CHAPTER V

Attempt towards the synthesis of novel enantiomerically pure (4S, 5S)-4- (2-hydroxy-2,2-diarylethyl)-2,2-Dimethyl \( \alpha,\alpha',\alpha',\alpha' \)-tetra aryl-1,3-dioxolane-4,5-dimethanols (TADDOLs) analogues and their application as chiral ligands in asymmetric Diels-Alder reaction.

V.01. Syntheses and applications of chiral diols: Chiral 1,2 Diols

The Chiral 1,2 diols are proven to be efficient synthons for a number of synthetic ventures including stereoselective synthesis of natural and synthetic targets. Chiral catalysts derived from certain 1,2-diol ligands have been found to show high enantioselectivity in certain asymmetric reactions like Diels- Alder reaction, Dialkyl zinc addition to aldehydes and ketones etc. A large number of 1, 2-diol based chiral molecules are commercially available\(^{144,145}\)(Figure-V.01).

![Figure-V.01: Commercially available chiral 1,2 diols](image)

It is inferred that the biological activity of some naturally occurring molecules are due to the presence of 1, 2-diol moiety\(^{146}\) (Figure-V.02).
There are several methods available for the syntheses of chiral diols which include Sharpless asymmetric dihydroxylation (ADH)\(^\text{147}\), Upjohn dihydroxylation\(^\text{148}\), Preovost reaction and Ruthenium catalysed dihydroxylation reaction\(^\text{149-152}\). Among them the most significant methods are the ADH and the RuO\(_4\)-catalysed oxidation of olefin to \(\alpha\)-hydroxy ketone.

**V.02. 1,4 Diols: TADDOLs**

The (4S, 5S)-4- (2- hydroxy- 2,2 – diarylethyl) -2,2–Dimethyl \(\alpha,\alpha,\alpha',\alpha'\)-tetra aryl-1,3-dioxolane-4,5-dimethanols (TADDOLs) are one of the versatile chiral reagents which contain two adjacent diarylhydroxymethyl groups in a trans relationship on a 1,3-dioxolane ring and can be prepared from acetals or ketals of tartrate esters using Grignard reagents. The basic structure of TADDOL is shown in Figure- V.03.

![Figure-V.03](image1.png)

The gross structure of the TADDOL has been found to have profound influence on both the rate and the enantioselectivity in cycloaddition reactions.

The two hydroxyl groups of TADDOL molecule can act as a double hydrogen-bond donor allowing the formation of bidentate complexes. Moreover, these functional groups can be easily substituted giving access to a variety of derivatives (Scheme- V. 01).
Reports on the preparation of large number of TADDOL analogues and their subsequent use as chiral agents (catalysts and ligands) are available. The chiral catalysis includes asymmetric dialkyl zinc addition to aldehydes and ketones.\textsuperscript{153, 154} Few of the widely used TADDOL ligands [169- 182] are given in (Figure- IV.04).

Scheme- V.01.

\[ X = \text{nucleophile, } Z = \text{Divalent metal} \]
V.03. Results and Discussion

In this background, attempts have been made to prepare chiral (4S,5S)-4-(2-Hydroxy-2,2-diarylethyl)-2,2-Dimethyl-\(\alpha,\alpha,\alpha',\alpha'\)-tetraaryl-1,3-dioxolane-4,5-dimethanols, analogous of TADDOL [170], from the title acids. Also attempts have been made to use these TADDOLates as chiral ligands in the asymmetric Diels-Alder reaction employing cyclopentadiene [189] and 3-crotonyl oxazolidinone [190], leading to the formation of endo adduct, namely 3-\((2S,3R)-3\)-methyl bicyclo [2.2.1] hept-5-on-2-yl\}-carbonyl \}-1,3-oxazolan-2-one [193], as the major product.

V.03(i). Preparation of Trialkyl (1S,2S)-and (1S,2R)-1,2-dihydroxy-1,2,3-propanetricarboxylates[114 – 117].

Owing to two chiral centres and vicinal diol moiety, trialkyl esters of 1 and 2 are expected to find extensive applications in asymmetric reactions. These derivatives have been prepared following the method given below.

The method has an added advantage over the conventional method of esterification. The conventional method often generate a mixture of dialkyl and trialkyl esters in almost equal amounts, where as the new method generate only trialkyl esters. Hence treatment of 1 or 2 with aqueous sodium hydroxide under refluxing condition followed by the addition of methanol furnished highly hygroscopic trisodium salts namely trisodium (1S,2S)-1,2-dihydroxy-1,2,3-propanetricarboxylate [112] and trisodium (1S,2R)-1,2-dihydroxy-1,2,3-propanetricarboxylate [113] (Scheme-V.02). The formation of 112 and 113 have been confirmed on the basis of \(^1\)H and \(^{13}\)C NMR spectral data (Figures -V.05 a-b and V.06a-b). Refluxing thionyl chloride with a suspension of 112 in methanol yielded exclusively the trimethyl ester namely trimethyl (1S,2S)-1,2-dihydroxy-1,2,3-propanetricarboxylate [114, \([\alpha]_D = +22.14^0 \) (c 0.52, CHCl\(_3\))]. Similarly the trimethyl (1S,2R)-1,2 dihydroxy-1,2,3-
propanetricarboxylate [116] was also obtained. Following the same procedure with isopropyl alcohol, trisopropyl (1S,2S)-1,2-dihydroxy-1,2,3-propanetricarboxylate [115, [α]D = +62.4° (c 0.75, CHCl₃)] and trisopropyl (1S,2R)-1,2-dihydroxy-1,2,3-propanetricarboxylate [117, [α]D = +101° (c 1.0, CHCl₃)] have been prepared (Scheme V.02). The compounds were characterized on the basis of IR, ¹H, ¹³C NMR and mass spectral data (Figures V.07a-d, V.08a-d, V.09a-d and V.10a-d).
Figure-V.06a

Figure-V.06b

Figure-V.07 a
$COOCH(CH_3)_2$
Figure V.09b

Figure V.09c

Figure V.09d

Figure V.10 a
V.03(ii). Preparation of Dimethyl (4S,5S)-and (4S,5R)-2,2-dialkyl-4-(2-oxo-2-methoxyethyl)-1,3-dioxolane-4,5-dicarboxylates [183-186].

One of the efficient methods for the protection of vicinal diol involves the conversion of the diol in to the corresponding acetonide derivatives. This type of protection is essential for further chemical transformations like Grignard reaction, alkylation reaction etc. Hence compounds 114,115,116 and 117 have been successfully converted to the corresponding acetonides derivatives 183-186.

Attempts to prepare acetonides [183-186] from 1,2 diols [114-117] following conventional procedures failed as the molecule is susceptible to lactonisation. This is due to the fact that, conditions for ketal formation are ideally suited for lactonisation also. However refluxing of solution of either 114 or 115 in dry acetone, in the presence of anhydrous copper sulphate and catalytic quantity of concentrated sulphuric acid, for 4 hours followed by work up furnished the acetonides namely Dimethyl (4S,5S)-4-[methoxy(oxo)ethyl]-2,2-dimethyl-1,3-dioxolane-4,5-dicarboxylate[183, [α]D = +29° (c 1.0, CHCl3)]and Diisopropyl (4S,5S)-2,2-dimethyl-4-(2-oxo-2-methoxyethyl)-1,3-dioxolane-4,5-dicarboxylate[184], respectively in good yield and purity(Scheme -V.03). These compounds have been characterized by IR,1H & 13C NMR and mass spectral data (Figures -V.11a-d & V.12a-d).

![Scheme-V.03](image-url)
Figure-V.11 a

Figure-V.11 b

Figure-V.11 c
V.03(iii). Synthesis of (4S,5S)-4-(2-hydroxy-2,2-diarylethyl)-2,2-dimethyl – α,α,α',α'- tetraaryl -1,3-dioxalane- 4,5-dimethanol

The Grignard reactions have been carried out on 183 and 185 with the aim of obtaining (4S,5S) -4-(2-hydroxy-2,2-diarylethyl)-2,2-dimethyl – α,α,α',α'- tetraaryl -1,3-dioxalane- 4,5-dimethanols adhering to the general method developed by Seebech et al in the preparation of tartaric acid derived TADDOL\textsuperscript{161} (Scheme-V.04).
Refluxing a solution of 183, derived from 1, with 1-Naphthyl magnesium bromide in dry THF furnished optically active (4S,5S)-4-[2-hydroxy-2,2-di(1-naphthyl) ethyl]-2,2-dimethyl-α,α,α',α'-tetra(1-naphthyl)-1,3-dioxalane-4,5-dimethanol [187, [α]D29 = - 27.03°(C 2.2, CHCl3)]. Similarly refluxing a solution of 183 with phenyl magnesium bromide in dry tetrahydrofuran yielded (4S,5S)-4-[2-hydroxy-2,2-diphenylethyl]-2,2-dimethyl-α,α,α',α'-tetraphenyl-1,3-dioxalane-4,5-dimethanol [188] (Scheme-V.05). However repeated work up failed to furnish pure products which is evident from the NMR spectrum. The formations of 187 & 188 have been tentatively proposed on the basis of IR and mass spectral data (Figure -V.13a-d).
The various steps involved in the conversion of 1 to TADDOL analogues is shown in (Scheme-V.06).
V.03(iv). Synthesis of Chiral Titanium TADDOLates

Reports are available on the preparation and use of Chiral alkoxytitanium complexes from chiral diols. These complexes have been effectively used as chiral Lewis acid catalysts in Diels-Alder reaction involving cyclopentadiene and acrylamide/crotonamide which lead to the formation of respective endo-cycloadducts with high enantiomeric excess (90–95%).\(^{162}\) It has also been found that a class of crotonamides (3-acyl-1,3-oxazolidin-2-ones) react with cyclopentadiene to give cycloadducts in the presence of certain titanium complexes (Scheme-V.07).
On the basis of the above observation attempts have been made to carry out the Diels-Alder reaction between cyclopentadiene and 3-crotonyl oxazolidinone employing chiral titanium complexes generated insitu from the chiral triols obtained from 1 and dichlorodiisopropoxy titanium reagents.

V.03(v). Asymmetric Diels-Alder reaction employing (4S,5S)-4-[2-hydroxy-2,2-diphenylethyl]-2,2-dimethyl-α,α',α'-tetraphenyl-1,3-dioxalane-4,5-dimethanol

The asymmetric Diels-Alder reaction, between 189 and 190 in the presence 188 as chiral catalyst, has been carried out to furnish 1-[(3-methyl bicyclo[2.2.1] hept-5-ene-2-yl) carbonyl]-1,3-oxazoline-2-one [193] (Scheme-V.08). The endo stereochemistry of 193 was confirmed on the basis of analytical data and it showed an optical rotation \([\alpha]_D = -23.892^\circ\). When the same reaction was carried out using the catalyst 187 the endo cycloadduct 193 was isolated and it showed an optical rotation of \([\alpha]_D = -15.00^\circ\). The formation of 193 has been ascertained on the basis of \(^1\)H and \(^{13}\)C NMR data (Figure.V.14a-b)

Enantiomeric excesses of endo products were calculated from the maximum specific rotation values available in the literature. The recorded \([\alpha]_D\) values and the calculated enantiomeric excess (ee) of the endo products are given in Table.V.01.
Table V.01. The Diels-Alder adducts and their optical activity.

<table>
<thead>
<tr>
<th>Ligand used</th>
<th>[α]_D of 193</th>
<th>Enantiomeric excess ( % )</th>
</tr>
</thead>
<tbody>
<tr>
<td>187</td>
<td>-15.00 °</td>
<td>7.85*</td>
</tr>
<tr>
<td>188</td>
<td>-23.892 °</td>
<td>12.04*</td>
</tr>
</tbody>
</table>

Reported \[163\] [α]_D value of 193 when tartaric acid based TADDOL was used as ligand: -191°

Thus 7.85 % ee is obtained for the *endo* adduct 193 when ligand 187 is used as catalyst in the Diels- Alder reaction and 12.04 % *e.e* is obtained in the case when 188 is used as catalyst.
V.04. Conclusion

The (2S,3S)-tetrahydro-3-hydroxy-5-oxo-2,3-furan dicarboxylic acid has been effectively converted to the TADDOL analogue namely (4S,5S)-4-(2-Hydroxy-2,2-diphenyl ethyl)-2,2-Dimethyl-α,α,α',α'-tetrylaryl-1,3-dioxolane-4,5-dimethanol [188] and (4S,5S)-4-(2-Hydroxy-2,2-di(1-naphthyl)ethyl)-2,2-Dimethyl-α,α,α',α'-tetraaryl-1,3-dioxolane-4,5-dimethanol [187]. These triols have been subsequently employed as chiral ligands in asymmetric Diels-Alder reactions involving cyclopentadiene and 3- crotonyl oxazolidinone. The optically active Diels-Alder adduct namely 1-[(3-methyl bicyclo[2.2.1] hept-5-ene-2-yl) carbonyl]-2-pyrrolidinone [193] is isolated as major product and the endo stereochemistry has been established.

V.05. Experimental

V.05(i). Preparation of Trisodium (1S,2S)-1,2-dihydroxy-1,2,3-propanetricarboxylate [112]

To an aqueous solution of 1 (1.0 g, 5.25 mmol, in 5 ml water), 2N of sodium hydroxide solution was added at about 80°C, till the reaction mixture is alkaline (~ pH = 9.0). The residue obtained after evaporation under reduced pressure, was triturated with dry methanol (5 x 25 ml). The solid obtained was finally dried under vacuum. Yield: 1.1 g (76.5 %).

\[
\begin{align*}
{^1H} \text{NMR} (D_2O) & : \delta 4.08 (s, 1H), 3.36 (s, 1H), 2.82(d, J = 15.9 \text{ Hz}, 1H), 2.71 (d, J = 15.9 \text{ Hz}, 1H) \text{ ppm.} \\
{^{13}C} \text{NMR} (D_2O) & : \delta 181.5, 180.6, 1793, 79.7, 77.9, 44.3 \text{ ppm.}
\end{align*}
\]

V.05(ii). Preparation of Trimethyl (1S,2S)-1,2-dihydroxy-1,2,3-propanetricarboxylate [114]

To a suspension of 112 (1.0 g, 3.65 mmol) in dry methanol (10 ml), thionyl chloride (1.5 ml, 20 mmol) was added at 0°C. After refluxing for two hours, the reaction mixture was cooled and neutralised with saturated aqueous solution of sodium bicarbonate. The residue obtained upon concentration under reduced pressure was extracted with chloroform (3 x 20 ml). The combined extract was dried and concentrated to furnish 114 as an yellow oil.
Yield : 0.5 g (50 %).

$[\alpha]_D$ : +22.14 $^0$ (c 0.52, CHCl$_3$)

IR (film) : 3494, 3009, 2969, 1748, 1452, 1128, 1081, 1013 cm$^{-1}$

$^1$H NMR (CDCl$_3$) : $\delta$ 4.98 (s, 1H), 3.84 (s, 6H), 3.68 (s, 3H), 3.2 (d, $J = 18.0$ Hz, 1H), 2.80 (d, $J = 18.0$ Hz, 1H) ppm.

$^{13}$C NMR (CDCl$_3$) : $\delta$ 172.3, 170.7, 166.9, 77.3, 74.6, 53.07 52.9, 51.7, 39.25 ppm.

Mass spectrum : m/z 251 (M+1) (100), 219 (23), 191 (32), 159 (50), 143 (3), 131 (4.5), 99 (10.5), 90 (15), 59 (6), 43 (15).

V.05(iii). Preparation of Triisopropyl (1S,2S)-1,2 dihydroxy-1, 2, 3-propanetricarboxylate [115]

The procedure adopted for 114 was followed with (2.0 g, 7.3 mmol), dry isopropyl alcohol (20 ml) and thionyl chloride (3 ml, 40 mmol). The white solid obtained after work-up was recrystallised. Yield 1.2g, 66 %) from hexane.

Yield : 1 g (82%).

$\text{Mp}$ : 128$^\circ$C;

$[\alpha]_D^{29}$ : +62.4 (c 0.75, CHCl$_3$)

IR (liquid film) : 3500, 3000, 1800, 1740, 1700, 1450, 1380, 1300, 1280, 1200, 1150, 1100, 1050 cm$^{-1}$

$^1$H NMR(CDCl$_3$) : $\delta$ 5.04-5.12(3H, m), 4.83 (1H, s), 3.06 (1H, d, $J =17.6$ Hz), 2.81(1H, d, $J = 17.6$ Hz), 1.62(6H, s), 1.26-1.31(12H, m)

$^{13}$C NMR (CDCl$_3$) : $\delta$ 172.7, 169.8, 165.6, 83.9, 78.4, 72.2, 70.6, 39.8, 21.6, 21.5, 21.3
Mass Spectrum (EIMS) : 
m/z 334 (3.1, M+), 238 (7.3), 206 (8.1), 193 (10.5), 170 (16.5), 160 (7.1), 145 (21), 128 (17.9), 115 (20.8), 100 (13.4), 87 (23.8), 69 (13.4), 56 (16.4), 42 (100%) 

Anal. found : C, 53.87%; H, 7.90% 
Calcd. for C\textsubscript{15}H\textsubscript{26}O\textsubscript{8} : C, 53.94%; H, 7.98%.

V.05(iv). Preparation of Trisodium (1S,2R)-1,2-dihydroxy-1,2,3-propanetricarboxylate [113] 
The procedure adopted for 112 was followed with 2 (2.0 g, 10.5 mmol) and gave the title compound 113 (1.1 g, 78.2 %) as a colourless solid. 

Yield : 1.1 g (78.2%). 
1H NMR (D\textsubscript{2}O) : δ 4.82 (1H, s), 4.12 (1H, s), 2.74 (1H, d, $J = 15.9$ Hz), 2.65 (1H, d, $J = 15.9$ Hz) ppm 

13C NMR (D\textsubscript{2}O) : δ 181.18, 178.99, 179.3, 80.15, 78.30, 44.4 ppm.

V.05(v). Preparation of Triisopropyl (1S,2R)-1,2-dihydroxy-1,2,3-propanetricarboxylate [117]. 
The procedure adopted for 115 was followed with (1.0 g, 3.65 mmol 106). After work-up and recrystallisation 117 (1.0 g, 82%) was obtained as white crystals. 

Yield : 1.0 g (82 %) 
Mp : 115°C 
$[\alpha]_D^{29}$ : +101 (c 1.0, CHCl\textsubscript{3}) 

IR (KBr) : 3463, 2985, 1809, 1747, 1635, 1454 1382, 1377, 1269, 1180, 1103 cm\textsuperscript{-1} 

1H NMR (CDCl\textsubscript{3}) : δ 5.28-5.10 (3H, m), 5.13 (1H, s), 3.02 (1H, d, $J = 17.4$ Hz), 2.83 (1H, d, $J = 17.4$ Hz), 1.62 (6H, s), 1.4-1.2 (12H, m) ppm
\(^{13}\)C NMR (CDCl\(_3\)) : \(\delta 171.9, 170.8, 164.8, 82.2, 72.4, 40.7, 21.7, 21.6, 21.5 \text{ ppm}\)

Mass Spectrum (EIMS) : 334(3.1, M\(^+\)), 238 (7.3), 206 (8.1), 193 (10.5), 170 (16.5), 160 (7.1)145 (21), 128 (17.9), 115 (20.8), 100(13.4), 87 (23.8), 69(13.4), 56 (16.4) 42 (100)

Anal. found : C, 53.89%; H, 7.89%
Calcd. for C\(_{15}\)H\(_{26}\)O\(_8\) : C, 53.94%; H, 7.85%.

V.05(vi). Preparation of Dimethyl (4S,5S)-4-[methoxy(oxo)ethyl]-2,2-dimethyl-1,3-dioxolane-4,5-dicarboxylate [183]

To a solution of 114 (1 g, 4 mmol) in dry acetone (25 mL) anhydrous copper sulphate (0.5 g) and a few drops of conc. Sulphuric acid were added. After refluxing for four hours, the reaction mixture was concentrated followed by extraction with hexane (3x25 mL). The combined extract was dried and evaporated to yield 183 as a yellow liquid.

Yield : 0.25 g (22%).

Mp : \(+29.5^0\text{C}\) (0.95%, CHCl\(_3\))

\([\alpha]_D^{29}\) : (c 1.0, CHCl\(_3\))

IR (KBr) : 2935, 2861, 1762, 1735, 1708, 1371, 1216, 926 cm\(^{-1}\)

\(^1\)H NMR (CDCl\(_3\)) : \(\delta 4.93(s,1H), 3.86(s,3H)3.81(s,3H) 3.68(s,3H), 2.98 (d, \text{J}=16.04\text{Hz},1H), 2.85(d, \text{J}=16.04\text{Hz},1H), 1.58(s,3H), 1.48(s,3H)\text{ppm}\)

\(^{13}\)C NMR (CDCl\(_3\)) : \(\delta 170.6, 169.3, 167.8, 112.8, 82.5, 78.8, 52.9, 52.3, 51.7, 38.9, 27.4, 25.5 \text{ppm}\)
Mass Spectrum (EIMS) : $m/z$ 290(M+)(1.0), 274(19.8), 230(36.4), 214(64.4), 198(19.4), 180(11.2), 172(100), 156(16.4), 144(29.2), 113(51.5), 105(14.2), 73(41.0), 59(43.3), 43(92.5)

V.05(vii). **Preparation of Dimethyl (4S,5R)-4-[methoxy(oxo)ethyl]-2,2-dimethyl-1,3-dioxolane-4,5-dicarboxylate [185]**

The procedure adopted for 183 was followed with 116 (1.0 g, 3.65 mmol) After work-up and concentration, 185 (1.0g, 82%) was obtained as yellow oil.

Yield : 0.25 g (21.6 %)

$[\alpha]_D^{29}$ : -21.65(c 1.28, CHCl$_3$)

IR (KBr) : 2928, 2861, 1748, 1708, 1452 cm$^{-1}$

$^1$HNMR(CDCl$_3$) : $\delta$4.45(s,1H), 3.87(s,3H), 3.82(s,3H), 3.79(s,3H), 3.40(d, $J=16$Hz,1H), 2.95(d, $J=16$Hz,1H), 1.74(s,3H), 1.50(s,3H) ppm

$^{13}$CNMR(CDCl$_3$) : $\delta$170.2, 169.2, 167.1, 112.7, 83.1, 80.1, 52.6, 52.3, 51.8, 40.4, 26.3, 26.2 ppm

Mass Spectrum (EIMS) : $m/z$ 290(M+)(6.0), 274(27.2), 230(44.6), 215(52.2), 199(23.2), 173(100), 153(11.66), 145(20.2), 113(43.2), 73(23.8), 59(39.3), 43(44.7)

V.05(viii). **Preparation of (4R,5R)-2,2-dimethyl α,α,α',α'-tetraphenyl-1,3-dioxalane-4,5-dimethanols**

The procedure reported by Seebech et al. have been employed for the preparation. Phenyl magnesium bromide is prepared by adding bromobenzene(3.6ml, 5.4 gm) dissolved in 10 ml dry THF to stirred magnesium turnings(1gm, 41.11mmol). The resulting mixture is heated to reflux for 30minutes. It is cooled to 0°C and ketal of diethyl tartarate (1.0gm, 2.14mmol) dissolved in 10ml dry THF is added dropwise. The reaction mixture is stirred at room temperature overnight and then heated to efflux for 2 hrs. To the chilled reaction mixture saturated ammonium chloride (15ml) was added carefully and
the organic phase was separated. The aqueous phase was further extracted with ether. Combined organic phase is dried over magnesium sulphate and concentrated under vacuum. The product is separated under column chromatography using 100% hexane as eluent and obtained as a white solid.

**Yield** : 0.84 gm(85%)

**Mp** : 192°C reported : 192°C

**[α]_D^29** : -73°(c 1.0, CHCl₃) reported : -68.5°

**¹H NMR (CDCl₃)** : δ7.59-7.24(m, 20H), 4.61(s, 1H), 4.4 (s, 1H), 1.1(s, 6H) ppm

**¹³C NMR(CDCl₃)** : δ145.87, 142.56, 128.61, 128.03, 127.60, 127.47,127.19,109.45, 80.86,78.11,27.06 ppm

V.05(ix). **Preparation of (4S,5S)-4-[2-hydroxy-2,2-di(1-naphthyl)ethyl]-2,2 dimethyl-α,α,α’,α’-tetra phenyl-1,3-diozolane-4,5-dimethanol [187]**

To a solution of 183 (1 g, 3.44 mmol.) in 10 ml THF and 21 mmol. of 1-naphthyl magnesium bromide (prepared from 3.2 ml 1-naphthyl bromide and 0.58 g. Magnesium turnings) in 10.ml. THF. The crude product was purified by column chromatography using hexane, chloroform (8:2) as eluent

**Yield** : 1.5 g. (45.8 %)

**[α]_D^29** : -27.03° (C 2.2, CHCl₃)

**IR Film** : 3392,2960,1689, 1603, 1510, 1363, 1164, 1014, 860,819, 758, cm⁻¹

**¹H NMR (CDCl₃)** : δ 8.2- 6.81(m, 42 H), 5.57(s,1H), 2.2 (s,2H), 1.7 (s,6H) ppm.
13C (CDCl₃) : δ 152.12, 135.47, 128.37, 127.13, 126.54, 125.94, 125.08, 122.25, 121.35, 109.31, 81.09, 80.05, 78.04, 39.55, 25.51 ppm.

Mass Spectrum : m/z 962 (M+) (2), 911 (2), 781 (2,1), 716 (4.4), 638 (13.3), 570 (6.6), 391 (11.1), 287 (66.6), 232 (44.4), 222 (100), 157 (100), 127 (100).

V.05(x). Preparation of 3-((E)-2-butanoyl)-1,3-oxazolidin-2-one

The 3-((E)-2-butanoyl)-1,3-oxazolidin-2-one has been prepared according to the procedure of Evans.¹⁶⁴ To a solution of 1,3 oxazolidinone (5g, 57.47 mmol) in anhydrous THF (150 ml, at -78 °C) was added n-butyl lithium (5.4 ml, eq.). After 15 min. freshly distilled 3-((E)-2-butenoyl chloride (6.5 ml) was added. The mixture was stirred at -78 °C for 30 min. and at 0 °C for 15 min. the reaction was quenched with excess saturated aqueous ammonium chloride, and the resultant slurry is concentrated in vacuo. The residue was extracted with ether. Ether layer was washed successively with saturated aqueous sodium bicarbonate and then with saturated aqueous NaCl. It is dried over magnesium sulphate, filtered and concentrated in vacuum to yield the product.

V.05(xi). Preparation of 3-[[2S,3S]-3-methyl bicyclo[2.2.1]hept-5-on-2-yl]-carbonyl]-1,3-oxazolan-2-one [193], employing 187

To a toluene suspension of powdered molecular sieves (4A, 1g) added toluene solution of Diisopropozo titanium(IV) chloride (1 ml, 2.5 M), cooled to −78 °C and added toluene solution of 1-Napthyl TADDOL [¹⁸⁷], (259 mg.) slowly for a period of 30 min. Slowly warmed to room temperature and stirred for 2 hr. the reaction mixture was the cooled to -78°C and 3-((E)-2-butanoyl)-1,3-oxazolidin-2-one, (388 mg, 2.55mmol. 1 equiv w.r.t polyol) in toluene(10 ml) was added, stirred for 15 min., followed by the addition of freshly distilled cyclopenta diene (4.4 ml, 55 mmol.) and further stirred for 2-4 hrs at -78 °C. the complex was decomposed by adding a saturated solution of NaHCO₃, filtered through sintered crucible over celite bed and extracted with dichloromethane. The organic layer was washed twice with saturated NaCl solution and dried over anhydrous sodium sulphate. Removal of the solvent under reduced pressure gave a crude residue, which on silica gel chromatography gave the pure endo adduct.
Yield: 200 mg. (36.19%)

$[\alpha]_D^{29}$: -15.00$^o$(c, 1.5, CHCl3)

$^1$HNMR (CDCl3): $\delta$ 1.50 (d, 3H, $J$ = 7.05 Hz), 1.82-2.08 (m, 3H), 2.46 (br, 1H), 3.65 (br, 1H), 3.91 (dd, 1H), 4.27-4.46 (m, 2H), 4.75-4.89 (m, 2H), 6.15 (dd, 1H, $J$ = 2.4 Hz, 5.4 Hz), 6.53 (dd, 1H, $J$ = 2.3 Hz, 5.4 Hz) ppm.

$^{13}$C NMR (CDCl3): $\delta$ 174.77, 153.37, 147.04, 131.28, 62.20, 51.64, 49.88, 47.81, 47.46, 43.35, 36.82, 20.73 ppm.

V.05(xii). Preparation of 3-(((1'S,2'S,3'R,4'R)-3'-methyl bicyclo[2.2.1]hept-5'-yl)-carbonyl)-1,3-oxazolidine-2-one: employing 188

The reaction was performed as described in the case of 190 using powdered, activated molecular sieves (1g), diisopropoxy titanium (IV) dichloride in dry toluene (1ml, 2.5 M), 164 (200 mg), 3((E)-2-butenoyl)-1,3-oxazolidine-2-one (388 mg) and cyclopentadiene (4.4 ml). Work up of the reaction followed by silica gel chromatography furnished the pure endo adduct.

Yield: 200 mg. (36.19%)

$[\alpha]_D$: -23.892$^o$(c 1.5, CHCl3)

$^1$H NMR (CDCl3): $\delta$ 1.50 (d, 3H, $J$ = 7.0 Hz), 1.8-2.1 (m, 3 H), 2.46 (br, 1H), 3.65 (br, 1H), 3.84 (dd, 1H), 4.29-4.48 (m, 2H), 4.75-4.83 (m, 2H), 6.15 (dd, 1H, $J$ = 2.8 Hz, 5.3 Hz), 6.75 (dd, 1H, $J$ = 3.2 Hz, 4.9 Hz) ppm.

$^{13}$C NMR (CDCl3): $\delta$ 174.77, 153.84, 140.03, 131.29, 62.24, 51.65, 49.88, 47.82, 47.47, 43.35, 36.83, 20.73 ppm.