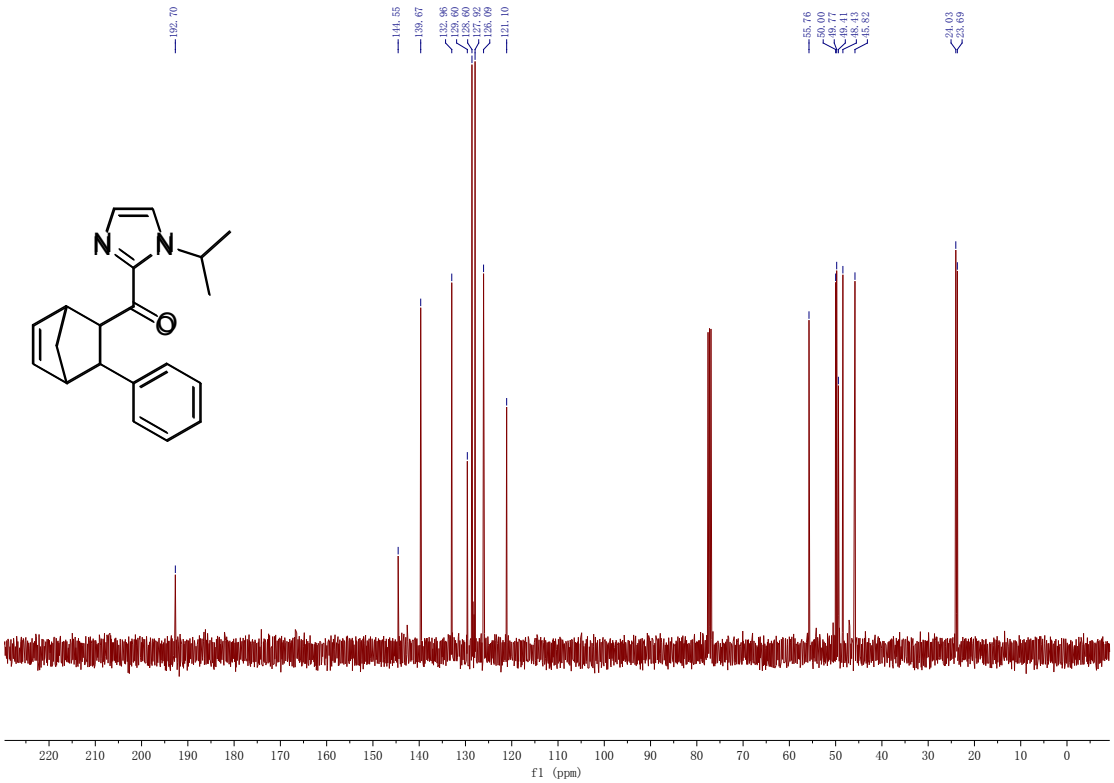
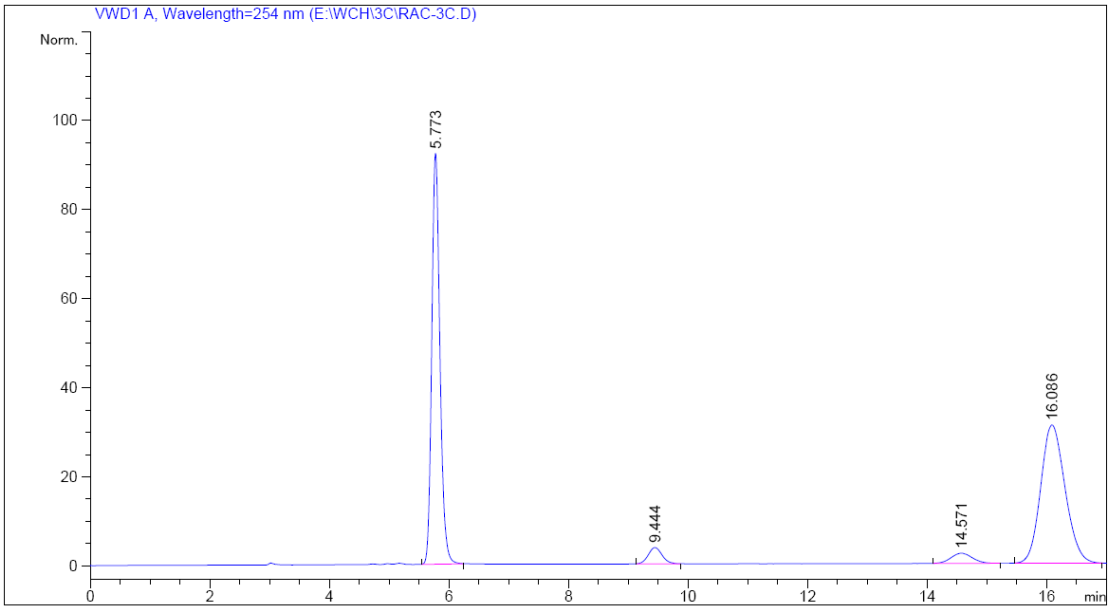


(1-isopropyl-1H-imidazol-2-yl)(3-phenylbicyclo[2.2.1]hept-5-en-2-yl)methanone (3c). Purified by column chromatography (SiO_2, EtOAc:petroleum ether = 1:3) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$, *endo* isomer) δ = 7.35 – 7.24 (m, 5H), 7.20 – 7.12 (m, 2H), 6.51 (dd, *J*=5.5, 3.2, 1H), 5.89 (dd, *J*=5.6, 2.7, 1H), 5.51 (dt, *J*=13.3, 6.7, 1H), 4.43 (dd, *J*=5.1, 3.6, 1H), 3.59 (s, 1H), 3.37 (d, *J*=4.7, 1H), 3.04 (s, 1H), 2.05 (d, *J*=8.5, 1H), 1.59 (dd, *J*=8.5, 1.5, 1H), 1.42 (dd, *J*=6.7, 2.0, 6H). ^{13}C NMR (100 MHz, $CDCl_3$, *endo* isomer) δ = 192.70 (s), 144.55 (s), 139.67 (s), 132.96 (s), 129.60 (s), 128.60 (s), 127.92 (s), 126.09 (s), 121.10 (s), 55.76 (s), 50.00 (s), 49.77 (s), 49.41 (s), 48.43 (s), 45.82 (s), 24.03 (s), 23.69 (s). HRMS (ESI) $[M+H]^+$ calcd for $C_{20}H_{22}N_2O$ 306.1732, found 306.1800. *Endo/exo* and ee were determined by chiral-phase HPLC (Daicel chiralpak-AD, hexane/*i*-PrOH 90:10, 1.0 mL/min, 254 nm). Retention times: 9.4, 14.6 (*exo* isomer); 5.8, 16.1 mins (*endo* isomer).


f1 (ppm)


f1 (ppm)

Racemic **3c**.

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=====================================================================
                        Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: VWD1 A, Wavelength=254 nm

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]    [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1   5.773 BB    0.1443  876.31085   92.27168  46.7865
   2   9.444 BB    0.2498   59.47094    3.68013   3.1752
   3  14.571 BB    0.3837   56.95030    2.29950   3.0406
   4  16.086 BB    0.4385  880.26697   31.06051  46.9977

Totals :                  1872.99905  129.31183

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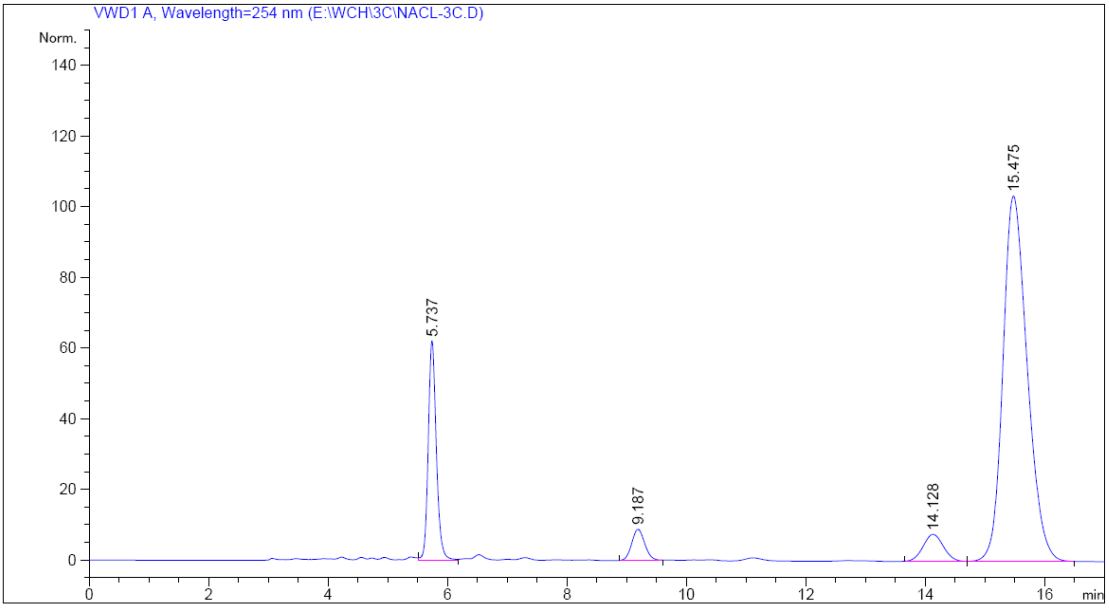
Product **3c** from the Diels-Alder reaction catalyzed by **ODN**-Cu^{2+} in the presence of 100 mM NaCl (67% ee).

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================================================================================
                          Area Percent Report
================================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: VWD1 A, Wavelength=254 nm

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]    [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1   5.737 VB    0.1434  584.88800   62.08662  15.3137
   2   9.187 BB    0.2334  132.07306    8.80120   3.4580
   3  14.128 BV    0.3692  182.38295    7.67132   4.7752
   4  15.475 VB    0.4329 2920.04102  103.40828  76.4532

Totals :                  3819.38503  181.96741


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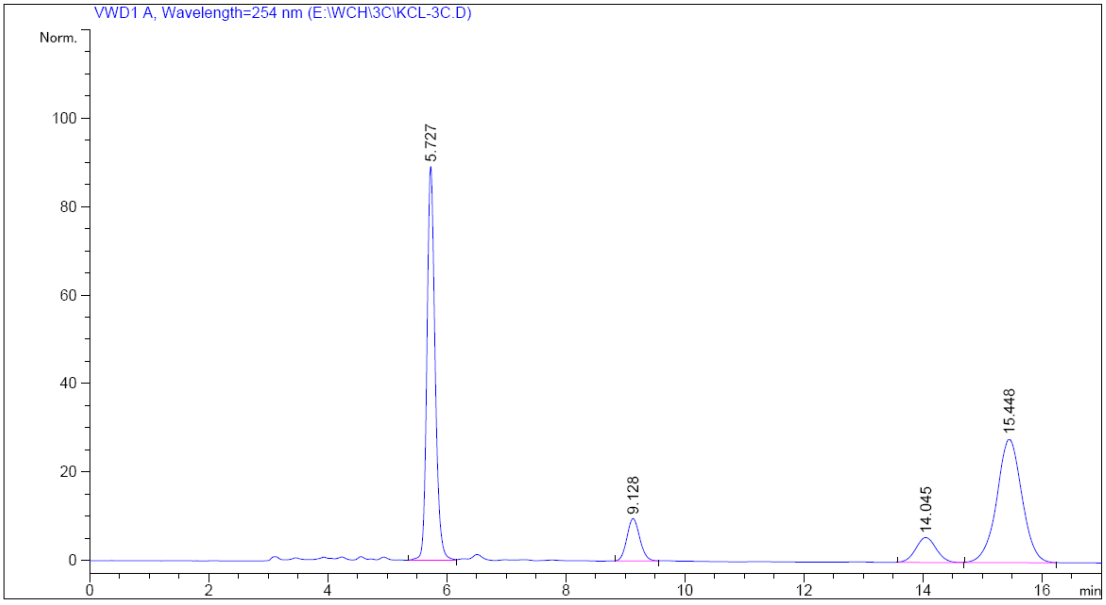
Product **3c** from the Diels-Alder reaction catalyzed by **ODN**-Cu^{2+} in the presence of 25 mM KCl (-2% ee).

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================================================================================
                          Area Percent Report
================================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: VWD1 A, Wavelength=254 nm

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]    [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1   5.727 BV    0.1460  847.36841   89.05751  43.5887
   2   9.128 BB    0.2333  143.51898    9.56747   7.3826
   3  14.045 BB    0.3747  135.22549    5.63617   6.9560
   4  15.448 BB    0.4467  817.89435   27.91838  42.0726

Totals :                  1944.00723  132.17953

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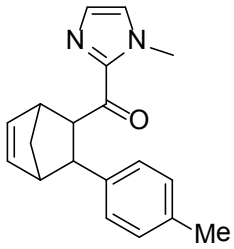
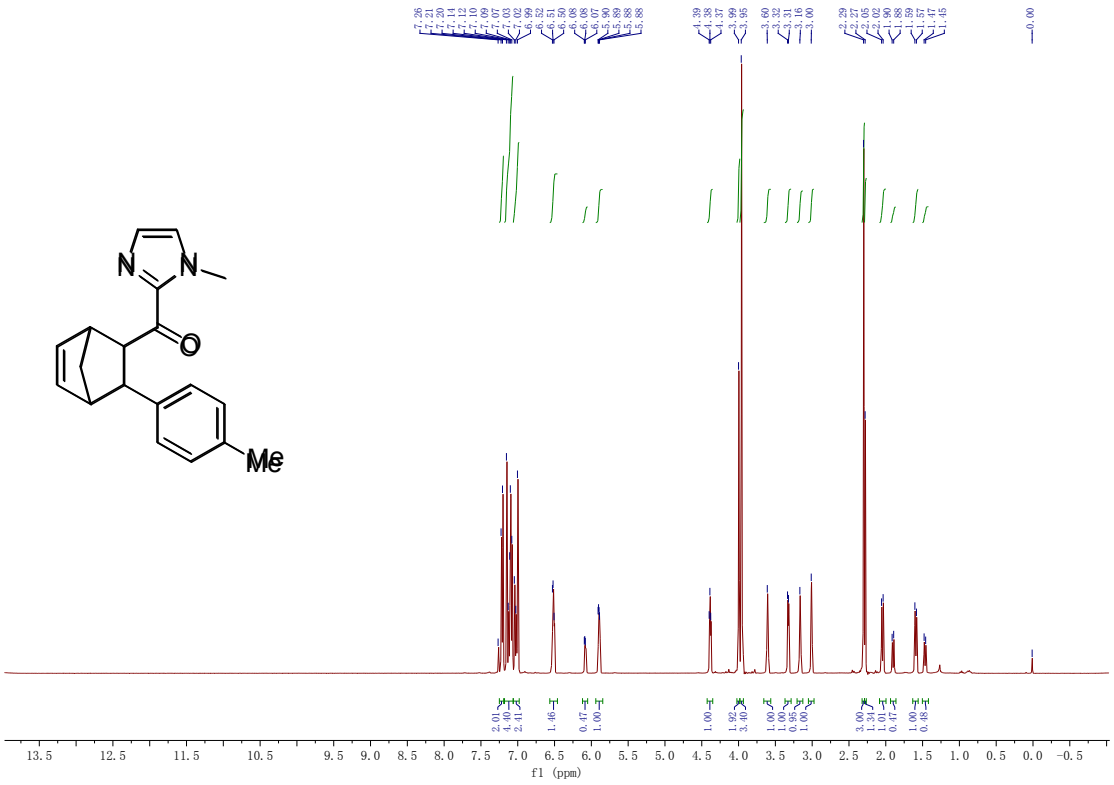
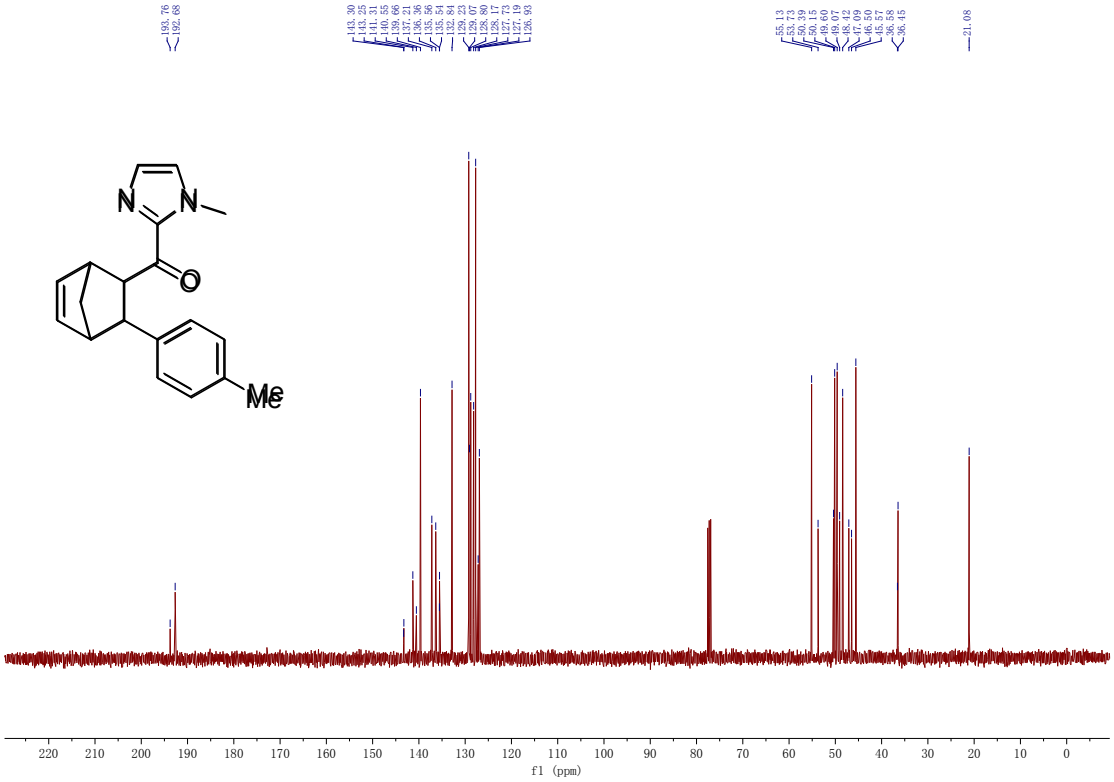
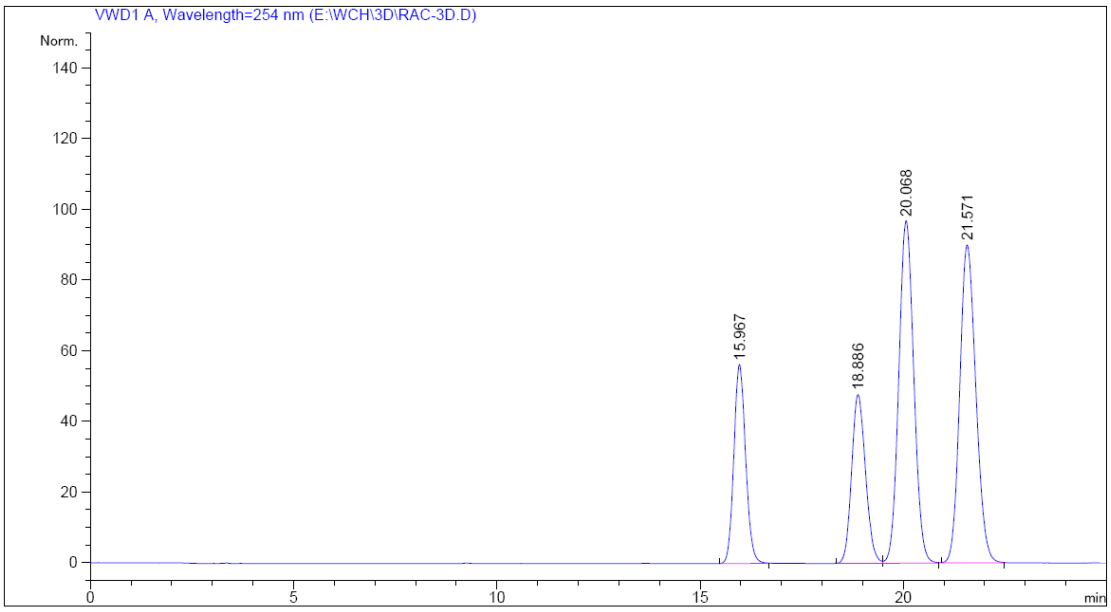


(1-methyl-1H-imidazol-2-yl)(3-*p*-tolylbicyclo[2.2.1]hept-5-en-2-yl)methanone (3d). Purified by column chromatography (SiO_2, EtOAc:petroleum ether = 1:3) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) *endo* isomer: δ = 7.21 (d, *J*=7.8, 2H), 7.17 – 7.05 (m, 2H), 7.05 – 6.97 (m, 2H), 6.55 – 6.45 (m, 1H), 5.89 (dd, *J*=5.3, 2.4, 1H), 4.42 – 4.34 (m, 1H), 3.95 (s, 3H), 3.60 (s, 1H), 3.32 (d, *J*=5.0, 1H), 3.00 (s, 1H), 2.29 (s, 3H), 2.04 (d, *J*=8.4, 1H), 1.58 (d, *J*=8.5, 1H). *exo* isomer: δ = 7.17 – 7.05 (m, 5H), 7.05 – 6.97 (m, 1H), 6.55 – 6.45 (m, 1H), 6.11 – 6.04 (m, 1H), 4.42 – 4.34 (m, 1H), 3.99 (m, 4H), 3.16 (m, 2H), 2.27 (s, 3H), 2.04 (d, *J*=8.4, 1H), 1.46 (d, *J*=8.5, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) *endo* isomer: δ = 192.68 (s), 143.26 (s), 141.31 (s), 139.66 (s), 135.54 (s), 132.84 (s), 129.23 (s), 128.80 (s), 127.73 (s), 126.93 (s), 55.13 (s), 50.15 (s), 49.60 (s), 48.42 (s), 45.57 (s), 36.46 (s), 21.08 (s). *exo* isomer: δ = 193.76 (s), 143.30 (s), 140.55 (s), 137.21 (s), 136.36 (s), 129.07 (s), 128.80 (s), 128.17 (s), 127.19 (s), 53.73 (s), 50.39 (s), 49.07 (s), 47.09 (s), 46.50 (s), 36.68 (s), 21.08 (s). HRMS (ESI) $[M+H]^+$ calcd for $C_{19}H_{20}N_2O$ 292.1576, found 292.1637. *Endo/exo* and ee were determined by chiral-phase HPLC (Daicel chiralpak-ADH, hexane/*i*-PrOH 97:3, 1.0 mL/min, 254 nm). Retention times: 16.0, 18.9 (*exo* isomer); 20.0, 21.6 mins (*endo* isomer).


N
N
O
Me
f1 (ppm)


N
N
O
Me
f1 (ppm)

Racemic **3d**.

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=====================================================================
                        Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: VWD1 A, Wavelength=254 nm

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]    [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  15.967 BB    0.3110 1134.93823   56.28815  15.6749
   2  18.886 BV    0.3683 1137.58557   47.74972  15.7115
   3  20.068 VB    0.3985 2486.53589   96.88984  34.3421
   4  21.571 BB    0.4267 2481.42236   89.97477  34.2715

Totals :                  7240.48206  290.90248

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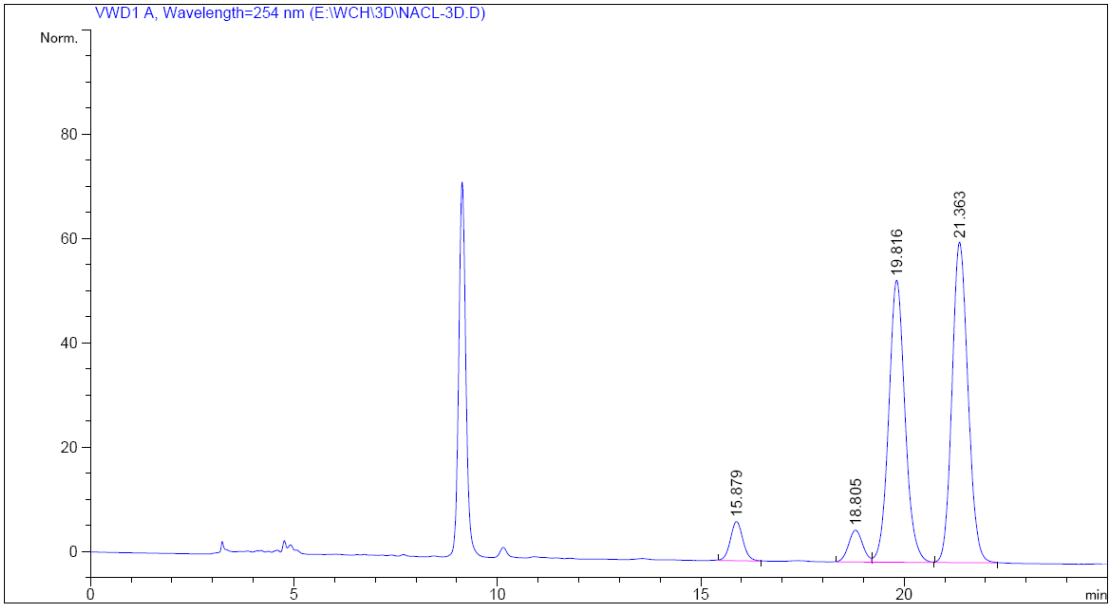
```

Product **3d** from the Diels-Alder reaction catalyzed by **ODN**-Cu^{2+} in the presence of 100 mM NaCl (5% ee).

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================================================================================
                          Area Percent Report
================================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: VWD1 A, Wavelength=254 nm

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]    [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  15.879 BB    0.3305  161.04433    7.50710   4.6151
   2  18.805 BV    0.3737  147.53377    6.10604   4.2279
   3  19.816 VB    0.4260 1507.77173   54.05308  43.2088
   4  21.363 BB    0.4212 1673.15344   61.43760  47.9482

Totals :                  3489.50327  129.10382


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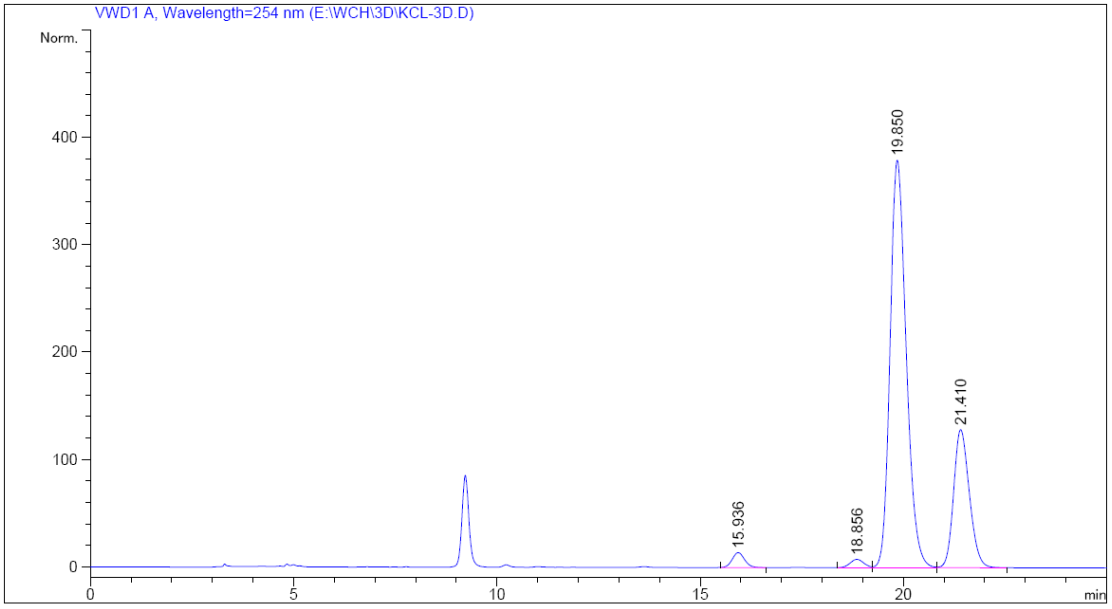
Product **3d** from the Diels-Alder reaction catalyzed by **ODN**-Cu^{2+} in the presence of 25 mM KCl (-50% ee).

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================================================================================
                          Area Percent Report
================================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: VWD1 A, Wavelength=254 nm

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]   [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1  15.936 BB    0.3312  299.18610   13.98679   2.0735
   2  18.856 BV    0.3651  183.54289    7.79464   1.2721
   3  19.850 VV    0.4243 1.04790e4   379.40588  72.6255
   4  21.410 VB    0.4137 3467.08691  128.60313  24.0289

Totals :                  1.44288e4   529.79045


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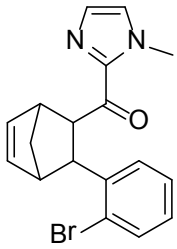
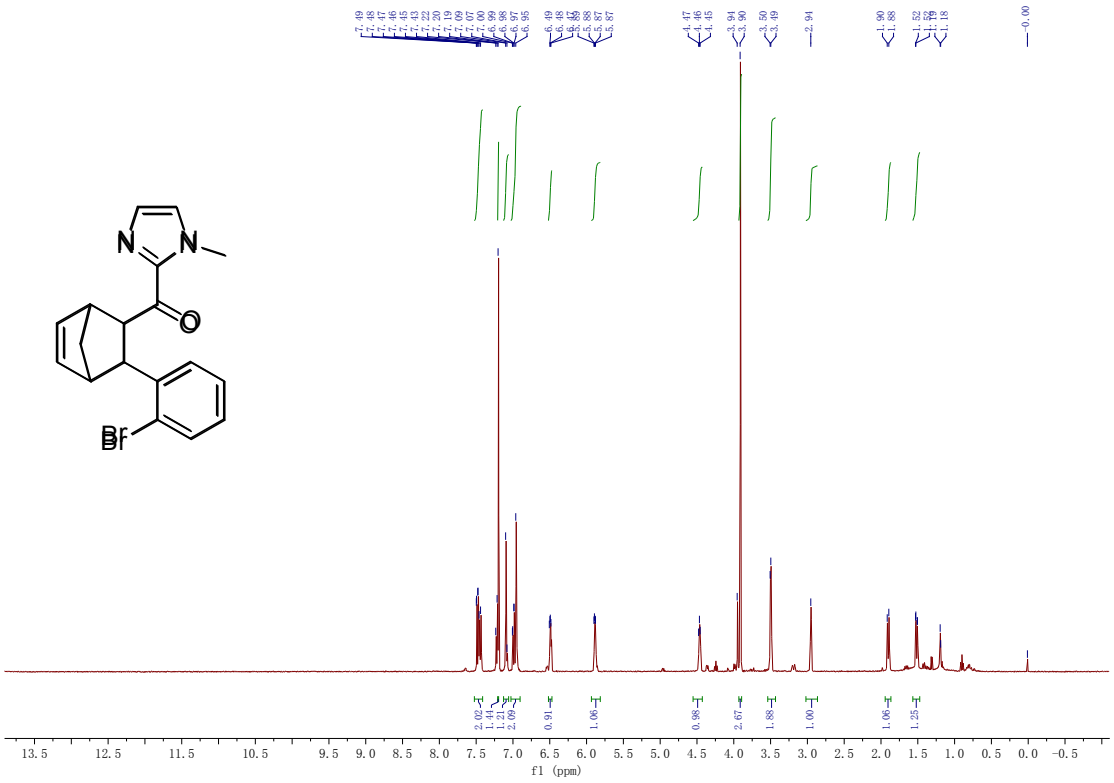
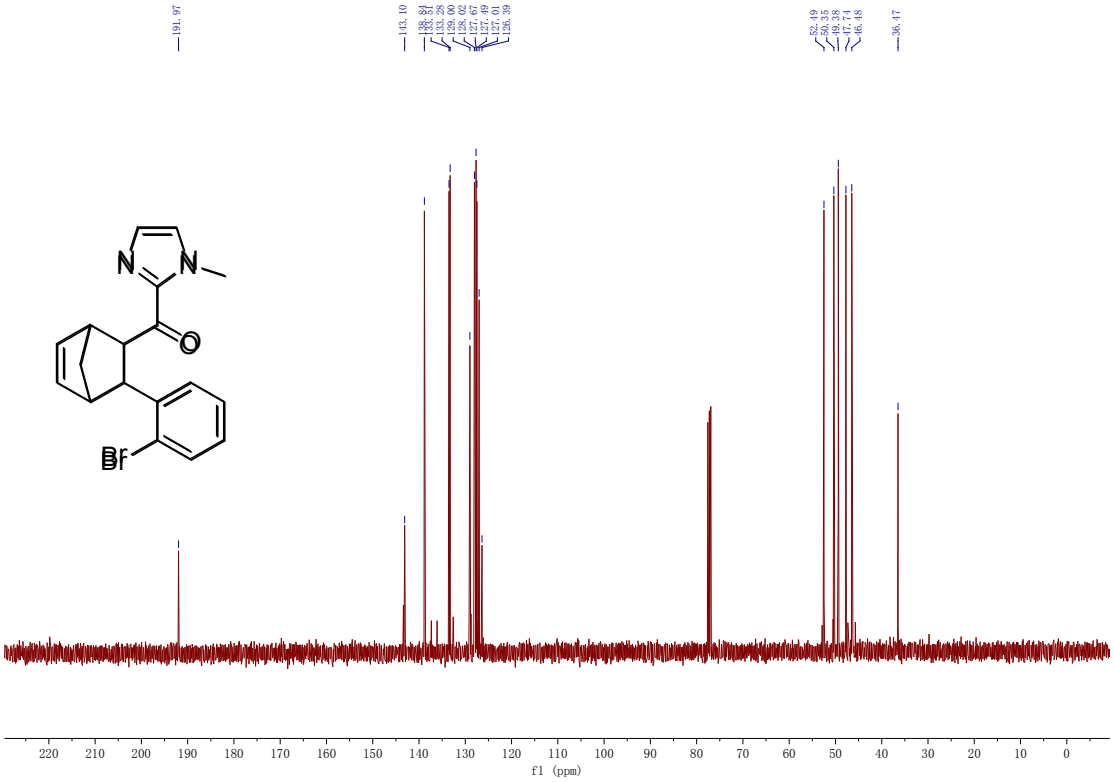
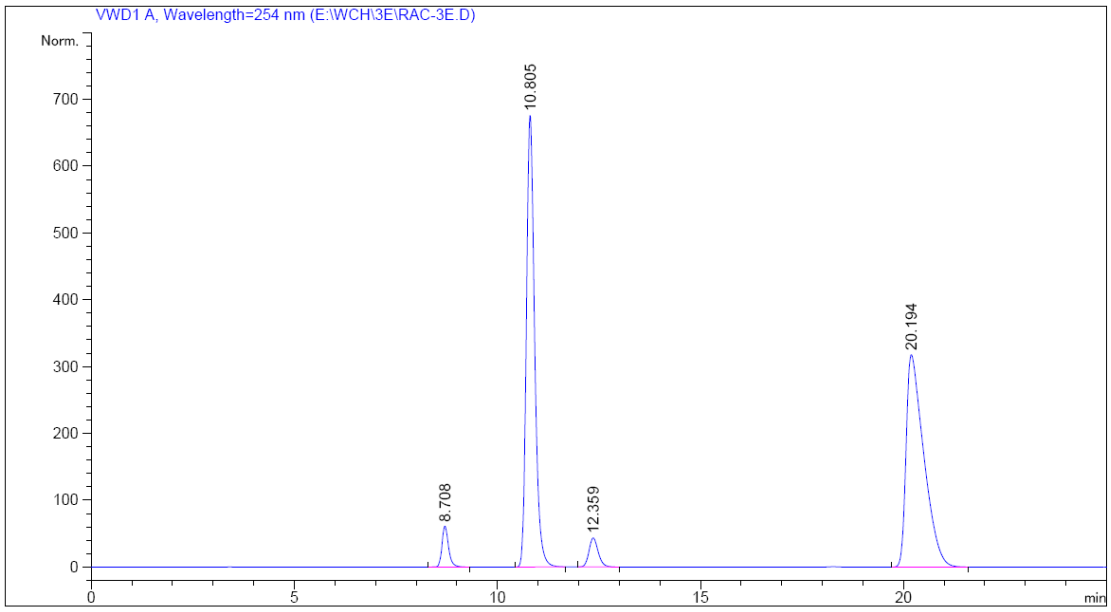


(3-(2-bromophenyl)bicyclo[2.2.1]hept-5-en-2-yl)(1-methyl-1H-imidazol-2-yl)methanone (3e). Purified by column chromatography (SiO_2, EtOAc:petroleum ether = 1:3) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$, *endo* isomer) δ = 7.51 – 7.40 (m, 2H), 7.19 (s, 1H), 7.08 (d, *J*=7.1, 1H), 7.02 – 6.89 (m, 2H), 6.48 (dd, *J*=5.5, 3.3, 1H), 5.88 (dd, *J*=5.6, 2.8, 1H), 4.54 – 4.42 (m, 1H), 3.90 (s, 3H), 3.49 (d, *J*=3.8, 2H), 2.94 (s, 1H), 1.89 (d, *J*=8.6, 1H), 1.51 (dd, *J*=8.7, 1.5, 1H). ^{13}C NMR (100 MHz, $CDCl_3$, *endo* isomer) δ = 191.97 (s), 143.10 (s), 138.84 (s), 133.51 (s), 133.28 (s), 129.00 (s), 128.02 (s), 127.67 (s), 127.49 (s) 127.01 (s), 52.49 (s), 50.35 (s), 49.38 (s), 47.74 (s), 46.48 (s), 36.47 (s). *Endo*/*exo* and ee were determined by chiral-phase HPLC (Daicel chiralpak-ADH, hexane/*i*-PrOH 97:3, 1.0 mL/min, 254 nm). Retention times: 8.7, 12.4 (*exo* isomer); 10.8, 20.2 mins (*endo* isomer).


7.49
7.48
7.47
7.46
7.45
7.43
7.22
7.20
7.19
7.09
7.07
7.00
6.98
6.96
6.95
6.49
6.48
6.47
6.46
5.88
5.87
5.87
4.47
4.46
4.45
3.94
3.90
3.50
3.49
2.94
1.90
1.88
1.52
1.51
1.19
1.18
0.00
2.02
1.44
1.21
2.09
0.91
1.06
0.98
2.67
1.88
1.00
1.06
1.25
13.5
12.5
11.5
10.5
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
f1 (ppm)
N
N
O
Br


191.97
143.10
138.84
138.51
133.28
129.00
128.82
127.67
127.49
127.01
126.39
52.49
50.35
49.38
47.74
46.48
36.47
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)
N
N
O
Br

Racemic **3e**.

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=====================================================================
                        Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: VWD1 A, Wavelength=254 nm

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]    [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1   8.708 BB    0.1715  693.29425   61.23072   3.3801
   2  10.805 BB    0.2168 9516.92188  675.82373  46.3991
   3  12.359 BB    0.2425  685.28882   43.41727   3.3411
   4  20.194 BB    0.4462 9615.49121  317.88895  46.8797

Totals :                  2.05110e4  1098.36067

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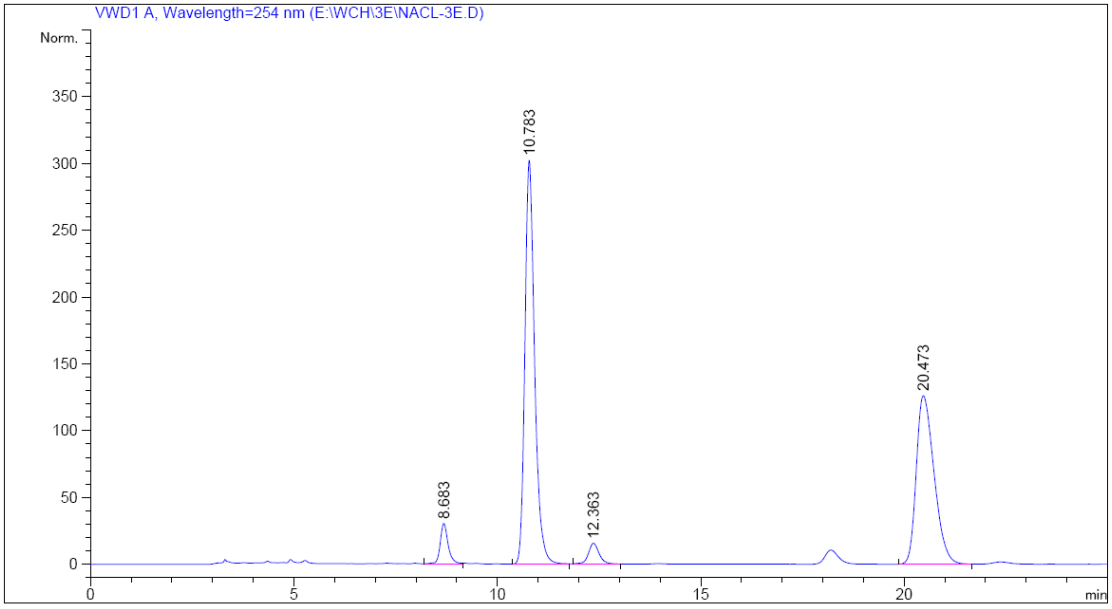
Product **3e** from the Diels-Alder reaction catalyzed by **ODN**-Cu^{2+} in the presence of 100 mM NaCl (13% ee).

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================================================================================
                          Area Percent Report
================================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: VWD1 A, Wavelength=254 nm

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]    [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1   8.683 VB    0.2033  410.20688   30.26702   4.2988
   2  10.783 BB    0.2519 5012.54346  302.14865  52.5288
   3  12.363 BB    0.2786  287.74933   15.54491   3.0155
   4  20.473 BB    0.4739 3831.95947  126.15402  40.1569

Totals :                  9542.45914  474.11460


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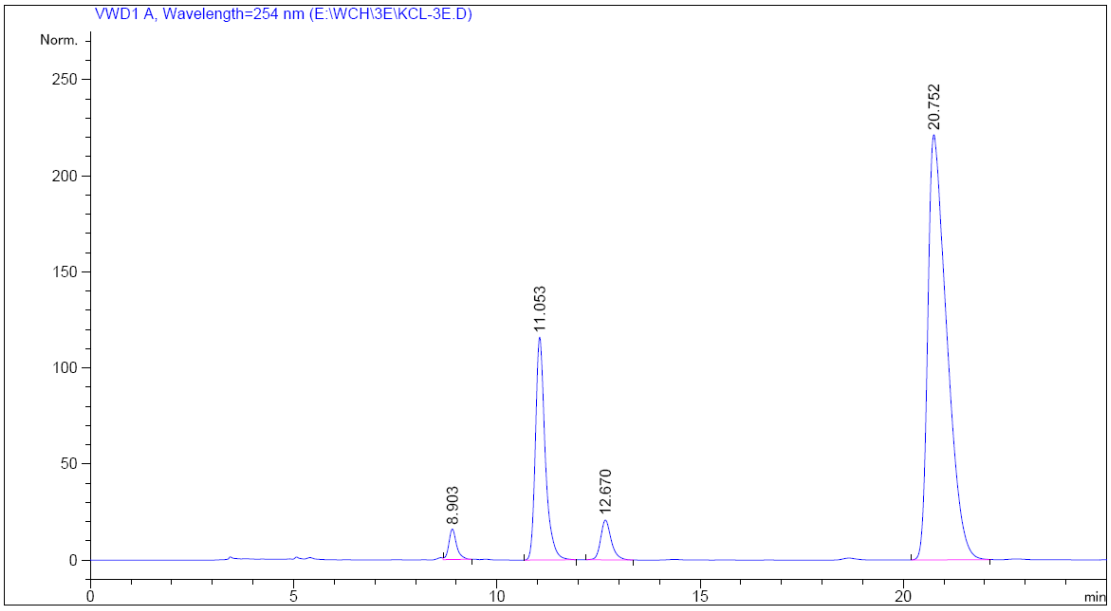
Product **3e** from the Diels-Alder reaction catalyzed by **ODN**-Cu^{2+} in the presence of 25 mM KCl (-58% ee).

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=====================================================================
                      Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier:                   :      1.0000
Dilution:                     :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: VWD1 A, Wavelength=254 nm

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]    [mAU*s]     [mAU]       %
----|-------|----|-------|----------|----------|--------|
   1   8.903 VB    0.1974  209.11696   15.87270   2.1595
   2  11.053 BB    0.2510 1928.89355  115.90283  19.9197
   3  12.670 BB    0.2739  374.79968   20.70445   3.8706
   4  20.752 BB    0.4978 7170.55420  221.13986  74.0502

Totals :                  9683.36440  373.61985

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