Supporting Information
for DOI: 10.1055/s-0031-1289537
© Georg Thieme Verlag KG Stuttgart · New York 2011
C-Quaternary vinylglycinols by metal catalysed cyclization of allylic bis-trichloroacetimidates

Kristine Klimovica, Liene Grigorjeva, Ansis Maleckis, Juris Popelis, Aigars Jirgensons

Latvian Institute of Organic Synthesis, Riga, LV-10 06, Latvia
Fax: + 371 754 14 08.
E-mail: aigars@osi.lv.

Supporting Information

Content
C-Quaternary vinylglycinols by metal catalysed cyclization of allylic bis-trichloroacetimidates ................................................................. 1
General.................................................................................................. 2
1. Synthesis of 2-substituted 1,4-but-2-ene diols Z, E-1 ................................. 2
   1.1. Synthesis of diols Z-1a,b (Scheme 1, Table 1) .................................... 2
   1.2. Synthesis of diols E-1a (Scheme 2) .................................................. 4
   1.3. Synthesis of diols E-1b-e (Scheme 2, Table 2) ................................. 5
2. Characterization of diols E-1a,b and Z-1a-e and intermediates for their synthesis. 6
3. Synthesis of bis-imidates Z-2a,b and E-2a-e (Scheme 4) ......................... 7
4. Characterization of bis-imidates Z-2a,b and E-2a-e ............................... 8
5. General procedures for cyclization of bis-imidates Z-2a,b and E-2a-e, synthesis of oxazolines 3 and 4 (Scheme 5) ...................................................... 10
6. Transformation of vinyloxazolines 3a-c to N-Boc vinylglycinols 5a-c (Scheme 6) ......................................................................................... 14
8. Characterization of N-Boc vinylglycinols 5a-c ........................................ 14
9. 1H-NMR and 13C-NMR spectra of compounds Z-2a,b, E-2a-e, 3a-e, 4a-d, 5a-c, Z-8b and Z-9b ........................................................................... 16
General
Reagents and starting materials were obtained from commercial sources and used as received. The solvents were purified and dried by standard procedures prior to use; petroleum ether of boiling range 60 – 80 °C was used. All reactions were performed under an argon atmosphere. Flash chromatography was carried out using Merck Kieselgel (230 – 400 mesh). Thin layer chromatography was performed on silica gel and was visualized with KMnO₄ stain. NMR spectra were recorded on Varian Mercury spectrometer (200 MHz and 400 MHz) with chemical shifts values (δ) in ppm relative to TMS using the residual chloroform signal as internal standard. Gas chromatographic analysis was performed using HP 6890 gas chromatographic system with HP 5972 MSD detector. HRMS were obtained using Q-TOF micro high resolution mass spectrometer with ESI (ESI+/ ESI-).

1. Synthesis of 2-substituted 1,4-but-2-ene diols Z, E-1

1.1. Synthesis of diols Z-1a,b (Scheme 1, Table 1)
Ethyl 4-(tetrahydro-2H-pyran-2-yloxy)but-2-ynoate (7) was obtained by addition of lithium acetylenide to the ethyl chloroformate according to the reported protocol.¹ Resulting ethyl 4-(tetrahydro-2H-pyran-2-yloxy)but-2-ynoate (7) was transformed to Z-8a using Me₂CuLi and to Z-8b using Ph₂CuMgBr as described in literature¹. Reduction of esters Z-8a,b with DIBAL-H gave products Z-9a,b which were deprotected to provide diols Z-1a,b.²

![Scheme 1](image-url)

**Preparation of ethyl 4-(tetrahydro-2H-pyran-2-yl)but-2-ynoate (7)**

A solution of THP-protected propargyl alcohol 6 (5.00 g, 35.70 mmol) in THF (100 mL) was cooled to -78 °C. n-BuLi (24.50 mL, 1.6 M in hexanes, 39.27 mmol) was added dropwise and the resulting mixture was stirred at -78 °C for 1 h. Ethyl chloroformate (6.86 mL, 71.40 mmol) was added dropwise, and the solution was allowed to warm to -10 °C over a period of 2 h. The reaction was then quenched with sat. NH₄Cl solution (50 mL) and warmed to room temperature. The mixture was concentrated and the residue was dissolved in Et₂O (50 mL). The organic layer was washed with 10% HCl aq. (50 mL), sat. NaHCO₃ solution (50 mL) and brine (50 mL). The organic phase was dried over Na₂SO₄, filtered and concentrated. The residue was purified by flash column chromatography on silica gel using EtOAc/petroleum ether (1 : 10) as an eluent to afford the desired ethyl 4-(tetrahydro-2H-pyran-2-yl)but-2-ynoate (7) (7.39 g, 97%) as a colorless oil.

**General procedure for synthesis of 3-substituted ethylbut-2-enoates: preparation of ethyl (2Z)-3-methyl-4-(tetrahydro-2H-pyran-2-yl)but-2-enoate (Z-8a)**

A solution of MeLi (4.2 mL, 1 M solution in THF, 4.2 mmol) was added dropwise to a suspension of CuI (0.39 g, 2.07 mmol) in THF (7 mL) at 0 °C. This mixture was stirred at 0 °C for additional 0.5 h, then the temperature was lowered to -78 °C. A solution of alkyne 7 (0.40 g, 1.88 mmol) in THF (4 mL) was added dropwise to the solution of dialkyl cuprate. The mixture was stirred at -78 °C for 3 h and then quenched with sat. NH₄Cl solution (11 mL). The mixture was then allowed to warm to room temperature and the precipitate was removed. The organic layer was then separated and aqueous layer extracted with Et₂O (3×10 mL). The combined organic phase was washed with brine (10 mL), dried over Na₂SO₄, filtered and concentrated. The residue was purified by flash column chromatography on silica gel using EtOAc/petroleum ether (1 : 4) as an eluent to afford the desired ethyl (2Z)-3-methyl-4-(tetrahydro-2H-pyran-2-yl)but-2-enoate (Z-8a) (0.37 g, 87%) as a yellow oil.

**General procedure for synthesis of O-THP-protected 2-substituted but-2-en-1,4-diols: preparation of (2Z)-3-methyl-4-(tetrahydro-2H-pyran-2-yl)but-2-en-1-ol (Z-9a).**
A solution of α,β-unsaturated ester Z-8a (0.58 g, 2.54 mmol) in DCM (10 mL) was cooled to 0 °C and to this DIBAL-H (4.70 mL, 1.2 M solution in toluene, 5.64 mmol) was added dropwise. After the addition was completed, the reaction was stirred at 0 °C for additional 1 h, then reaction was quenched with 1 M sodium potassium tartrate solution (10 mL). The organic layer was then separated and aqueous layer was extracted with DCM (3×10 mL). The combined organic phase was washed with distilled H$_2$O (10 mL) and brine (10 mL), dried over Na$_2$SO$_4$, filtered and concentrated to afford the desired (2Z)-3-methyl-4-(tetrahydro-2H-pyran-2-yloxy)but-2-en-1-ol (Z-9a) (0.37 g, 78%) as a colorless oil.

General procedure for synthesis of (2Z)-2-substituted but-2-en-1,4-diols: preparation of (2Z)-2-methylbut-2-ene-1,4-diol (Z-1a)

To a solution of THP-protected 2-methylbut-2-ene-1,4-diol Z-9a (0.30 g, 1.61 mmol) in MeOH (18 mL) p-TsOH·H$_2$O (0.06 g, 0.32 mmol) was added. The mixture was stirred at room temperature for 1 h, then Et$_3$N (0.10 mL) and 2 g of silica gel were added. Resulting mixture was concentrated and purified by flash column chromatography on silica gel using EtOAc as an eluent to afford the desired (2Z)-2-methylbut-2-ene-1,4-diol (Z-1a) (0.13 g, 82%) as a colorless oil.

Table 1

Yields of intermediates and products in the synthesis of Z-diols 1a,b

<table>
<thead>
<tr>
<th>Entry</th>
<th>R</th>
<th>Yield, % (7)</th>
<th>Yields, % (Z-8a,b)</th>
<th>Yields, % (Z-1a,b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Me</td>
<td>97</td>
<td>87, (Z-8a)</td>
<td>85, (Z-1a)</td>
</tr>
<tr>
<td>2</td>
<td>Ph</td>
<td>76, (Z-8b)</td>
<td>87, (Z-1b)</td>
<td></td>
</tr>
</tbody>
</table>

*Total yield in two steps

1.2. Synthesis of olefin E-1a (Scheme 2)

2-Methylbut-2-ene-1,4-diol (E-1a) was synthesized from mesaconic acid 10 by esterification$^3$ and subsequent reduction with DIBAL-H according to the reported protocol.$^4$

---


Preparation of 2-methyl but-2-ene-1,4-diol (E-1a)

Esterification of mesaconic acid

To a solution of mesaconic acid 10 (8.00 g, 61.50 mmol) in MeOH (100 mL) conc. H$_2$SO$_4$ (2 mL) was added. The reaction mixture was refluxed for 5 h (until a complete conversion by TLC) and then neutralized by addition of TEA (1 mL). Silica gel (8 g) was added and the resulting mixture was concentrated in vacuo. The dry residue was applied to a silica gel column and eluted with EtOAc/petroleum ether (1 : 1) to afford the desired mesaconic acid dimethyl ester (8.44 g, 87%) as a colorless oil.

Reduction of mesaconic acid dimethyl ester

Solution of mesaconic acid dimethyl ester (2.00 g, 12.60 mmol) in DCM (26 mL) was cooled to 0 $^\circ$C and DIBAL-H (54.6 mL 1.2 M solution in toluene, 65.52 mmol) was added dropwise. Reaction mixture was stirred at 0 $^\circ$C temperature for 1 h (complete conversion by TLC) and then the reaction was quenched with MeOH (12 mL) and H$_2$O (40 mL). After quenching, the mixture was allowed to warm to room temperature over 2 h, then filtered through a pad of Celite®. Solvent was removed and desired 2-methyl but-2-ene-1,4-diol (E-1a) (1.10 g, 86%) was obtained as a colorless oil.

1.3. Synthesis of olefins E-1b-e (Scheme 2, Table 2)

2-Substituted but-2-ene-1,4-diols E-1b-e was obtained from but-2-yne-1,4-diol (11) and corresponding Grignard reagent as described in literature$^5$.

---

General procedure for synthesis of (2E)-2-substituted but-2-en-1,4-diol: preparation of (2E)-2-phenylbut-2-ene-1,4-diol (E-1b)

To a solution of PhMgBr (15.10 mL, 3.23 M solution in Et₂O, 48.80 mmol) in Et₂O (183 mL) solution of but-2-ynyne-1,4-diol (11) (1.05 g, 12.20 mmol) in THF (25 mL) was added dropwise. Reaction mixture was stirred at room temperature for 0.5 h, then refluxed for 2 h (until complete conversion by TLC). Reaction was cooled to 0 °C and quenched with sat. NH₄Cl solution (60 mL). The mixture was allowed to warm to room temperature then layers were separated and the aqueous layer was extracted with Et₂O (3×50 mL). Organic layers were combined and washed with brine (50 mL) and dried over Na₂SO₄, filtered and concentrated. The residue was purified by flash column chromatography on silica gel using EtOAc as an eluent to give product (2E)-2-phenylbut-2-ene-1,4-diol (E-1b) (1.26 g, 63%) as a colorless oil.

Table 2

<table>
<thead>
<tr>
<th>Entry</th>
<th>RMgX</th>
<th>Yield, % (E-1b-e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PhMgBr</td>
<td>63 (E-1b)</td>
</tr>
<tr>
<td>2</td>
<td>p-MeOC₆H₄MgBr</td>
<td>53 (E-1c)</td>
</tr>
<tr>
<td>3</td>
<td>AllyIMgBr</td>
<td>40 (E-1d)</td>
</tr>
<tr>
<td>4</td>
<td>BnMgCl</td>
<td>20 (E-1e)</td>
</tr>
</tbody>
</table>

2. Characterization of diols E-1a,b and Z-1a-e and intermediates for their synthesis.

Compounds 7, 8a, 9a, 10a, 1b, 1e, 1b-e have been previously described in literature.

Ethyl (2Z)-3-phenyl-4-(tetrahydro-2H-pyran-2-yl)oxy)but-2-enoate (Z-8b)

\[ ^1H-NMR \delta_H, \text{ppm.} \ (400 \text{ MHz}, \text{CDCl}_3): 1.28 \ (3H, t, J 7.1 \text{ Hz}, -OCH}_2\text{CH}_3), 1.41-1.75 \ (6H, m, -OCH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{-}), 3.47-3.55 \ (1H, m, -OCH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{-}), 3.76-3.83 \ (1H, m, -OCH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{-}), 4.20 \ (2H, q, J 7.1 \text{ Hz}, -OCH}_2\text{CH}_3), 4.68 \ (1H, t, J 3.5 \text{ Hz}, -

OCHO), 5.01 (1H, d, J 12.5 Hz, -OCH₂C(Ph)=CH-), 5.09 (1H, d, J 12.5 Hz, -OCH₂C(Ph)=CH-), 6.17 (1H, s, -OCH₂C=CH-), 7.34-7.35 (3H, m, Ph), 7.51-7.53 (2H, m, Ph).

$^{13}$C-NMR: δC, ppm. (100 MHz, CDCl₃): 14.19, 18.70, 25.33, 30.37, 60.20, 62.08, 63.50, 98.56, 120.00, 127.11, 128.17, 128.60, 139.29, 154.10, 165.77.

(2Z)-3-Phenyl-4-(tetrahydro-2H-pyran-2-yl-oxo)-but-2-en-1-ol (Z-9b)

$^1$H-NMR: δH, ppm. (200 MHz, CDCl₃): 1.56-1.78 (6H, m, -OCH₂CH₂CH₂CH₂-), 2.53 (1H, t, J 6.6 Hz -OH), 3.49-3.63 (1H, m, -OCH₂CH₂CH₂CH₂-), 3.81-3.93 (1H, m, -OCH₂CH₂CH₂CH₂-), 4.23-4.51 (2H, m, =CHCH₂OH), 4.54 (1H, d, J 12.5 Hz, -OCH₂C(Ph)=), 4.65 (1H, d, J 12.5 Hz, -OCH₂C(Ph)=), 4.76 (1H, m, -OCHO-), 6.30 (1H, t, J 7.4 Hz, =CHCH₂OH), 7.15-7.37 (3H, m, Ph), 7.47-7.52 (2H, m, Ph).

3. Synthesis of bis-imidates Z-2a,b and E-2a-e (Scheme 4)

**Scheme 4**

General procedure for the synthesis of bis-imidates: preparation of (2Z)-2-methyl but-2-ene-1,4-diol bis-trichloroacetimidate (Z-2a)

To a solution of (2Z)-2-methyl-2-butene-1,4-diol (Z-1a) (0.24 g, 2.35 mmol) in THF (8 mL) 4 Å molecular sieves and DBU (35 μl, 0.23 mmol, 10 mol%) were added. The reaction mixture was cooled to -5 °C, then trichloroacetonitrile (0.60 ml, 5.88 mmol) was added and the reaction mixture was stirred at -5 °C until TLC showed complete conversion (1.5 h). Reaction mixture was filtered through a pad of Celite®. Solvent was removed and the residue was purified by flash column chromatography using petroleum ether/EtOAc (10:1) as an eluent to gave (2Z)-2-methyl but-2-ene-1,4-diol bis-trichloroacetimidate (Z-2a) (0.74 g, 89%) as a colorless oil.
Table 2

Yields of intermediates and products in the synthesis of Z- and E-bis-imidates

<table>
<thead>
<tr>
<th>Entry</th>
<th>R</th>
<th>Yield, % (Z-2a,b)</th>
<th>Yield, % (E-2a-e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Me</td>
<td>89 (Z-2a)</td>
<td>85 (E-2a)</td>
</tr>
<tr>
<td>2</td>
<td>Ph</td>
<td>88 (Z-2b)</td>
<td>80 (E-2b)</td>
</tr>
<tr>
<td>3</td>
<td>p-MeOC₆H₄</td>
<td>-</td>
<td>85 (E-2c)</td>
</tr>
<tr>
<td>4</td>
<td>Allyl</td>
<td>-</td>
<td>80 (E-2d)</td>
</tr>
<tr>
<td>5</td>
<td>Bn</td>
<td>-</td>
<td>69 (E-2e)</td>
</tr>
</tbody>
</table>

4. Characterization of bis-imidates Z-2a,b and E-2a-e

(2Z)-2-Methyl but-2-ene-1,4-diol bis-trichloroacetimidate (Z-2a)

\[ ^1H\text{-NMR} \delta_H, \text{ppm. (400 MHz, CDCl}_3\text{): 1.93 (3H, s, -Me), 4.90 (2H, s, -OCH}_2\text{C(Me)=), 4.93 (2H, d, } J 7.0 \text{Hz, -OCH}_2\text{CH=), 5.72 (1H, t, } J 7.0 \text{Hz, -OCH}_2\text{CH=), 8.31-8.35 (2H, bs, =NH).} \]

\[ ^13\text{C-NMR} \delta_C, \text{ppm. (100 MHz, CDCl}_3\text{): 21.16, 65.10, 67.48, 91.46, 91.54, 123.30, 136.41, 162.29, 162.30.} \]

Unstable in the conditions for HRMS.

(2Z)-2-Phenyl but-2-ene-1,4-diol bis-trichloroacetimidate (Z-2b)

\[ ^1H\text{-NMR} \delta_H, \text{ppm. (400 MHz, CDCl}_3\text{): 5.17 (2H, d, } J 6.7 \text{Hz, =CHCH}_2\text{OH), 5.31 (2H, s, =C(Ph)CH}_2\text{O-), 6.26 (1H, t, } J 6.7 \text{Hz, =CHCH}_2\text{O-), 7.28-7.37 (3H, m, Ph), 7.47-7.49 (2H, m, Ph), 8.38-8.40 (2H, bs, =NH).} \]

\[ ^13\text{C-NMR} \delta_C, \text{ppm. (100 MHz, CDCl}_3\text{): 65.94, 66.28, 91.10, 91.27, 126.70, 127.31, 128.22, 128.58, 138.81, 139.43, 162.53, 162.57.} \]

Unstable in conditions for HRMS.

(2E)-2-Methyl but-2-ene-1,4-diol bis-trichloroacetimidate (E-2a)

\[ ^1H\text{-NMR} \delta_H, \text{ppm. (400 MHz, CDCl}_3\text{): 1.84 (3H, s, -Me), 4.74 (2H, s, =C(Me)CH}_2\text{OH), 4.89 (2H, d, } J 6.6 \text{Hz, =CHCH}_2\text{O-), 5.86 (1H, t, } J 6.6 \text{Hz, =CHCH}_2\text{O-), 8.32-8.34 (2H, bs, =NH).} \]
$^{13}$C-NMR $\delta_C$, ppm. (100 MHz, CDCl$_3$): 14.38, 65.58, 73.25, 91.66, 121.74, 136.03, 162.63, 162.76.

Unstable in the conditions for HRMS.

(2$E$)-2-Phenyl but-2-ene-1,4-diol bis-trichloroacetimida te ($E$-2b)

$^1$H-NMR $\delta_H$, ppm. (400 MHz, CDCl$_3$): 4.79 (2H, d, J 6.8, $=$CHCH$_2$O-), 5.07 (2H, d, J 1.1 Hz, $=$C(Ph)CH$_2$O-), 6.19 (1H, dd, J 1.1 and 6.8 Hz, $=$CHCH$_2$O-), 7.29-7.40 (5H, m, Ph), 8.27 (1H, bs, $=$NH), 8.37 (1H, bs, $=$NH).

$^{13}$C-NMR $\delta_C$, ppm. (100 MHz, CDCl$_3$): 66.44, 71.81, 91.24, 91.36, 123.21, 128.39, 128.61, 128.62, 136.23, 141.14, 162.43, 162.64.

Unstable in the conditions for HRMS.

(2$E$)-2-Methoxyphenyl but-2-ene-1,4-diol bis-trichloroacetimida te ($E$-2c)

$^1$H-NMR $\delta_H$, ppm. (400 MHz, CDCl$_3$): 3.82 (3H, -OMe), 4.80 (2H, d, J 6.8 Hz, $=$CHCH$_2$O-), 5.04 (2H, s, $=$C(p-MeOC$_6$H$_4$)CH$_2$O-), 6.14 (1H, t, J 6.9 Hz, CHCH$_2$O-), 6.88-6.90 (2H, m, Ph), 7.23-7.25 (2H, m, Ph), 8.27 (1H, bs, $=$NH), 8.36 (1H, bs, $=$NH).

$^{13}$C-NMR $\delta_C$, ppm. (100 MHz, CDCl$_3$): 55.24, 66.41, 71.69, 81.21, 114.08, 127.04, 129.69, 134.79, 139.83, 159.04, 162.29, 162.49.

Unstable in the conditions for HRMS.

(2$E$)-2- Allyl but-2-ene-1,4-diol bis-trichloroacetimida te ($E$-2d)

$^1$H-NMR $\delta_H$, ppm. (200 MHz, CDCl$_3$): 3.00 (2H, d, J 6.6 Hz, H$_2$C=$CHCH$_2$-), 4.76 (2H, s, -OCH$_2$C(Allyl)=), 4.90 (2H, d, J 6.6 Hz, -OCH$_2$CH=), 5.05-5.17 (2H, m, H$_2$C=CHCH$_2$=), 5.70-5.98 (2H, m, -OCH$_2$CH= and H$_2$C=CHCH$_2$), 8.33 (2H, bs, $=$NH).

Unstable in the conditions for HRMS.

(2$E$)-2-Benzyl but-2-ene-1,4-diol bis-trichloroacetimida te ($E$-2e)
**1H-NMR** $\delta_{H}$, ppm. (400 MHz, CDCl$_3$): 3.66 (2H, s, -CH$_2$C$_6$H$_5$), 4.70 (2H, s, =C(Bn)CH$_2$O-), 5.05 (2H, d, $J$ 6.8 Hz, =CHCH$_2$O-), 6.07 (1H, t, $J$ 6.8 Hz, =CHCH$_2$O-), 7.22 – 7.33 (5H, m, Ph), 8.33 (1H, bs, =NH), 8.39 (1H, bs, =NH).

**13C-NMR** $\delta_{C}$, ppm. (100 MHz, CDCl$_3$): 34.63, 57.07, 65.55, 71.48, 91.58, 123.45, 126.82, 128.91, 128.94, 137.97, 139.01, 162.57, 162.83.

Unstable in the conditions for HRMS.

5. General procedures for cyclization of bis-imidates Z-2a,b and E-2a-e, synthesis of oxazolines 3 and 4 (Scheme 5)

Method A

To a stirred solution of 2-substituted but-2-ene-1,4-diol bis-trichloroacetimidate 2 (1.00 mmol) in DCM (10 mL) 4 Å molecular sieves and PdCl$_2$(MeCN)$_2$ (0.026 g, 0.10 mmol, 10 mol%) were added. Reaction mixture was stirred at room temperature till full conversion (TLC control), filtered through a short layer of silica gel and then evaporated in vacuo. The residue was purified by chromatography on a short silica gel column eluting with a mixture of light petroleum ether and ethyl acetate (8 : 1) to afford the products 3 and 4.

Method B

To a solution of PdCl$_2$(PPh$_3$)$_2$ (0.007 g, 0.01 mmol, 1 mol-%) in DCM (5 mL) AgBF$_4$ (0.006 g, 0.03 mmol, 3 mol%) was added. Resulting solution was stirred for 0.5 h at room temperature and then this was added to a solution of 2-substituted but-2-ene-1,4-diol bis-trichloroacetimidate 2 (1.00 mmol) in DCM (5 mL), containing 4 Å molecular sieves. Reaction was stirred at room temperature till full conversion (TLC control), filtered through a short layer of silica gel and then reaction solvent was removed under reduced pressure. The residue was purified by chromatography on a
short silica gel column eluting with a mixture of light petroleum ether and ethyl acetate (8 : 1) to afford the product 3.

**Method C**

4 Å Molecular sieves and Lewis acid catalyst (0.10 mmol, 10 mol%) were added to a stirred solution of bis-imidate 2 (1.00 mmol) in DCM (10 mL) at rt. After reaction was complete (TLC control), TEA (0.50 mmol, 50 mol%) was added to the reaction mixture and then the solvent was removed under reduced pressure. The residue was purified by chromatography on a short silica gel column eluting with a mixture of light petroleum ether and ethyl acetate (8 : 1) to afford the product 3.

6. **Characterization of oxazolines 3 and 4**

4-Methyl-4-vinyl-2-(trichloromethyl)oxazoline (3a)

![Structure of 4-Methyl-4-vinyl-2-(trichloromethyl)oxazoline (3a)]

$^1$H-NMR $\delta_H$, ppm. (400 MHz, CDCl$_3$): 1.49 (3H, s, -Me), 4.33 (1H, d, $J$ 8.3 Hz, -OCH$_2$-), 4.48 (1H, d, $J$ 8.3 Hz, -OCH$_2$-), 5.20 (1H, d, $J$ 10.7 Hz, H$_2$C=CH-), 5.24 (1H, d, $J$ 17.4 Hz, H$_2$C=CH-), 5.98 (1H, dd, $J$ 10.7 and 17.4 Hz, H$_2$C=CH-).

$^{13}$C-NMR $\delta_C$, ppm. (100 MHz, CDCl$_3$): 25.77, 72.28, 81.20, 86.64, 114.79, 140.59, 161.86.

HR-MS (EI) [M+H]$^+$: calcd for C$_7$H$_9$NOCl$_3$, 227.9744, found 227.9750.

4-Phenyl-4-vinyl-2-(trichloromethyl)oxazoline (3b)

![Structure of 4-Phenyl-4-vinyl-2-(trichloromethyl)oxazoline (3b)]

$^1$H-NMR $\delta_H$, ppm. (400 MHz, CDCl$_3$): 4.66 (1H, d, $J$ 8.5 Hz, -CH$_2$O-), 4.92 (1H, d, $J$ 8.5 Hz, -CH$_2$O-), 5.27 (1H, J 17.3 Hz, H$_2$C=CH-), 5.31 (1H, d, $J$ 10.6 Hz, H$_2$C=CH-), 6.20 (1H, dd, $J$ 10.6 and 17.26 Hz, H$_2$C=CH-), 7.28-7.33 (1H, m, Ph), 7.35-7.41 (4H, m, Ph).

$^{13}$C-NMR $\delta_C$, ppm. (100 MHz, CDCl$_3$): 78.13, 81.29, 86.78, 115.41, 125.99, 127.89, 128.94, 139.93, 142.94, 162.26.

HR-MS (EI) [M+H]$^+$: calcd for C$_{12}$H$_{11}$NOC$_3$, 289.9900, found 289.9906.

4-Methoxyphenyl-4-vinyl-2-(trichloromethyl)oxazoline (3c)
**4-Allyl-4-vinyl-2-(trichloromethyl)oxazoline (3d)**

1H-NMR δH, ppm. (400 MHz, CDCl3): 2.46 (1H, dd, J 7.4 un 13.9 Hz, H2C=CHCH2-), 2.56 (1H, dd, J 6.8 un 13.9 Hz, H2C=CHCH2-), 4.42 (1H, d, J 8.5 Hz, CCH2O-), 4.50 (1H, d, J 8.5 Hz, CCH2O-), 5.16-5.27 (4H, m, H2C=CH-, H2C=CHCH2-), 5.67-5.77 (1H, m, H2C=CHCH2-), 6.02 (1H, dd, J 10.7 and 17.5 Hz, H2C=CH-).

13C-NMR δC, ppm. (100 MHz, CDCl3): 43.42, 74.76, 78.06, 115.19, 120.04, 139.69, 161.89.


**4-Benzyl-4-vinyl-2-(trichloromethyl)oxazoline (3e)**

1H-NMR δH, ppm. (400 MHz, CDCl3): 2.93 (1H, d, J 13.7 Hz, -CH2Ph), 3.16 (1H, d, J 13.7 Hz, -CH2Ph), 4.38 (1H, d, J 8.5 Hz, -CH3O-), 4.56 (1H, d, J 8.5 Hz, -CH3O-), 5.25-5.29 (2H, m, H2C=CH-), 6.09 (1H, dd, J 10.7 and 17.5 Hz, H2C=CH-), 7.20-7.32 (5H, m, Ph).

13C-NMR δC, ppm. (100 MHz, CDCl3): 45.09, 75.55, 77.92, 86.64, 115.36, 127.15, 128.47, 130.85, 135.25, 140.35, 161.83.

HR-MS (EI) [M]^+: calcd for C13H13NOCl3, 304.0063, found 304.0042.

**4-(Prop-1-ene-2-yl)-2-(trichloromethyl)oxazoline (4a)**

1H-NMR δH, ppm. (400 MHz, CDCl3): 1.75 (3H, s, Me), 4.40 (1H, t, J 8.4 Hz, -CHCH2O-), 4.71 (1H, dd, J 8.5 and 10.1 Hz, -CHCH2O-), 4.86 (1H, dd, J 7.7 and 10.1 Hz, -CHCH2O-), 4.95
(1H, m, H₂C=C(CH₃)-), 5.00 (1H, m, H₂C=C(CH₃)-).

$^{13}$C-NMR $\delta$C, ppm. (100 MHz, CDCl₃): 18.46, 71.79, 75.23, 81.03, 113.67, 142.35, 163.14.

HR-MS (EI) [M+H]$^+$: calcd for C₇H₉NOCl, 227.9744, found 227.9750.

4-(1-Phenylvinyl)-2-(trichloromethyl)oxazoline (4b)

$^1$H-NMR $\delta$H, ppm. (400 MHz, CDCl₃): 4.29 (1H, t, $J$ 8.3 Hz, -CHCH₂O-), 4.80 (1H, dd, $J$ 8.4 and 10.2 Hz, -CHCH₂O-), 5.37 (1H, s, H₂C=CH-), 5.41 (1H, dd, $J$ 8.4 and 10.2 Hz, -CHCH₂O-), 5.50 (1H, s, H₂C=CH-), 7.30-7.39 (5H, m, Ph).

$^{13}$C-NMR $\delta$C, ppm. (100 MHz, CDCl₃): 69.29, 76.72, 86.67, 114.48, 126.64, 128.33, 128.84 138.79, 146.76, 163.57.

HR-MS (EI) [M+H]$^+$: calcd for C₁₂H₁₁NOC₁₃, 289.9900, found 289.9906.

4-(4-Methoxyphenylvinyl)-2-(trichloromethyl)oxazoline (4c)

$^1$H-NMR $\delta$H, ppm. (400 MHz, CDCl₃): 3.82 (3H, s, -OMe), 4.28 (1H, t, $J$ 8.3 Hz, -CHCH₂O-), 4.80 (1H, dd, $J$ 8.4 and 10.3 Hz, -CHCH₂O-), 5.27-5.28 (1H, m, H₂C=C-), 5.38 (1H, dd, $J$ 8.5 and 10.3 Hz, -CHCH₂O-), 5.41 (1H, s, H₂C=C-), 6.88-6.90 (2H, m, p-MeOC₆H₄), 7.27-7.29 (2H, m, p-MeOC₆H₄).

HR-MS (EI) [M+H]$^+$: calcd for C₁₃H₁₃NO₂C₁₃, 320.0000, found 320.0012.

4-(1-Methylenebut-3-en-1-yl) 2-(trichloromethyl)oxazoline (4d)

$^1$H-NMR $\delta$H, ppm. (400 MHz, CDCl₃): 2.69-2.81 (2H, m, H₂C=CHCH₂-), 4.32 (1H, t, $J$ 8.2 Hz, -CHCH₂O-), 4.66 (1H, dd, $J$ 8.2 and 10.2 Hz, -CHCH₂O-), 4.82 (1H, dd, $J$ 8.0 and 10.1 Hz, -CHCH₂O-), 4.95 (1H, d, $J$ 1.0 Hz, H₂C=CHCH₂-), 5.01-5.09 (3H, m, H₂C=CHCH₂-, H₂C=CH-), 5.70-5.80 (1H, m, H₂C=CHCH₂).

$^{13}$C-NMR $\delta$C, ppm. (100 MHz, CDCl₃): 37.5, 70.49, 75.66, 113.45, 117.49, 134.97, 145.29, 163.21.

GC-MS: m/z (EI): 254 (M$^+$).
7. Transformation of vinyloxazolines 3a-c to N-Boc vinylglycinols 5a-c (Scheme 6)

\[
\begin{align*}
3a-c & \xrightarrow{1) \ 6 \ M \ HCl, \text{EtOH}, \text{r.t.}} \ 5a-c \\
& \xrightarrow{2) \ \text{sat. NaHCO}_3, \text{Boc}_2\text{O}, \text{THF}, \text{r.t.}} \\
\end{align*}
\]

Scheme 6


\[6 \ M \ HCl_{aq} (1 \ mL) \text{ was added to a solution of oxazoline } 3a (0.11 \ g, 0.50 \ mmol) \text{ in EtOH (1 mL) and the reaction mixture was stirred at room temperature for 12 h, then concentrated in vacuo. The residue was dissolved in a mixture of saturated NaHCO}_3 \text{ solution (3 mL) and THF (3 mL). Boc}_2\text{O (0.33 g, 1.5 mmol, 3 equiv) was added to the resulting biphasic mixture and vigorous stirring was continued overnight. Layers were separated and the aqueous phase was extracted with EtOAc (3×5 mL). Organic layers were combined and washed with distilled H}_2\text{O (10 mL) and brine (10 mL), dried over Na}_2\text{SO}_4 \text{ and concentrated. The residue was purified by flash column chromatography on silica gel eluting with a mixture of petroleum ether and ethyl acetate (gradient 4 : 1 to 1 : 1) to afford tert-butyl [1-(hydroxymethyl)-1-methylprop-2-en-1-yl]carbamate (5a) (0.07 g, 70%).} \]

8. Characterization of N-Boc vinylglycinols 5a-c.

**Tert-butyl [1-(hydroxymethyl)-1-methylprop-2-en-1-yl]carbamate (5a)**

\[\begin{align*}
\text{^1H-NMR} \ \delta_H, \ \text{ppm. (400 MHz, CDCl}_3): \ 1.32 \ (3H, \ s, \ Me), \ 1.44 \ (9H, \ s, \ -C(CH}_3}_3), \ 3.58 \ (1H, \ dd, \ J 11.4 \text{ and } 5.5 \text{ Hz, } -CH}_2\text{OH),} \\
3.64 \ (1H, \ dd, \ J 11.4, \ 6.7 \text{ Hz, } -CH}_2\text{OH),} \ 3.76 \ (1H, \ bs, \ -OH), \ 4.85 \ (1H, \ bs, \ -NH), \ 5.18 \ (1H, \ m, \ H}_5\text{C=CH- and H}_2\text{C=CH-},) \ 5.88 \ (1H, \ dd, \ J 10.6 \text{ and 17.6, Hz, } -CH=CH}_2). \\
\text{^13C-NMR} \ \delta_C, \ \text{ppm. (100 MHz, CDCl}_3): 23.06, \ 28.31, \ 58.47, \ 70.05, \ 79.89, \ 114.1, \ 140.46, \ 150.87. \\
\text{HR-MS (EI) [M+Na]}}^+: \text{calcd for C}_{10}H_{19}NO_3Na, 224.1263, \text{found 224.1236.}
\]
**Tert-butyl [1-(hydroxymethyl)-1-phenylprop-2-en-1-yl]carbamate (5b)**

\[^1^H\text{-NMR}\] \(\delta_{H}, \text{ppm. (400 MHz, CDCl}\text{)}^3\): 1.43 (9H, m, -OC(CH\text{)}_3\text{)}, 3.83-4.03 (3H, m, -OH and -CH\text{2OH}), 5.22-5.31 (2H, m, -NH and H\text{2C=CH)}), 5.40 (1H, d, \(J 10.7 \text{ Hz, H\text{2C=CH}}\)), 6.25 (1H, dd, \(J 10.7 \text{ and } 17.4 \text{ Hz, H\text{2C=CH}}\)), 7.27-7.30 (1H, m, Ph), 7.34-7.41 (4H, m, Ph).

\[^{13}\text{C-NMR}\] \(\delta_{C}, \text{ppm. (100 MHz, CDCl}\text{)}^3\): 28.42, 69.57, 80.31, 116.04, 126.39, 127.66, 128.67, 138.83, 141.65, 155.92.

**HR-MS** (El) [M]: calcld for C\text{15}H\text{21}NO\text{3}Na 286.1419, found 286.1397.

**Tert-butyl[1-(hydroxymethyl)-1-(4-methoxyphenyl)prop-2-en-1-yl]carbamate (5c)**

\[^1^H\text{-NMR}\] \(\delta_{H}, \text{ppm. (400 MHz, CDCl}\text{)}^3\): 1.42 (9H, bs, -OC(CH\text{)}_3\text{)}, 3.80 (4H, m, -OCH\text{3} and -OH), 3.99 (2H, m, -CH\text{2OH}), 5.20-5.25 (2H, m, -NH and H\text{2C=CH)}, 5.38 (1H, d, \(J 10.7 \text{ Hz, H\text{2C=CH}}\)), 6.22 (1H, dd, \(J 10.7 \text{ and } 17.4 \text{ Hz, H\text{2C=CH}}\)), 6.87-6.89 (2H, m, -C\text{6H}_4\text{)}, 7.30-7.32 (2H, m, -C\text{6H}_4\text{}).

\[^{13}\text{C-NMR}\] \(\delta_{C}, \text{ppm. (100 MHz, CDCl}\text{)}^3\): 28.45, 55.41, 64.59, 69.64, 80.32, 114.03, 115.86, 127.60, 133.73, 138.99, 155.93, 159.01.

**LC-MS**: m/z (El): 294 (M\text{+}).
9. $^1$H-NMR and $^{13}$C-NMR spectra of compounds Z-2a,b, E-2a-e, 3a-e, 4a-d, 5a-c, Z-8b and Z-9b
(2Z)-2-Methyl but-2-ene-1,4-diol bis-trichloroacetimidate (Z-2a) ($^1$H-NMR)
(2Z)-2-Methyl but-2-ene-1,4-diol bis-trichloroacetimidate (Z-2a) (\(^{13}\text{C}-\text{NMR}\)
(2Z)-2-Phenyl but-2-ene-1,4-diol bis-trichloroacetimide (Z-2b) ($^1$H-NMR)
(2Z)-2-Phenyl but-2-ene-1,4-diol bis-trichloroacetimidate (Z-2b) \((^{13}\text{C-NMR})\)
(2E)-2-Methyl but-2-ene-1,4-diol bis-trichloroacetimide (E-2a) (¹H-NMR)
(2E)-2-Methyl but-2-ene-1,4-diol bis-trichloroacetimidate (E-2a) ($^{13}$C-NMR)
(2E)-2-Phenyl but-2-ene-1,4-diol bis-trichloroacetimidate (E-2b) (1H-NMR)
(2E)-2-Phenyl but-2-ene-1,4-diol bis-trichloroacetimdate (E-2b) $^{13}$C-NMR
(2E)-2-Methoxyphenyl but-2-ene-1,4-diol bis-trichloroacetimidate (E-2c) (\(^1\)H-NMR)
(2E)-2-Methoxyphenyl but-2-ene-1,4-diol bis-trichloroacetimide (E-2c) ($^{13}$C-NMR)
(2E)-2-Allyl but-2-ene-1,4-diol bis-trichloroacetimidate (E-2d) ($^1$H-NMR)
(2E)-2-Benzyl but-2-ene-1,4-diol bis-trichloroacetimidate (E-2e) (1H-NMR)
(2E)-2-Benzyl but-2-ene-1,4-diol bis-trichloroacetimidate (E-2e) ($^{13}$C-NMR)

![Chemical Structure Diagram](image-url)
4-Methyl-4-vinyl-2-(trichloromethyl)oxazoline (3a) ($^1$H-NMR)
4-Methyl-4-vinyl-2-(trichloromethyl)oxazoline (3a) ($^{13}$C-NMR)
4-Phenyl-4-vinyl-2-(trichloromethyl)oxazoline (3b) ($^1$H-NMR)
4-Phenyl-4-vinyl-2-(trichloromethyl)oxazoline (3b) ($^{13}$C-NMR)
4-Methoxyphenyl-4-vinyl-2-(trichloromethyl)oxazoline (3c) ($^1$H-NMR)
4-Methoxyphenyl-4-vinyl-2-(trichloromethyl)oxazoline (3c) \(^{13}\text{C-NMR}\)
4-Allyl-4-vinyl-2-(trichloromethyl)oxazoline (3d) (\(^1\)H-NMR)
4-Allyl-4-vinyl-2-(trichloromethyl)oxazoline (3d) ($^{13}$C-NMR)
4-Benzyl-4-vinyl-2-(trichloromethyl)oxazoline (3e) ($^1$H-NMR)
4-Benzy1-4-vinyl-2-(trichloromethyl)oxazoline (3e) ($^{13}$C-NMR)
4-(Prop-1-ene-2-yl)-2-(trichloromethyl)oxazoline (4a) \(^1\)H-NMR

\[
\text{\begin{tikzpicture}
    \node (a) at (0,0) {4-(Prop-1-ene-2-yl)-2-(trichloromethyl)oxazoline (4a) \(^1\)H-NMR};
    \end{tikzpicture}}
\]
4-(Prop-1-ene-2-yl)-2-(trichloromethyl)oxazoline (4a) ($^{13}$C-NMR)
4-(1-Phenylvinyl)-2-(trichloromethyl)oxazoline (4b) ($^1$H-NMR)
4-(1-Phenylvinyl)-2-(trichloromethyl)oxazoline (4b) ($^{13}$C-NMR)
4-(4-Methoxyphenylvinyl)-2-(trichloromethyl)oxazoline (4c) $({}^1$H-NMR)
4-(1-Methylenebut-3-en-1-yl) 2-(trichloromethyl)oxazoline (4d) (\(\text{\(^1\)H-NMR}\))
4-(1-Methylenebut-3-en-1-yl) 2-(trichloromethyl)oxazoline (4d) (\(^{13}\)C-NMR)
Tert-butyl [1-(hydroxymethyl)-1-methylprop-2-en-1-yl]carbamate (5a) ($^1$H-NMR)
$Tert$-butyl [1-(hydroxymethyl)-1-methylprop-2-en-1-yl]carbamate (5a) ($^{13}$C-NMR)

| 140.47 | 111.06 | 79.999 | 69.421 | 58.491 | 38.248 | 25.101 |

![Chemical Structure](image)
Tert-butyl [1-(hydroxymethyl)-1-phenylprop-2-en-1-yl]carbamate (5b) ($^1$H-NMR)

![NMR spectrum of tert-butyl [1-(hydroxymethyl)-1-phenylprop-2-en-1-yl]carbamate (5b)](image-url)
Tert-butyl [1-(hydroxymethyl)-1-phenylprop-2-en-1-yl]carbamate (5b) \(^{13}\text{C-NMR}\)
Tert-butyl[1-(hydroxymethyl)-1-(4-methoxyphenyl)prop-2-en-1-yl]carbamate (5c) (\(^1\)H-NMR)
*Tert*-butyl[1-(hydroxymethyl)-1-(4-methoxyphenyl)prop-2-en-1-yl]carbamate (5c) ($^{13}\text{C-NMR}$)
Ethyl (2Z)-3-phenyl-4-(tetrahydro-2H-pyran-2-yloxy)but-2-enoate (Z-8b) ($^1$H-NMR)
Ethyl (2Z)-3-phenyl-4-(tetrahydro-2H-pyran-2-yl)oxy)but-2-enoate (Z-8b) ($^{13}$C-NMR)
2Z)-3-Phenyl-4-(tetrahydro-2H-pyran-2-yl)oxy)but-2-en-1-ol (Z-9b) \(^{1}H-NMR\)