Chapter II

Total Synthesis of (+)-Erogorgiaene
Present Work:

Diterpenes continue to be the target of investigations worldwide for potential biomedical uses as they are one of the valuable natural sources of unique metabolites of interesting biological activities like analgesic, anti-inflammatory, antibacterial, cytotoxicity etc. A recent bioassay-guided search for new anti-tubercular agents from the West Indian gorgonian octocoral *Pseudopterogorgia elisabethae*, led to the discovery of two new benzoxazole alkaloids, pseudopteroxazole and seco-pseudopteroxazole (Figure 1).

![Chemical structures](image)

**Figure 1.** Antitubercular diterpenes isolated from *Pseudopterogorgia elisabethae*.

Pseudopteroxazole was found to affect potent inhibitory activity (97%) against *Mycobacterium tuberculosis* H37Rv at a concentration of 12.5 μg/mL, whereas seco-pseudopteroxazole inhibited 66% of mycobacterial growth. Two serratulane based-diterpenes ergorgiaene and 7-hydroxy ergorgiaene (Figure 1) were also obtained from the hexane extracts of the coral. Ergorgiaene induced 96% growth inhibition for *M. tuberculosis* H37Rv at a concentration of 12.5 μg/mL. On the other hand, 7-hydroxy ergorgiaene inhibited 77% of mycobacterial growth at a concentration of 6.25 μg/mL, which indicates that C-7 hydroxylation apparently does not reduce the activity. Since, seco-pseudopteroxazole, ergorgiaene and pseudopteroxazole induced 66, 96 and 97% inhibition of *M. tuberculosis* growth at 12.5 μg/mL, respectively; clearly the benzoxazole moiety is not essential for activity. Follow-up biological screening of 7-hydroxy ergorgiaene in the National Cancer Institute's (NCI) 60-cell-line tumor cell panel indicated no significant *in vitro* cancer cell cytotoxicity, suggesting that ergorgiaene will probably display minimal toxicity.
Erogorgiaene possesses high order of activity against *Mycobacterium tuberculosis* H₃₇Rv, making it an interesting lead in the synthesis of new anti-tubercular agents. Although the molecule is structurally not complex, the major challenge associated with its synthesis is the control of stereocenters. The stereocontrol has been challenging due to the lack of functional groups near to the stereogenic centres. As a part of our ongoing research programme of synthesizing new anti-tubercular agents, we took initiatives towards the total synthesis of erogorgiaene in early 2004.

The most common and popular way of constructing a bicyclic core is via a Diels-Alder reaction. We, in our very initial approach, made an attempt to synthesize the bicyclic core via a Diels-Alder reaction (Scheme 1), similar kind as that attempted by Eklund, Sarvary and Frejd.³ Although we had a different diene system, the reaction failed to occur even under forcing conditions.

![Scheme 1](image)

After the unsuccessful attempt, we adopted a simple strategy to synthesize the bicyclic core, a tetralone, via a Friedel-Crafts acylation reaction of an acid derived from ester 7. The retrosynthetic analysis has been depicted in Figure 2.

**Retrosynthetic analysis:**

![Figure 2](image)

The stereogenic centre in ester 7 was initially planned to introduce through regioselective nucleophilic opening of an epoxy alcohol derived *via* a Sharpless asymmetric epoxidation reaction.
Synthesis of ester 7:

To synthesize ester 7 we started with commercially available \( p \)-tolualdehyde, which underwent Wittig olefination with ethyl(triphenylphosphono)acetate in refluxing benzene to afford unsaturated ester 2 in quantitative yield. The \(^1\)H NMR spectrum of unsaturated 2 showed resonance at 1.32 (t) and 4.24 ppm (q) corresponding to ethyl ester. The doublets at 6.34 and 7.61 ppm with \( J = 14.8 \) Hz indicated the formation of trans-olefin. The unsaturated ester 2 was reduced to allyl alcohol 3 in 88\% yield with aluminium hydride, generated \textit{in situ} by mixing LiAlH\(_4\) with AlCl\(_3\) in anhydrous ether at 0 °C (Scheme 2). Allyl alcohol 3 in its \(^1\)H NMR spectrum showed resonance 4.26 ppm (d) for allylic protons. The olefinic protons showed resonance at 6.27 (td) and 6.55 ppm (d).

```
CH₂CHO  Ph₃PCH₂CO₂Et  benzene, reflux  3 h, 100%  \( \rightarrow \)  CH₂=CHCO₂Et  \( \rightarrow \)  CH₂=CHCH₂OH
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\text{Scheme 2}

The allylic alcohol 3 was subjected to Sharpless asymmetric epoxidation using L-\((+)-\)diisopropyltartrate at -30 °C to get epoxy alcohol 4 (Scheme 3). Low conversion and yield (25\%) of epoxy alcohol 4 was observed.

```
CH₂=CHCH₂OH  (+)-DIPT, Ti(OtPr)_4  TBHP, 4 A° MS  -30 °C, 1 h, 25%  \( \rightarrow \)  \( \rightarrow \)  OCH₂OH
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\text{Scheme 3}

Carrying out the reaction at lower temperatures (-40 to -45 °C) and/or using stoichiometric amount of catalytic system (DIPT/ Ti(OtPr)_4) did not improve the yield. The reason behind the low conversion may be due to the \((+)-\)inductive effect\(^{4b}\) of the methyl group at \textit{para}-position to the incoming epoxide making the epoxide formation difficult.
The epoxy alcohol on treatment with dimethylolithiumcuprate, generated in situ from MeLi and Cul in ether, underwent regioselective epoxide opening\(^5\) furnishing exclusively the 1,2-diol 5 in 95% yield (Scheme 3). The diol 5 was confirmed from its \(^1\)H NMR spectrum, which showed resonance at 1.24 (d) ppm for \(-\text{CH}_3\) protons, 2.74-2.85 ppm (m) for benzylic proton. The fact that 1,2-diol formed was also established by its transformation into unsaturated ester 6.

Sodium periodate treatment of diol 5 in THF/H\(_2\)O at 0 °C led to aldehyde which was in situ treated with stabilized Wittig ylide resulting in unsaturated ester 6 in 80% yield (Scheme 4). Compound 6 in its \(^1\)H NMR showed resonance at 1.30 (t) and 4.16 ppm (q) for \(-\text{CO}_2\text{CH}_2\text{CH}_3\) protons and 5.75 ppm (dd) indicating the presence of unsaturated ethyl ester.

The C-C double bond in unsaturated ester 6 was reduced with Pd/C, H\(_2\) in ethyl acetate in quantitative yield. The \(^1\)H NMR spectrum showed the absence of olefinic protons and appearance of multiplets at 1.79-2.00 ppm (m) indicating the presence of saturated ester 7. The compound was further confirmed by EIMS with m/z at 220 (M\(^+\)). IR spectrum showed absorption peak at 1728 cm\(^{-1}\) indicating the presence of ester functionality.

Although we could synthesize the desired ester 7 via Sharpless asymmetric epoxidation, the overall yield (17%) was too low to be synthetically useful. We therefore, adopted a different strategy, the widely used Evans diastereoselective alkylation, to introduce a stereogenic centre at the benzylic position.

**Synthesis of ester 7 via Evans diastereoselective alkylation:**

Commerically available ethyl \(p\)-tolylacetate 8 was hydrolyzed to the corresponding acid with lithium hydroxide in methanol (Scheme 5). The crude acid 9
obtained was used for next step without further purification. The $^1$H NMR spectrum of acid 9 showed absence of resonance corresponding to ester protons.

![Scheme 5](image)

Acid 9 was coupled with lithiated Evans auxiliary 10 (prepared from unnatural D-phenylalanine using literature procedure; lithiated at -20 °C using $n$-BuLi in anhydrous THF$^a$) under mixed anhydride conditions$^b$ furnishing imide 11 in good yield (84%) (Scheme 5).

The imide 11 in its $^1$H NMR spectrum showed the presence of both oxazolidinone and $p$-tolyl moiety. While double doublet at 2.68 and 3.26 ppm and multiplet at 4.56-4.66 ppm indicated the presence of oxazolidinone moiety, the singlet at 2.31 ppm showed the presence of $p$-tolyl moiety. The $^{13}$C NMR spectrum of compound 11 also showed the presence of two carbonyl-carbons at 153.2 and 171.2 ppm. The molecular formula of the coupling product 11 was confirmed by HRMS data.

![Scheme 6](image)

Alkylation of the lithium enolate of imide 11, generated by treatment with LDA in THF at -78 °C, with Mel afforded compound 12 with high diastereoselectivity$^7$ (>99%) and moderate yield (Scheme 6). The $^1$H NMR spectrum of compound 12 showed all the
Chapter II, Present Work

characteristic peaks of imide 11 along with one additional doublet at 1.50 ppm corresponding to -CHCH₃ protons. ¹³C NMR spectrum also showed one additional peak at 19.4 ppm corresponding to the newly created methyl centre along with other peaks which appeared in the spectrum of compound 11. The diasteroselectivity was evaluated on the basis of examination of ¹H NMR spectrum of the crude product.

![Scheme 7](image)

After introduction of methyl stereogenic centre, the auxiliary in imide 12 was eliminated by reducing with NaBH₄ in THF/H₂O (1:1) at room temperature furnishing alcohol 13 in high yield (95%) (Scheme 7) along with the auxiliary 10 which was recycled for further preparation of 11. Alcohol in its ¹H NMR spectrum showed resonance at 3.63 ppm (d) corresponding to -CH₂OH protons. The ¹³C NMR spectrum resonated at 68.5 ppm clearly indicating the presence of -CH₂OH carbon. IR spectrum also confirmed the presence of hydroxyl functionality.

![Scheme 8](image)

Alcohol 13 was oxidized under Swem conditions and in situ treated with two-carbon stabilized Wittig ylide to obtain the unsaturated ester, which showed identical ¹H NMR spectrum with compound 6 synthesized via Sharpless asymmetric epoxidation. The
C-C double bond was then reduced with Pd/C, H₂ furnishing saturated ester 7 with $[\alpha]_D^{15}$ = +13.9.

\[
\begin{align*}
\text{ester 7} & \xrightarrow{\text{DIBAL-H, DCM, -78 °C, 30 min., 78%}} \text{aldehyde 14} \\
\text{aldehyde 14} & \xrightarrow{\text{Me₃C₆PPh₃, n-BuLi, THF, 0 °C, 3 h, 88%}} \text{(S)-(+)-curcumene (15)}
\end{align*}
\]

Scheme 9

The optical purity of the ester 7 was confirmed by the synthesis of optically pure (S)-(+-)-curcumene. For this, ester 7 was first treated with DIBAL-H in DCM at -78 °C resulting in aldehyde 14 in 78% yield (Scheme 9). ¹H NMR spectrum of aldehyde 14 showed resonance at 9.65 ppm indicating the presence of aldehyde functionality. The ¹³C NMR spectrum also showed resonance at 202.1 ppm corresponding to carbonyl carbon.

Aldehyde 14 underwent Wittig olefination with isopropyltriphenylphosphorane in THF at 0 °C resulting in (S)-(+)-curcumene 15 in 88% yield. Compound 15 in its ¹H NMR spectrum showed the appearance of two singlets at 1.50 and 1.65 ppm corresponding to =C(CH₃) protons and one broad triplet at 5.05 ppm corresponding to the olefinic proton. The ¹³C NMR spectrum also showed good agreement with that reported in literature. This is a new enantioselective route to the bisabolane type terpenoids. Either enantiomer can be synthesized just by changing the enantiomer of the Evans auxiliary.

After synthesizing the ester 7 with moderate overall yield (46%), we proceeded to synthesize ergogorgiaene via Friedel-Crafts acylation and zinc mediated Barbier type reactions.

**Synthesis of ergogorgiaene:**

Ester 7 was first hydrolyzed to corresponding acid by lithium hydroxide in methanol. The crude acid, without further purification, was treated with polyphosphoric acid at 90 °C to get tetralone 16 in 70% yield (Scheme 10). ¹H NMR spectrum of
compound 16 showed the multiplicity for aromatic proton as 7.16 (d), 7.28 (d) and 7.80 ppm (s) indicating the formation of Ar-CO- bond. IR spectrum showed absorption peak at 1674 cm\(^{-1}\) indicating the presence of carbonyl group.

\[
\text{Zn, THF/NH}_2\text{Cl (aq)} \quad 0\, ^\circ\text{C}, \, 4\, \text{h}, \, 78%\]

Scheme 10

Zinc mediated Barbier type allylation\(^{12}\) reaction of tetralone 16 with crotyl bromide at 0 °C furnished homoallyl alcohol 17 (Scheme 10) which possessed almost same \(R_f\) value with tetralone 16. To ease the separation, crude reaction mixture was treated with NaBH\(_4\) in methanol at 0 °C to reduce tetralone 16 to the corresponding alcohol. Careful separation on wet silica gel column chromatography of a solution of the crude reaction mixture in 5% ethyl acetate/hexanes produced compound 17 as an inseparable diastereomeric mixture. Compound 17 in its \(^1\)H NMR spectrum showed olefinic protons resonating at 4.82-5.01 (m) and 5.36-5.64 ppm (m). IR spectra showed broad absorption peak at 3430 cm\(^{-1}\) indicating the presence of hydroxyl functionality.

\[
\text{DBU, THF} \quad 85% \text{ on } 17
\]

Scheme 11

Hydroboration of compound 17 with borane-dimethyl sulfide complex in THF at 0 °C produced diol which on treatment with silica gel produced the spiro ether 18 in 65% yield (Scheme 11) as 1:1 mixture of diastereomers. \(^1\)H NMR spectrum of compound 18 showed resonance at 3.89-4.09 ppm (m) for -OCH\(_2\)- protons and absence of resonance

36
for olefinic protons indicating the presence formation spiro ether. Mass spectrum with \( m/z 254 \) for \((M+H)\) also confirmed the structure.

\[
\text{Scheme 12}
\]

Initially, the ether linkage in the spiro compound 18 was attempted to cleave with trimethylsilyl iodide\(^{13}\). For this a solution of compound 18 in acetonitrile was added to a ice-cold solution of TMSI generated \textit{in situ} by mixing equimolar amount of TMSCl and NaI in dry acetonitrile furnishing compound 19 in low yield (27\%, Scheme 12). Ethereal cleavage did not go to completion and starting material was recovered.

\[
\text{Scheme 13}
\]

Considering the ethereal linkage in compound 18 as the benzylic one, we made an attempt to cleave the ethereal linkage under standard conditions\(^{14}\). Thus, carrying out the reaction under acidic conditions, \textit{i.e.}, carrying out the hydrogenolysis in ethyl acetate containing acetic acid, furnished alcohol 20 as 1:1 diastereomeric mixture in 80\% yield (Scheme 13). The diastereomeric mixture was confirmed from its \(^1\text{H} \)NMR spectrum. While the doublet at 0.69 ppm indicated the \( \alpha \)-orientation of C-11 methyl group, the doublet at 1.04 ppm indicated \( \beta \)-orientation. Unfortunately, the diastereomers were not completely separable even after flash column chromatography. Attempts to separate the diastereomers by derivatization of hydroxyl group \textit{viz.} acetate, TBS ether, \( p \)-nitro
benzoate were ineffective. We would have been only two steps away from the final target if the diastereomers were separable.

As we did not have exact control over the methyl centre on lower part of the molecule (C-11 stereogenic centre), we planned a different strategy where we would have control over the methyl centre, starting from ester 7. Two important methodologies that helped us arriving at the strategy are:

1. Diastereoselective cationic cyclization of allylic acetates\textsuperscript{15}
2. Highly diastereoselective hydroboration with 9-BBN-H of terminal olefin\textsuperscript{16}

Based on these two methodologies we arrived at the retrosynthetic analysis as depicted in Figure 3.

**Modified retrosynthetic analysis:**

![Figure 3](image)

Although, Ma and Zheng\textsuperscript{15} carried out the cyclization using allylic acetates, we planned to carry out the reaction with alcohol, (S)-(+)-nuciferol itself as we felt protonated alcohol (under acidic conditions), would act as better leaving group.

**Cationic cyclization approach to the synthesis of erogorgiaene:**

Ester 7 was first treated with DIBAL-H in DCM at -78 °C. The resulting aldehyde was \textit{in situ} treated with stabilized Wittig ylide to get unsaturated ester 21 in 80% yield (Scheme 14). The \textsuperscript{1}H NMR spectrum of unsaturated ester showed resonance at 4.17 ppm (q) for ethyl ester and 6.68 (t) for olefinic proton indicating the presence of unsaturated 21.

38
Unsaturated ester 21 upon reduction with DIBAL-H in DCM at -78 °C produced allylic alcohol, (S)-(+) - nuciferol 22 with [α]_D^27 = +33.2. ^1H NMR spectrum showed resonance at 3.94 (s) for -CH_2OH protons. No resonance appeared for ester protons. The ^13C NMR spectrum resonated at 68.94 ppm for -CH_2OH carbon.

(S)-(+) - nuciferol 22 initially was treated with trifluoromethanesulfonic acid in DCM at -15 °C to undergo cationic cyclization. Monitoring by TLC, a complete conversion of compound 22 to a non-polar compound was observed. The ^1H NMR spectrum of the crude reaction mixture showed the appearance resonance at 5.80 ppm (t), indicating the presence of olefinic proton. Resonance at 1.16-1.27 ppm (m) indicated the presence of isopropyl group. No resonance appeared corresponding to =CCH_3 protons. ^1H NMR spectrum analysis revealed the presence of compound 23 with endocyclic
double and not the desired compound 24 (Scheme 15). Less acidic methanesulfonic acid also produced the same result under similar reaction conditions.

![Scheme 16](image)

The compound 23 can be converted to a diastereomeric mixture (5:1) of calamenenes by reduction with Pd/C, H₂ thereby confirming the formation of compound 23. Unfortunately, the diastereomeric mixture in compound 25 was not separable by column chromatography. The major diastereomer was found to be (S,S)-isomer from the comparison of ¹H NMR spectrum of 25 with the authentic one. ¹H NMR spectrum of (S,S)-calamenene showed resonance at 2.57-2.65 (m) and 2.84-2.93 (m) whereas (S,R)-isomer showed resonance at 2.61-2.78 ppm (m) for the two benzylic tertiary protons. The two diastereomers also differ in the chemical shift values for the –CH₃ protons.

Carrying out the reaction at cryogenic temperatures produced compound 23 along with a small amount of the desired compound 24 as revealed from the ¹H NMR spectrum of the crude reaction mixture. Singlets at 4.62 and 4.86 ppm in the ¹H NMR spectrum were indicative of the presence of the olefinic compound 24. To control the exclusive formation of the compound 24, we planned to carry out the cyclization reaction under mild reaction conditions. Performing the reaction in presence of two equivalents of p-toluenesulfonic acid in DCM was fruitful. The reaction resulted in compound 24 in low yield (40-45%) along with some unwanted side product (Scheme 17).

![Scheme 17](image)
The idea of using stoichiometric amount of Lewis acids, generally employed for Friedel-Crafts reaction,\textsuperscript{19} did finally solve the problem of clean reaction with improved yield. The Lewis acids that were studied have been listed in Table 1 below.

### Table 1: Lewis acid mediated cyclization of (S)-(+)-mufamol 22

<table>
<thead>
<tr>
<th>Entry</th>
<th>Lewis acid</th>
<th>Reaction conditions</th>
<th>Diastereomeric ratio\textsuperscript{a}</th>
<th>Yield(%),\textsuperscript{b}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AICI\textsubscript{3}</td>
<td>DCM, -78 °C to rt</td>
<td>complex reaction mixture</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>FeCl\textsubscript{3}</td>
<td>DCM, -78 °C to rt</td>
<td>4:1</td>
<td>68</td>
</tr>
<tr>
<td>3</td>
<td>BF\textsubscript{3}OEt\textsubscript{2}</td>
<td>DCM, -78 °C to rt</td>
<td>5:1</td>
<td>68</td>
</tr>
<tr>
<td>4</td>
<td>Cu(OTf)\textsubscript{2}</td>
<td>DCM, rt</td>
<td>2:1</td>
<td>58</td>
</tr>
<tr>
<td>5</td>
<td>Sc(OTf)\textsubscript{3}</td>
<td>DCM, rt</td>
<td>2:5</td>
<td>70</td>
</tr>
</tbody>
</table>

\textsuperscript{a} diastereomeric ratio was determined based on \textsuperscript{1}H NMR spectra of the reduced product

\textsuperscript{b} optimized and isolated yield

Among the Lewis acids, although scandium triflate was found to produce best results in terms of cleaner reaction profile, but the diastereoselectivity was found to be low. The use of stoichiometric amount of metal triflates is less practical and economical due to their higher cost. The cheaper and readily available BF\textsubscript{3}OEt\textsubscript{2} mediates the reaction with higher diastereoselectivity and good yield but the reaction had to be carried out under dilute conditions to avoid the formation of compound 23. Ferric chloride was found to be Lewis acid of choice both in terms of cleaner reaction and diastereoselectivity. The major diastereomer formed in the cyclization reaction was identified by comparison of its hydrogenated product (Scheme 18) with the \textsuperscript{1}H NMR spectra of the calamenenes reported in the literature.\textsuperscript{18} The required (S,R)-isomer was in higher diastereomeric ratio.
After standardization of reaction condition and confirming the major diastereomer formed in the Lewis acid mediated cyclization reaction, we proceeded to carry out the diastereoselective hydroboration reaction of olefin 24 following the literature protocol. Compound 24 on hydroboration\(^6\) with 9-BBN-\(H\) in THF at room temperature for 24 hours provided alcohol with high diastereoselectivity (6:1) over the methyl centre at C-11 as confirmed from the \(^1\)H NMR spectrum of the inseparable diastereomeric mixture of alcohol 27 (Scheme 19).

Resonance at 1.01 (d) indicated the presence of \(\beta\)-methyl centre at C-11. This assignment was made based on the comparison of \(^1\)H NMR spectrum of 27 with that of 20. While the doublet at 0.72 ppm indicates the presence of \(\alpha\)-methyl (which is in minor amount), the resonance at 1.10 ppm refers to \(\beta\)-orientation of the methyl group. Readily available (+)- and (-)-Ipc\(_2\)BH are also frequently used for the control of stereocentres.\(^{20}\) But from the literature it appeared that hydroboration of terminal olefins with (+)/(−)-Ipc\(_2\)BH leads to mixture of diastereomers.\(^{21}\) As the diastereomers were not separable in our case, we did not make any attempt to do hydroboration with (+)/(−)-Ipc\(_2\)BH and planned a new strategy where we would have absolute control over all the stereocentres.

Intramolecular Friedel-Crafts reaction of cyclic systems generally proceeds via a \(S_N\)\(_2\) type of mechanism resulting in inversion of configuration at the centre.\(^{22}\) Epoxides are known to undergo intramolecular Friedel-Crafts reaction resulting in a single
We anticipated that an oxetane, being an extension to epoxide, would also lead to the same result. The retrosynthetic analysis based on the intramolecular Friedel-Crafts reaction of an oxetane has been depicted in Figure 4 below.

**Modified retrosynthetic analysis:**

![Figure 4](image)

**Synthesis of ergogorgiaene via oxetane opening:**

In this approach, to derive the oxetane, we started with the aldehyde 14 which underwent smooth aldol coupling with the titanium enolate of acyl thiazolidinone 28 under Crimmins protocol with high diastereoslectivity (49:1) and 93% isolated yield (Scheme 20). The minor diastereomer was separated by flash column chromatography.

![Scheme 20](image)

\(^1\)H NMR spectrum of aldol product 29 showed resonance at 2.47 (d) and 3.21 (dd, corresponding to the PhCH\textsubscript{2}- of thiazolidinone moiety. The –CHOH proton resonated at 3.89-4.01 ppm (m) and two methyl groups showed resonance at 1.12 (d) and 1.24 ppm (d). \(^13\)C NMR spectrum showed resonance at 177.89 and 185.05 ppm for the two carbonyl carbons and 10.23 and 20.79 ppm for two –CH\textsubscript{3} carbons. IR spectrum showed
broad absorption peak at 3451 and 1694 cm\(^{-1}\) for hydroxyl and carbonyl functionalities. Molecular formula was confirmed by HRMS analysis.

![Scheme 21]

The free hydroxyl group in compound 29 was protected as its TBS ether with TBSOTf and 2,6-lutidine in DCM (Scheme 21). The less polar TBS ether 30 was confirmed from the resonance at 0.0 (s) and 0.05 ppm in the \(^1\)H NMR spectrum. The \(^{13}\)C NMR spectrum showed resonance at -4.4 and -4.0 ppm for the carbons attached to silicon. The molecular formula was confirmed from the HRMS analysis.

Compound 30 on reduction\(^25\) with NaBH\(_4\) in methanol results in primary alcohol 31 in 78\% yield (Scheme 22). The auxiliary can be recycled for further preparation of 28.

![Scheme 22]

The \(^1\)H NMR spectrum of compound 31 showed resonance at 3.58 (dt) and 3.70 ppm (dt) corresponding to -CH\(_2\)OH protons. No resonance was found corresponding to the protons of thiazolidinone moiety. Resonance at 65.95 ppm showed the presence - CH\(_2\)OH carbon. Broad absorption peak at 3423 cm\(^{-1}\) in the IR spectrum confirmed the presence of hydroxyl group.
Alcohol 31 was tosylated with freshly recrystallized tosyl chloride and triethyl amine in DCM at room temperature (Scheme 22). $^1$H NMR spectrum of tosylate 32 showed resonance at 2.40 (s) and 2.54 ppm (s) for ArCH$_3$ protons and 7.40 (d) and 7.85 ppm (d) for the aromatic protons of the tosyl group.

The tosylate 32 was first treated with catalytic amount of p-toluenesulfonic acid in methanol to deprotect the TBS ether. After removing methanol completely, the crude product was treated with NaH in THF to undergo replacement resulting in oxetane 33 (Scheme 23). The oxetane was confirmed from its $^1$H NMR spectrum. Down-field resonance at 3.97 (t) and 4.62-4.72 ppm (m) revealed the presence of cyclic ether. The $^{13}$C NMR spectrum showed resonance at 75.5 and 85.1 ppm for –C-O– carbons confirming the formation of oxetane 33. The molecular formula was confirmed by HRMS analysis.

The crucial intramolecular Friedel-Crafts reaction of oxetane 33 was carried out following the literature procedure generally employed for epoxides. Thus, to a dilute solution of oxetane 33 in anhydrous DCM was carefully added stoichiometric amount of BF$_3$·OEt$_2$ at -78 °C. This resulted in smooth regio- and distereoselective intramolecular opening of the oxetane with aromatic ring producing alcohol 34 in 81% yield (Scheme 24). Interestingly, only a single diastereomer was formed in the reaction as confirmed from the $^1$H NMR spectrum.
Alcohol 34 in its $^1$H NMR spectrum showed characteristic resonance at 3.46-3.70 ppm as multiplet corresponding to $-\text{CH}_2\text{OH}$ protons. In addition, the spectrum showed the presence of only three aromatic protons as 6.89 (d), 6.97 (s), and 7.07 ppm (d), indicating the formation of the alcohol 34. The $^{13}$C NMR spectrum showed only one resonance at 66.5 ppm corresponding to $-\text{CH}_2\text{OH}$ carbon. The presence of hydroxyl functionality was confirmed from the absorption band at 3418 cm$^{-1}$ in the IR spectrum. Alcohol 34 was further confirmed from the ESIMS spectrum with m/z at 241 for (M+Na). The molecular formula was confirmed from its HRMS analysis.

At this stage all stereogenic centres had been introduced. The stereochemistry (1,4-relationship) of the tetrahydronaphthalene moiety of the alcohol 34 was further confirmed from its conversion to known ($S,R$)-calamenene 36.\textsuperscript{18} Alcohol 34 was first treated with tosyl chloride and triethyl amine in DCM affording tosylate 35 in 97% yield (Scheme 25).

The $^1$H NMR spectrum of the tosylate showed resonance at 2.34 ppm (s) and 7.45 (d) and 7.82 (d) ppm in addition to the regular resonances of alcohol 34. The $-\text{CH}_2\text{OTs}$ protons showed down-field resonance compared to that of alcohol 34. The tosylate was then treated with LiAlH$_4$ in refluxing THF for 3 hours affording ($S,R$)-calamenene 36 in 80% yield (Scheme 25). The $^1$H NMR spectrum and optical rotation of 36 were in good
agreement with the literature reports. This is entirely a new route to calamenes. It is possible to synthesize all the possible stereoisomers of calamene using this strategy.

To complete the synthesis of erogorgiaene, alcohol 34 was first oxidized under Swern conditions. The resulting aldehyde was treated in situ with stabilized Wittig ylide to yield the unsaturated ester 37 in 84% yield (Scheme 26).

![Scheme 26]

The unsaturated ester 37 was confirmed from its $^1$H NMR spectrum. The chemical shift value at 5.81 ppm (d) was assigned to the olefinic proton whereas quartet at 4.22 ppm was assigned to the $\text{-OCH}_2\text{CH}_3$ protons of ethyl ester. $^{13}$C NMR spectrum showed chemical shift values at 120.3 and 153.9 ppm corresponding to the olefinic carbons and 60.1 ppm for $\text{-OCH}_2\text{CH}_3$ carbon. The ester functionality present in compound 37 was confirmed from the absorption band at 1710 cm$^{-1}$ in the IR spectrum.

The unsaturated ester 37 was then reduced to the saturated ester 38 with Pd/C, H$_2$ in ethyl acetate in quantitative yield. $^1$H NMR spectrum ester 38 showed the absence of resonance at 5.81 ppm and appearances of new resonance at 2.31-2.40 ppm as multiplet corresponding to the $\text{-CH}_2\text{CH}_2\text{CO}_2\text{Et}$ protons. No resonance was observed for olefinic proton. The ESIMS spectrum also confirmed the compound 38 with $m/z$ at 311 for (M+Na). The molecular formula of the compound 38 was confirmed from the HRMS analysis.

![Scheme 27]
Ester 38 was then reduced to corresponding aldehyde 39 by careful addition of DIBAL-H in DCM at -78 °C in good yield (80%) (Scheme 27). The aldehyde was confirmed from its \(^1\)H NMR spectrum which showed resonance at 9.83 ppm as singlet assigned to the aldehyde proton. No resonance was found corresponding to the protons of ethyl ester indicating complete conversion of the ester 38.

To attach the isopropenyl tail, aldehyde 39 was subjected to Wittig olefination with isopropyltriphenylphosphorane, generated \textit{in situ} from the corresponding phosphonium salt and \textit{n}-BuLi in THF at 0 °C. The reaction proceeded smoothly affording erogorgiaene in 80% yield (Scheme 28).

\[
\begin{align*}
\text{PhPCH}(\text{CH}_3)&\rightarrow \text{erogorgiaene} \\
39 &\xrightarrow{n\text{-BuLi, THF, 0 °C, 3 h, 80%}} \text{erogorgiaene}
\end{align*}
\]

Scheme 28

The \(^1\)H NMR and \(^{13}\)C NMR spectral data of our synthetic compound were in good agreement with the data previously reported in literature.\(^{226}\) The optical rotation measured as +23.2 (c 0.75, CHCl\(_3\)) was close to that of natural product (+24.6).\(^{2}\) Thus, we have accomplished an enantioselective synthesis of erogorgiaene in 17 steps with an overall yield of 8.2% in an entirely new approach.

The special features of our synthesis are:
1. use of Evans diastereoselective alkylation to introduce the benzylic methyl stereogenic centre
2. use of versatile and highly diastereoselective Crimmins aldol coupling to synthesize a chiral oxetane and
3. an unprecedented highly diastereoselective intramolecular Friedel-Crafts reaction of an oxetane.

While the oxetane opening controlled the crucial tertiary stereogenic centre of erogorgiaene, Crimmins aldol coupling controlled the required stereochemistry of the oxetane. These made the strategy quite versatile and can be applied to the synthesis of all possible stereoisomers of erogorgiaene and other serrulatane diterpenes.

48
Experimental

(E)-Ethyl 3-p-tolylacrylate (2).

\[
\text{\textbf{Experimental}}
\]

\[
\text{(E)-Ethyl 3-p-tolylacrylate (2).}
\]

\[
\text{A mixture of p-tolualdehyde (4.0 g, 33.33 mmol) and ethyl(triphenylphosphono)acetate (12.75 g, 36.66 mmol) in benzene (100 mL) was refluxed for 3 hours. After cooling to room temperature, benzene was evaporated under reduced pressure. The resulting crude reaction mixture was purified by silica gel column chromatography using hexane/ethyl acetate (19:1) as eluent affording ester 2 as light brown oil (6.3 g, 100%); R}_{f} 0.50 (19:1 hexane: ethyl acetate).}
\]

\[
^1\text{H NMR (CDCl}_3, 300 MHz) \delta 1.32 (t, 3H, J = 6.8 Hz), 2.36 (s, 3H), 4.24 (q, 2H, J = 6.8 Hz), 6.34 (d, 1H, J = 14.8 Hz), 7.13 (d, 2H, J = 8.4 Hz), 7.38 (d, 2H, J = 8.4 Hz), 7.61 (d, 1H, J = 14.8 Hz).
\]

(E)-3-p-Tolyprop-2-en-1-ol (3).

\[
\text{LiAlH}_4 (1.79 g, 47.3 mmol) was weighed in a 250 mL two-neck round bottomed flask fitted with a septum, nitrogen inlet and a magnetic bar. The flask was placed in an ice-bath and added 100 mL of anhydrous ether. To this suspension, anhydrous AlCl}_3 (2.0 g, 15.7 mmol) was added in portions over a period of 10 minutes. The resulting suspension was stirred at 0 °C for 30 minutes before adding slowly a solution of unsaturated ester 2 (6.0 g, 31.5 mmol) in 30 mL of anhydrous ether. After stirring for another 30 minutes at 0 °C, the reaction mixture was quenched with saturated aqueous NH}_4Cl solution (20 mL), added 100 mL of ethylacetate and stirred for 1 hour. Filtered through a small pad of celite and the residue was washed with ethyl acetate (2 x 20 mL). Combined filtrate was dried over anhydrous Na}_2SO}_4 and evaporated under reduced pressure. The crude product was purified by silica gel column chromatography using hexane/ethyl acetate (17:1) as eluent.}
\]

49
to afford allylic alcohol 3 as white crystalline solid (4.11 g, 88%); R\textsubscript{f} 0.40 (3:2 hexane: ethyl acetate).

m. p. 85-86 °C.

\textsuperscript{1}H NMR (CDCl\textsubscript{3}, 200 MHz)

\(\delta\) 2.35 (s, 3H), 4.26 (d, 2H, \(J = 6.2\) Hz), 6.27 (td, 1H, \(J = 6.2, 16.4\) Hz), 6.55 (d, 1H, \(J = 16.4\) Hz), 7.08 (d, 2H, \(J = 8.3\) Hz), 7.23 (d, 2H, \(J = 8.3\) Hz).

((2S,3S)-3-p-Tolyloxiran-2-yl)methanol (4).

Finely powdered activated molecular sieves (4Å, 1.0 g) was taken in a 250 mL two-neck round bottomed flask equipped with a septum, nitrogen inlet and a magnetic bar. 100 mL of anhydrous DCM was cannulated and the suspension was then cooled to -23 °C. L-(+)-diisopropyltartrate (1.38 mL, 6.7 mmol) and Ti(O'Pr)\textsubscript{4} (1.39 mL, 5.4 mmol) was added sequentially and the resulting mixture was stirred for 30 minutes before adding a solution of allylic alcohol 3 (4.0 g, 27.0 mmol) in 20 mL of anhydrous DCM. After stirring for another 30 minutes at -23 °C, TBHP (4.0 M in toluene, 13.5 mL, 54 mmol) was added dropwise over a period 15 minutes. The resulting mixture was stirred for 1 hour and quenched with 10 mL of 10% NaOH solution in brine. After stirring for 15 minutes, 10 g of anhydrous Na\textsubscript{2}SO\textsubscript{4} was added. The solution was then filtered though a small pad of celite and washed the residue with DCM (2 x 20 mL). The combined DCM layer was evaporated under reduced pressure and the residue dissolved in ether (100 mL). After cooling to 0 °C, 20 mL of 10% NaOH solution in brine was added and stirred for 1 hour at 0 °C. DCM layer was separated, dried over anhydrous Na\textsubscript{2}SO\textsubscript{4} and evaporated. The crude reaction mixture was purified by column chromatography using hexane/ethyl acetate (4:1) as eluent to afford epoxy alcohol 4 as colourless oil (1.1 g, 25%); R\textsubscript{f} 0.38 (3:2 hexane: ethyl acetate).

\textsuperscript{1}H NMR (CDCl\textsubscript{3}, 200 MHz)

\(\delta\) 2.37 (s, 3H), 2.96-3.10 (m, 1H), 3.62-3.81 (m, 2H), 3.88-4.17 (m, 1H), 6.98-7.10 (m, 4H).
Cul (2.78 g, 14.63 mmol) was charged into a 250 mL flame dried two-neck round bottomed flask fitted with a septum, nitrogen inlet and a magnetic bar. To the flask, 60 ml of anhydrous ether was cannulated and cooled to 0 °C. The resulting suspension was treated with freshly prepared MeLi (1.0 M in ether, 29.3 mL, 29.26 mmol) until the solution became colourless. After cooling to -78 °C, a solution of epoxy alcohol I (1.0 g, 6.09 mmol) in anhydrous ether (10 mL) was added and the reaction mixture was allowed to attain room temperature over a period of 1 hour. Stirred at room temperature for another two hours before quenching with saturated aqueous NH₄Cl solution (10 mL) at 0 °C. The ether layer was washed with saturated aqueous NaHCO₃ solution (2 x 20 mL), dried over anhydrous Na₂SO₄ and evaporated. The crude product was purified by silica gel column chromatography using hexane/ethyl acetate (7:3) as eluent to afford 1,2-diol 5 as light brown oil (1.04 g, 95%); Rf 0.30 (3:7 hexane: ethyl acetate).

\( ^1H \text{NMR (CDCl}_3, 200 \text{ MHz}) \quad \delta 1.24 \text{ (d, 3H, } J = 6.7 \text{ Hz)}, 2.34 \text{ (s, 3H)}, 2.74-2.85 \text{ (m, 1H)}, 3.46-3.55 \text{ (m, 1H)}, 3.64-3.78 \text{ (m, 2H)}, 7.04-7.14 \text{ (m, 4H)}. \)

(5S,6E)-Ethyl 4-p-tolylpent-2-enoate (6).

A solution of diol 5 (900 mg, 5.0 mmol) in 25 mL of THF/H₂O (4:1) was cooled to 0 °C and added sodium periodate (2.67 g, 7.5 mmol). The resulting white suspension was stirred at room temperature until complete conversion took place (ca. 2 hours). The reaction mixture was then diluted with CHCl₃ (75 mL). The organic layer was washed with brine (1 x 20 mL) and dried over anhydrous Na₂SO₄ and transferred to a 250 mL round bottomed flask. To the solution containing crude aldehyde, 2.67g (7.5 mmol) of ethyl(triphenylphosphono)acetate was added and stirred overnight. Solvent was
evaporated and crude product was purified by silica gel column chromatography to afford unsaturated ester 6 as colourless oil (870 mg, 80%); \( R_f 0.35 \) (19:1 hexane: ethyl acetate).

**\(^1\)H NMR (CDCl\(_3\), 200 MHz)**  
\( \delta \ 1.30 \ (t, \ 3H, \ J = 7.2 \ Hz), \ 1.43 \ (d, \ 3H, \ J = 7.2 \ Hz), \ 2.35 \ (s, \ 3H), \ 3.48-3.66 \ (m, \ 1H), \ 4.16 \ (q, \ 2H, \ J = 7.2 \ Hz), \ 5.75 \ (dd, \ 1H, \ J = 1.4, 15.9 \ Hz), \ 7.01-7.12 \ (m, \ 5H) \)

\((S)\)-Ethyl 4-p-tolylpentanoate (7).

The unsaturated ester 6 (800 mg) was dissolved in EtOAc (10 mL), added Pd/C (100 mg) and kept under H\(_2\) atmosphere (1 atm.) for three hours. Filtered through a small pad of celite and washed the celite pad with EtOAc (3 x 10 mL). The combined filtrate was evaporated to obtain saturated ester 7 which was further purified by silica gel column chromatography. Colourless liquid (800 mg, quant.); \( R_f 0.35 \) (19:1 hexane: ethyl acetate).  

\([\alpha]_D^{25} + 12.8 \ (c \ 4.2, \ CHCl_3)\);  
**IR (KBr, neat)**  
\( \nu 2952, 2937, 2865, 1728, 1575, 1365, 1246, 1145, 1021, 845 \ cm^{-1} \)

**\(^1\)H NMR (CDCl\(_3\), 300 MHz)**  
\( \delta \ 1.25 \ (t, \ 3H, \ J = 6.8 \ Hz), \ 1.28 \ (d, \ 3H, \ J = 7.5 \ Hz), \ 1.79-2.00 \ (m, \ 2H), \ 2.11-2.20 \ (m, \ 2H), \ 2.34 \ (s, \ 3H), \ 2.61-2.75 \ (m, \ 1H), \ 4.10 \ (q, \ 2H, \ J = 6.8 \ Hz), \ 7.04 \ (d, \ 2H, \ J = 8.3 \ Hz), \ 7.08 \ (d, \ 2H, \ J = 8.3 \ Hz) \)

**EI-MS \( m/z \) (%)**  
220 (\( M^+ \) 5), 175 (10), 141 (15), 132 (75), 119 (100), 91 (30), 43 (40).

**2-p-Tolylacetic acid (9).**

Ethyl 2-p-tolylacetate (5.0 g, 33.3 mmol) was dissolved in methanol (100 mL) and added LiOH·H\(_2\)O (1.39 g, 33.3 mmol). The resulting mixture was stirred at room temperature for 1 hour. Methanol was removed under reduced pressure and added water (50 mL).
Acidified with 1N HCl at 0 °C and extracted with ether (3 x 75 mL). The ether layer was washed with brine (1 x 25 mL), dried over anhydrous Na₂SO₄ and evaporated to get 4.2 g (100%) of crude acid as white solid which was used for next step without purification.

**¹H NMR (CDCl₃, 300 MHz)**

δ 2.33 (s, 3H), 3.55 (s, 2H), 7.07 (d, 2H, J = 8.2 Hz), 7.12 (d, 2H, J = 8.2 Hz).

4-Methyl-3-(2-p-tolylacetyl)oxazolidin-2-one (10).

To a stirred solution of acid 9 (3.8 g, 25.3 mmol), Et₃N (7.0 mL, 50.6 mmol) in anhydrous THF (100 mL) at -20 °C was added pivaloyl chloride (3.4 mL, 27.8 mmol) dropwise. To this a solution of lithiated auxiliary (lithiated with n-BuLi, 2.5 M in hexane, 10.2 mL, 25.5 mmol, in 75 mL of anhydrous THF at -20 °C) was cannulated as soon as pivaloyl chloride addition was over. The resulting mixture was stirred at -20 °C for 1 hour then allowed to warm up to room temperature. After stirring at room temperature for 3 hours, the reaction mixture was quenched with saturated aqueous NH₄Cl solution (50 mL). Layers were separated and aqueous layer was extracted with ethyl acetate (2 x 20 mL). Combined organic layer was washed with water (1 x 20 mL), brine (1 x 20 mL), dried over anhydrous Na₂SO₄ and evaporated. The crude reaction mixture was purified by silica gel column chromatography to obtain imide 11 as brown oil, 6.6 g (84%); Rₙ 0.45 (3:2 hexane: ethyl acetate).

[α]₀²⁵ -60.9 (c 3.75, CHCl₃);

IR (KBr, neat) v 3055, 2923, 1753, 1685, 1425, 1345, 1235, 954, 722 cm⁻¹;

**¹H NMR (CDCl₃, 300 MHz)** δ 2.31 (s, 3H), 2.68 (dd, 1H, J = 3.0, 12.8 Hz), 3.26 (dd, 1H, J = 3.0, 12.8 Hz), 4.10-4.18 (m, 2H), 4.22 (q, 2H, J = 15.1 Hz), 4.56-4.66 (m, 1H), 7.11 (d, 4H, J = 8.3 Hz), 7.20 (d, 2H, J = 8.3 Hz), 7.22-7.27 (m, 3H);
Chapter II, Present Work

$^{13}$C NMR (CDCl$_3$, 75MHz) δ 20.9, 37.5, 41.0, 55.1, 127.1, 128.7, 129.1, 129.3, 129.5, 130.3, 135.0, 136.7, 153.2, 171.2;

ESIMS $m/z$ 332 (M+Na).$^*$

HRMS Calcd. for C$_{19}$H$_{19}$N$_2$O$_3$Na: 332.1262 found 332.1268.

4-Methyl-3-((R)-2-p-tolylpropanoyl)oxazolidin-2-one (12).

Diisopropyl amine (2.99 mL, 21.3 mmol) was charged into a flame dried 250 mL two-neck round bottomed flask equipped with a magnetic bar, nitrogen inlet and a septum. After addition of 65 mL of anhydrous THF, the mixture was cooled to 0 °C and added n-BuLi (2.5 M in hexane, 8.4 mL, 21.0 mmol) via syringe. After stirring for 30 minutes, the resulting LDA solution was cannulated to a solution of imide 11 (6.0 g, 19.4 mmol) in 50 mL of anhydrous THF at -78 °C. Stirring was continued for 1 hour before adding HMPA (4.8 mL, 23.3 mmol) and MeI (1.8 mL, 29.1 mmol). The mixture was slowly warmed to -30 °C and stirred at that temperature for 2 hours before quenching with saturated aqueous NH$_4$Cl solution (25 mL). Layers were separated and aqueous layer extracted with EtOAc (3 × 20 mL). The combined organic layer was dried over anhydrous Na$_2$SO$_4$ and evaporated. The crude reaction mixture was purified by flash column chromatography to obtain methylated imide 12 as brown oil (3.52 g, 56%); $R_f$ 0.55 (3:2 hexane: ethyl acetate).

$[\alpha]_D^{25}$ -104.9 (c 7.51, CHCl$_3$);

IR (KBr, neat) ν 3027, 2976, 1780, 1696, 1451, 1359, 1215, 960, 701 cm$^{-1}$;

$^1$H NMR (CDCl$_3$, 300 MHz) δ 1.50 (d, 3H, $J$ = 6.8 Hz), 2.31 (s, 3H), 2.73 (dd, 1H, $J$ = 3.0, 12.8 Hz), 3.36 (dd, 1H, $J$ = 3.0, 12.8 Hz), 3.97-4.13 (m, 2H), 4.47-4.57 (m, 1H), 5.40 (q, 1H, $J$ = 6.8 Hz), 7.07 (d, 2H, $J$ = 7.5 Hz), 7.18-7.34 (m, 7H);
**Chapter II, Present Work**

$^{13}$C NMR (CDCl$_3$, 75 MHz) δ 19.4, 20.9, 37.8, 42.6, 55.7, 65.7, 127.2, 127.9, 128.8, 129.2, 129.3, 135.3, 136.8, 137.2, 152.8, 174.7;

ESIMS $m/z$ 346 (M+Na)$^+$. *

HRMS Calcd. for C$_{20}$H$_{21}$NO$_3$Na: 346.1419 found 346.1421

(R)-2-p-Tolylpropan-1-ol (13).

\[
\begin{array}{c}
\text{Ph} \\
\text{OH}
\end{array}
\]

To a stirred mixture of imide 12 (3.4 g, 10.5 mmol) in THF/H$_2$O (40 mL, 1:1) at room temperature, NaBH$_4$ (0.58 g, 15.7 mmol) was added. The resulting mixture was stirred at room temperature for 12 hours and extracted with EtOAc (3 x 30 mL). The combined organic layer was washed with water (1 x 50 mL), brine (1x 30 mL), dried over anhydrous Na$_2$SO$_4$ and then evaporated. Crude reaction mixture was purified by silica gel column chromatography using hexane/ethyl acetate (17:3) to obtain alcohol 13 as light brown oil (1.49 g, 95%); $R_f$ 0.25 (5:1 hexane: ethyl acetate).

\([\alpha]_D^{25}\) +14.1 (c 2.75, CHCl$_3$);

IR (KBr, neat) ν 3376, 2926, 2869, 1465, 1376, 1029, 813 cm$^{-1}$;

$^1$H NMR (CDCl$_3$, 300 MHz) δ 1.25 (d, 3H, $J = 6.8$ Hz), 1.40 (brs, 1H, OH), 2.32 (s, 3H), 2.81-2.94 (m, 1H), 3.63 (d, 2H, $J = 6.8$ Hz), 7.01-7.12 (m, 4H);

$^{13}$C NMR (CDCl$_3$, 75 MHz) δ 17.5, 20.8, 41.9, 68.5, 127.2, 129.1, 136.0, 140.5.

(S,E)-Ethyl 4-p-tolylpent-2-enoate (6).

\[
\begin{array}{c}
\text{Ph} \\
\text{CO}_{2}\text{Et}
\end{array}
\]

Oxalyl chloride (1.65 mL, 18.9 mmol) was charged into a 250 mL two neck round bottomed flask equipped with a magnetic spin bar, nitrogen inlet and a septum. After addition of anhydrous DCM (35 mL), the solution was cooled to -78 °C. To this a solution of DMSO (2.68 mL, 37.8 mmol) in 15 mL of anhydrous DCM was cannulated. The resulting white suspension was stirred for 30 minutes before adding a solution of
alcohol 13 (1.42 g, 9.4 mmol) in 10 mL of anhydrous DCM. After stirring for 1.5 hours at -78 °C, Et₃N (7.8 mL, 56.4 mmol) was added. The mixture was allowed to come to room temperature over a period of 1 hour. Diluted with DCM and washed with water (1 x 30 mL), brine (1 x 20 mL) and dried over anhydrous Na₂SO₄. Stabilized Wittig ylide (4.9 g, 14.1 mmol) was added to the crude reaction mixture and stirred overnight. DCM was evaporated and crude reaction mixture was purified by silica gel column chromatography using hexane/ethyl acetate (50:1) as eluent to obtain 6 as colourless liquid (1.77 g, 86%); R_f 0.35 (19:1 hexane: ethyl acetate).

(S)-Ethyl 4-p-tolylpentanoate (7).

The unsaturated ester 6 (1.70 g) was reduced to the saturated ester 7 (1.69 g, 99%) following the same procedure as stated earlier; R_f 0.35 (19:1 hexane: ethyl acetate).

IR \((\text{KBr, neat})\) ν 2958, 2925, 2858, 1690, 1645, 1514, 1455, 1378, 1261, 1022, 870 cm⁻¹.

A solution of saturated ester 7 (1.6 g, 7.2 mmol) in 22 mL of anhydrous DCM was cooled to -78 °C. DIBAL-H (7.3 mL, 7.3 mmol; 1.0 M solution in toluene) was then added dropwise over a period of 5 minutes. The resulting mixture was stirred for 30 minutes before quenching with saturated aqueous sodium-potassium tartrate solution (20 mL). The mixture was warmed to room temperature and stirred for 1 hour. Organic layer was separated and aqueous layer extracted with DCM (2 x 10 mL). Combined organic layer was dried over anhydrous Na₂SO₄ and evaporated. The crude reaction mixture was purified by silica column chromatography to obtain aldehyde 14 as colourless liquid (1.28 g, 78%); R_f 0.30 (5:1 hexane: ethyl acetate).
\textbf{Chapter II, Present Work}

$^1$H NMR (CDCl$_3$, 300 MHz) \hspace{1cm} \delta 1.28\,(d,\ 3H,\ J = 7.5\ Hz),\ 1.79-2.00\ (m,\ 2H),\ 2.04-2.20\ (m,\ 2H),\ 2.34\ (s,\ 3H),\ 2.57-2.76\ (m,\ 1H),\ 7.04\ (d,\ 2H,\ J = 8.3\ Hz),\ 7.08\ (d,\ 2H,\ J = 8.3\ Hz),\ 9.65\ (s,\ 1H);

$^{13}$C NMR (CDCl$_3$, 75 MHz) \hspace{1cm} \delta 20.8,\ 22.2,\ 30.8,\ 38.8,\ 42.0,\ 126.7,\ 129.1,\ 135.6,\ 142.9,\ 202.1.

(S)-(+-)Curcumene (15).

Isopropyltriphenylphosphonium iodide (147 mg, 0.34 mmol) was charged into a 25 mL round bottomed flask equipped with a magnetic bar, nitrogen inlet and a septum. After adding anhydrous THF (3 mL), the mixture was cooled to 0 °C. n-BuLi (1.6 M in hexane, 0.16 mL, 0.255 mmol) was added and the resulting deep brown mixture was aged for 30 minutes. A solution of aldehyde 14 (30 mg, 0.17 mmol) in THF (1.5 mL) was added via syringe and resulting mixture was stirred at 0 °C for 3 hours and then warmed to room temperature. Quenched with saturated aqueous NH$_4$Cl solution (3 mL) and extracted with pentane (3 x 10 mL). Combined organic layer was washed with water (1 x 10 mL), brine (1 x 5 mL), dried over anhydrous Na$_2$SO$_4$ and evaporated. Silica gel column chromatography of the crude product with hexane as eluent yielded 30 mg (88%) of (S)-(+)-curcumene as colourless liquid; Rf 0.55 in hexanes.

$[^a]_D^{25}$ + 42.3 (c 1.0, CHCl$_3$)

$^1$H NMR (CDCl$_3$, 300 MHz) \hspace{1cm} \delta 1.21\,(d,\ 3H,\ J = 7.8\ Hz),\ 1.50\ (s,\ 3H),\ 1.51-1.62\ (m,\ 2H),\ 1.65\ (s,\ 3H),\ 1.78-1.89\ (m,\ 2H),\ 2.30\ (s,\ 3H),\ 2.56-2.68\ (m,\ 1H),\ 5.05\ (brt,\ 1H,\ J = 6.7\ Hz),\ 6.98-7.07\ (m,\ 4H);

$^{13}$C NMR (CDCl$_3$, 75 MHz) \hspace{1cm} 17.64,\ 20.96,\ 22.44,\ 25.68,\ 26.18,\ 38.47,\ 39.03,\ 124.58,\ 126.88,\ 128.93,\ 131.31,\ 135.11,\ 144.65.

57
To solution of ester 7 (750 mg, 3.40 mmol), in 10 mL of MeOH was added LiOH·H₂O (142 mg, 3.40 mmol) and stirred at room temperature for 1 hour. The reaction mixture, after diluting with water (5 mL), was acidified with 1N HCl and extracted with ether (4 x 30 mL). The combined ether layer was dried over anhydrous Na₂SO₄ and evaporated.

The crude acid obtained was used directly for the Friedel-Crafts acylation reaction. Polyphosphoric acid (5 g) taken in a 25 mL beaker was heated to 90 °C in an oil-bath. To this, the crude acid (liquid) was added at once; the reaction mixture was then stirred at 90 °C for 10 minutes and cooled to 70 °C. At this temperature water (20 mL) was added slowly to hydrolyze the excess polyphosphoric acid. The aqueous layer was extracted with ether (4 x 20 mL). The combined ether layer was washed with saturated aqueous NaHCO₃ solution (2 x 20 mL), dried over anhydrous Na₂SO₄ and evaporated. The crude reaction mixture was purified by silica gel column chromatography to afford tetralone 16 as brown liquid (415 mg, 70%); Rf 0.38 (19:1 hexane: ethyl acetate).

IR (KBr, neat) ν 2935, 2854, 1674, 1534, 1432, 1144, 1032, 965, 854 cm⁻¹;

¹H NMR (CDCl₃, 300 MHz) δ 1.38 (d, 3H, J = 6.8 Hz), 1.78-1.96 (m, 1H), 2.14-2.31 (m, 1H), 2.35 (s, 3H), 2.45-2.63 (m, 1H), 2.65-2.84 (m, 1H), 2.94-3.14 (m, 1H), 7.16 (d, 1H, J = 8.3 Hz), 7.28 (d, 1H, J = 8.3 Hz), 7.80 (s, 1H).

(S)-1-(But-3-en-2-yl)-4,7-dimethyl-1,2,3,4-tetrahydronaphthalen-1-ol (17).

To a vigorously stirred solution of tetralone 16 (400 mg, 2.29 mmol) and crotyl bromide (0.354 mL, 3.44 mmol) in 8 mL of THF/H₂O (1:1) at 0 °C was added powdered zinc (298 mg, 4.59 mmol). After stirring at 0 °C for 1 hour, the reaction mixture was warmed up to
room temperature and stirred for 4 hours and then extracted with EtOAc (3 x 15 mL). The combined ethyl acetate layer was washed with saturated aqueous NH₄Cl solution (1 x 10 mL), brine (1 x 10 mL), dried over anhydrous Na₂SO₄ and evaporated. The crude product was dissolved in MeOH (7 mL), cooled to 0 °C and treated with NaBH₄ (43 mg, 1.13 mmol) to reduce the unreacted tetralone. MeOH was removed completely under reduced pressure, added water (10 mL) and extracted with EtOAc (3 x 15 mL). The combined EtOAc layer was washed with water (1 x 15 mL), brine (1 x 15 mL), dried over Na₂SO₄ and evaporated. The crude product was dissolved in hexane/ethyl acetate (19:1, 5 mL), added over a column loaded with silica wet with hexane and eluted with hexane/ethyl acetate (50:1) to afford 412 mg (78%) of alcohol 17 as light brown oil; Rf 0.38 (19:1 hexane: ethyl acetate).

IR (KBr, neat) u 3430, 2925, 2878, 1543, 1410, 1256, 1042, 967, 756 cm⁻¹.

¹H NMR (CDCl₃, 300 MHz) δ 1.12-1.32 (m, 6H), 1.35-1.72 (m, 2H), 1.73-2.10 (m, 2H), 2.34 (s, 3H), 2.38-2.72 (m, 1H), 2.75-2.96 (m, 1H), 4.82-5.01 (m, 2H), 5.36-5.64 (m, 1H), 6.97 (d, 1H, J = 8.2 Hz), 7.08 (d, 1H, J = 8.2 Hz), 7.32 (s, 1H).

Spiro-ether (18).

To a stirred solution of alcohol 17 (400 mg, 1.739 mmol) in anhydrous THF (7 mL) under nitrogen atmosphere at 0 °C was added BH₃·THF (1.0 M in THF, 2.60 mL, 2.60 mmol). The solution was then allowed to warm up to room temperature and stirred for 4 hours before quenching with aqueous 3N NaOH solution (3 mL) at 0 °C. After stirring for 10 minutes, 1.5 mL of 30% H₂O₂ (aq.) was added, stirred for another 10 minutes and extracted with ether (4 x 10 mL). The combined ether layer was dried over anhydrous Na₂SO₄ and evaporated. The crude diol obtained as brown oil was absorbed on silica gel
(60-120 mesh) and purified by column chromatography to afford 261 mg (65%) of spiro ether 18 as light brown oil; \( R_f 0.55 \) (9:1 hexane: ethyl acetate).

\[ ^1H \text{NMR (CDCl}_3, 300 \text{ MHz)} \]
\[
\delta 1.00 (d, 3H, J = 6.7 \text{ Hz}), 1.25 (d, 3H, J = 6.7 \text{ Hz}), 1.45-1.70 (m, 2H), 1.76-2.10 (m, 3H), 2.16-2.40 (m, 1H), 2.32 (s, 3H), 2.45-2.65 (m, 1H), 2.74-2.94 (m, 1H), 3.89-4.09 (m, 2H), 6.96 (d, 1H, J = 7.8 \text{ Hz}), 7.04 (d, 1H, J = 7.8 \text{ Hz}), 7.20 (s, 1H);
\]

\[ \text{ESIMS} m/z \]
\[ 254 (M+H)^+ \]

(S)-3-(4,7-Dimethyl-3,4-dihydropthalen-1-yl)butan-1-ol (19).

\[
\begin{align*}
&\text{A mixture of NaI (49 mg, 0.326 mmol) and freshly distilled TMSCl (35 mg, 0.322 mmol) in anhydrous acetonitrile (3 mL) was stirred at 0^\circ \text{C} for 30 minutes. To this, a solution of spiro-ether 18 (50 mg, 0.217 mmol) in anhydrous acetonitrile (2 mL) was added and stirred for another 1 hour before quenching with saturated aqueous Na$_2$S$_2$O$_3$ solution (3 mL). The reaction mixture was then extracted with ethyl acetate (3 × 10 mL). The combined ethyl acetate layer was washed with brine (1 × 10 mL), dried over anhydrous Na$_2$SO$_4$ and evaporated. The crude reaction mixture was purified by silica gel column chromatography to afford inseperable diastereomeric mixture (1:1) of alcohol 19 (13 mg, 27%) as brown oil; \( R_f 0.20 \) (4:1 hexane: ethyl acetate).
\]
\[ ^1H \text{NMR (CDCl}_3, 300 \text{ MHz)} \]
\[
\delta 1.14-1.35 (m, 6H), 1.55-1.76 (m, 1H), 1.78-1.95 (m, 1H), 1.96-2.17 (m, 1H), 2.28-2.51 (m, 1H), 2.34 (s, 3H), 2.72-2.88 (m, 1H), 2.94-3.10 (m, 1H), 3.70 (t, 2H, J = 7.1 \text{ Hz}), 5.88 (q, 1H, J = 5.7 \text{ Hz}), 6.93-7.08 (m, 2H), 7.15 (s, 1H).
\]
3-((4S)-4,7-Dimethyl-1,2,3,4-tetrahydronaphthalene-1-yl)butan-1-ol (20).

![Diagram of 3-((4S)-4,7-Dimethyl-1,2,3,4-tetrahydronaphthalene-1-yl)butan-1-ol (20).]

A stirred mixture of spiro-ether 18 (100 mg) and Pd/C in EtOAc/AcOH (5 mL, 9:1) was kept under hydrogen atmosphere (1 atm.) for 36 hours. The mixture was then filtered through a small pad of celite, washed the celite pad with EtOAc (2 x 5 mL). Combined ethyl acetate layer was evaporated under reduced pressure and crude product purified by silica gel column chromatography to afford an inseparable 1:1 mixture of diastereomers of alcohol 20 (80 mg, 80%) as colourless oil; Rf 0.20 (4:1 hexane: ethyl acetate).

IR (KBr, neat)  v 3345, 2968, 2856, 1531, 1354, 1281, 1107, 875 cm⁻¹

¹H NMR (CDCl₃, 300 MHz)  δ 0.69 (d, 3H, J = 6.7 Hz, α-Me), 1.17-1.46 (m, 5H), 1.50-1.90 (m, 4H), 2.23-2.41 (m, 1H), 2.28 (s, 3H), 2.62-2.76 (m, 1H), 2.77-2.88 (m, 1H), 3.40-3.78 (m, 2H), 6.80-7.05 (m, 3H).

ESIMS m/z  255 (M+Na)⁺

(S,E)-Ethyl 2-methyl-6-p-tolylhept-2-enoate (21).

![Diagram of (S,E)-Ethyl 2-methyl-6-p-tolylhept-2-enoate (21).]

To a stirred solution of ester 7 (1.0 g, 4.54 mmol) in 15 mL of anhydrous DCM at -78 °C, DIBAL-H (4.6 mL, 4.6 mmol; 1.0 M solution in toluene) was added dropwise over a period of 5 minutes. The resulting mixture was stirred for 10 minutes before quenching with saturated aqueous sodium-potassium tartrate solution (20 mL). The mixture was then warmed up to room temperature and stirred for 1 hour. Layers separated and aqueous layer was extracted with DCM (2 x 10 mL). The combined DCM layer was dried over anhydrous Na₂SO₄ and evaporated. To the crude aldehyde, added to 20 mL of benzene followed by 2.47 g (6.81 mmol) of three-carbon stabilized Wittig ylide and
stirred at 60 °C for 3 hours. After evaporation of solvent under reduced pressure, the crude product was purified by silica gel column chromatography using hexane/ethyl acetate (19:1) as eluent to afford 945 mg (80%) of unsaturated ester 21 as light brown oil; Rf 0.30 (19:1 hexane: ethyl acetate).

IR (KBr, neat) \(\nu\) 2958, 2925, 1710, 1648, 1514, 1452, 1368, 1263, 1179, 1131, 1093, 1030, 970 cm\(^{-1}\)

\(^1\)H NMR (CDCl\(_3\), 300 MHz) \(\delta\) 1.20-1.35 (mixture of doublet and triplet, 6H), 1.65-1.74 (m, 5H), 1.98-2.12 (m, 2H), 2.33 (s, 3H), 2.56-2.75 (m, 1H), 4.17 (q, 2H, \(J=6.8\) Hz), 6.68 (t, 1H, \(J=6.7\) Hz), 6.98-7.12 (m, 4H).

(S)-(+-)-Nuciferol (22).

To a stirred solution of ester 21 (900 mg, 3.46 mmol) in 10 mL of anhydrous DCM at -78 °C under nitrogen atmosphere, DIBAL-H (7.0 mL, 7.0 mmol; 1.0 M solution in toluene) was added dropwise over a period of 15 minutes. The resulting mixture was stirred for 1 hour before quenching with saturated aqueous sodium-potassium tartrate solution (15 mL). The mixture was then warmed up to room temperature and stirred for 1 hour. Layers separated and aqueous layer was extracted with DCM (3 x 15 mL). The combined DCM layer was dried over anhydrous Na\(_2\)SO\(_4\) and evaporated. The crude product was purified by silica gel column chromatography using hexane/ethyl acetate (20:3) as eluent to afford 700 mg (93%) of allylic alcohol 22 as colourless oil; Rf 0.20 (4:1 hexane: ethyl acetate).

\([\alpha]_D^{27}\) +33.2 (c 0.6, CHCl\(_3\))

\(^1\)H NMR (CDCl\(_3\), 200 MHz) \(\delta\) 1.24 (d, 3H, \(J=7.2\) Hz), 1.58 (s, 3H), 1.55-1.72 (m, 2H), 1.86-2.02 (m, 2H), 2.35 (s, 3H), 2.56-2.75 (m, 1H), 3.94 (s, 2H), 5.35 (t, 1H, \(J=6.4\) Hz), 7.00-7.12 (m, 4H).

\(^{13}\)C NMR (CDCl\(_3\), 75 MHz) \(\delta\) 13.64, 20.98, 22.57, 25.82, 38.07, 39.16, 68.94, 126.23, 126.91, 129.01, 134.75, 135.27, 144.40.
ESIMS m/z

241 (M+Na).*

(S)-4-Isopropyl-1,6-dimethyl-1,2-dihydronaphthalene (23).

To a stirred solution of allylic alcohol 22 (100 mg, 0.458 mmol) in anhydrous DCM (3 mL) at 0 °C under nitrogen atmosphere was added trifluoromethanesulfonic acid (0.04 mL, 0.46 mmol) dropwise. The reaction mixture was stirred at 0 °C for 15 minutes before quenching with saturated aqueous NaHCO₃ solution (5 mL). The mixture was extracted with DCM (3 x 10 mL). The combined DCM layer was washed with brine (1 x 10 mL), dried over anhydrous Na₂SO₄ and evaporated. The crude product was purified by silica gel column chromatography using hexane as eluent to afford 65 mg (70%) of dihydronaphthalene 23 as colourless oil; Rf 0.50 (hexane).

^1H NMR (CDCl₃, 200 MHz) δ 1.16-1.27 (m, 9H), 2.00-2.18 (m, 1H), 2.34-2.52 (m, 1H), 2.40 (s, 3H), 2.74-2.88 (m, 1H), 2.90-3.10 (m, 1H), 5.80 (t, 1H, J = 5.7 Hz), 6.98 (d, 1H, J = 8.3 Hz), 7.06 (s, 1H), 7.12 (d, 1H, J = 8.3 Hz).

cis-Calamenene (25).

Dihydronaphthalene 23 (60 mg, 0.30 mmol) was reduced with Pd/C, H₂ following the same procedure described for the preparation of ester 7 to obtain 60 mg (100%) of inseparable diastereomeric mixture (5:1) of calamenenes as colourless oil; Rf 0.50 (hexane).

^1H NMR (CDCl₃, 300 MHz) for major (cis) diastereomer: δ 0.81 (d, 3H, J = 6.8 Hz), 1.07 (d, 3H, J = 6.8 Hz), 1.28 (d, 3H, J = 6.8 Hz), 1.60-1.90 (m, 4H), 2.20-2.35 (m, 1H), 2.32 (s, 3H), 2.57-2.65 (m, 1H), 2.84-2.93 (m, 1H), 6.89 (d,
Chapter II, Present Work

1H, J = 7.8 Hz), 6.98 (s, 1H), 7.02 (d, 1H, J = 7.8 Hz).

(1S)-1,6-Dimethyl-4-(prop-1-en-2-yl)-1,2,3,4-tetrahydronaphthalene (24).

Method A: To stirred solution of allylic alcohol 22 (100 mg, 0.458 mmol) in anhydrous DCM (3 mL) under nitrogen atmosphere was added Sc(OTf)3 (225 mg, 0.458 mmol). The mixture was stirred at room temperature for 3 hours before quenching with saturated aqueous NaHCO3 solution (3 mL). The reaction mixture was then extracted with DCM (3 x 10 mL), the combined DCM layer dried over anhydrous Na2SO4 and evaporated. The crude product was purified by silica gel column chromatography using hexane as eluent to afford 64 mg (70%) of tetrhydronaphthalene 24 as colourless oil.

Method B: To stirred solution of allylic alcohol 22 (100 mg, 0.458 mmol) in anhydrous DCM (3 mL) at -78 °C under nitrogen atmosphere was added anhydrous FeCl3 (74 mg, 0.458 mmol). The mixture was slowly allowed to warm up to room temperature and stirred for 2 hours before quenching with saturated aqueous NH4Cl solution (3 mL). The reaction mixture was then extracted with DCM (3 x 10 mL), the combined DCM layer dried over anhydrous Na2SO4 and evaporated. The crude product was purified by silica gel column chromatography using hexane as eluent to afford 62 mg (68%) of tetrhydronaphthalene 24 as colourless oil; Rf 0.55 (hexane).

1H NMR (CDCl3, 300 MHz) δ 1.26 (d, 3H, J = 6.7 Hz), 1.32-1.47 (m, 1H), 1.62 (s, 3H), 1.64-1.78 (m, 1H), 1.83-2.02 (m, 2H), 2.25 (s, 3H), 2.75-2.90 (m, 1H), 3.38-3.51 (m, 1H), 4.62 (s, 1H), 4.86 (s, 1H), 6.83 (s, 1H), 6.88 (d, 1H, J = 7.9 Hz), 7.06 (d, 1H, J = 7.9 Hz).
Compound 24 was reduced to an inseperable mixture of diastereomers (2.5:1) using Pd/C, H₂ in EtOAc at room temperature to yield 26 as colourless liquid; R_f 0.50 (hexane).

\[ \text{H NMR (CDCl₃, 300 MHz) for major (trans) diastereomer: } \delta 0.71 \text{ (d, 3H, } J = 6.5 \text{ Hz)}, 1.00 \text{ (d, 3H, } J = 6.5 \text{ Hz)}, 1.25 \text{ (d, 3H, } J = 6.7 \text{ Hz)}, 1.28-1.40 \text{ (m, 1H)}, 1.52-1.66 \text{ (m, 1H)}, 1.70-1.88 \text{ (m, 1H)}, 1.89-2.00 \text{ (m, 1H)}, 2.15-2.30 \text{ (m, 1H)}, 2.28 \text{ (s, 3H)}, 2.61-2.78 \text{ (m, 2H)}, 6.86 \text{ (d, 1H, } J = 7.8 \text{ Hz)}, 6.95 \text{ (s, 1H)}, 7.04 \text{ (d, 1H, } J = 7.8 \text{ Hz}). \]

2-((4S)-4,7-Dimethyl-1,2,3,4-tetrahydronaphthalen-1-yl)propan-1-ol (27).

To stirred solution of tetrahydronaphthalene 24 (50 mg, 0.25 mmol) in anhydrous THF (3 mL) at 0 °C under nitrogen atmosphere was added solid dimeric 9-BBN-H (42 mg, 0.295 mmol). The mixture was then stirred at room temperature for 24 hours before quenching with aqueous 3N NaOH solution (1 mL) at 0 °C. After stirring for 10 minutes, added 1mL of 30% aqueous H₂O₂, stirred for 10 minutes and extracted with ether (3 x 10 mL). The combined ether layer was dried over anhydrous Na₂SO₄ and evaporated. The crude product was purified by silica gel column chromatography using hexane/ethyl acetate (9:1) as eluent to afford 43 mg (80%) of inseperable diastereomeric mixture of alcohol 27 as light brown oil; R_f 0.40 (4:1 hexane: ethyl acetate).

IR (KBr, neat) \[ v 3418, 2924, 2872, 1513, 1455, 1015, 814 \text{ cm}^{-1}; \]

\[ \text{H NMR (CDCl₃, 300 MHz) for major diastereomer: } \delta 1.01 \text{ (d, 3H, } J = 6.8 \text{ Hz)}, 1.25 \text{ (d, 3H, } J = 6.8 \text{ Hz)}, 1.46-1.98 \text{ (m, 4H)}, 2.17-2.31 \text{ (m, 1H)}, 2.29 \text{ (s, 3H)}, 2.70-2.86 \text{ (m, 2H)}, 3.34- \]

65
3.45 (m, 1H), 3.46-3.64 (m, 1H), 6.89 (d, 1H, J = 8.2 Hz), 6.98 (s, 1H), 7.05 (d, 1H, J = 8.2 Hz).

ESIMS m/z 241 (M+Na).*

\((2R,3S,6S)\)-1-\((\text{S})\)-4-\text{Bezy}-2-thioxoaoxazolidin-3-yl\)-3-hydroxy-2-methyl-6-\text{p}-tolylheptan-1-one (29).

Auxiliary 28 (1.7 g, 6.8 mmol) was charged into a 100 mL round bottomed flask equipped with a magnetic bar, nitrogen inlet and a septum. After addition of anhydrous DCM (25 mL), the solution was cooled to 0 °C. Freshly distilled TiCl₄ (1.49 mL, 13.6 mmol) was added via syringe. After 5 minutes, N,N-diisopropylethylamine (1.29 mL, 7.48 mmol) was added. The resulting deep red enolate was aged for 20 minutes at 0 °C then cooled to -78 °C. A solution of aldehyde 14 (1.2 g, 6.8 mmol) in anhydrous DCM (10 mL) was then added via cannula. The resulting mixture was stirred at -78 °C for 1.5 hours and then warmed to room temperature. Quenched with half-saturated aqueous NH₄Cl solution (20 mL). The organic layer was separated and aqueous layer extracted with DCM (2 x 10 mL). The combined DCM layer dried over anhydrous Na₂SO₄ and evaporated. Crude reaction mixture was purified by flash column chromatography to obtain diastereomerically pure 29 as brown oil (2.69 g, 93%); \( R_{f} \) 0.25 (5:1 hexane: ethyl acetate).

\([\alpha]_{D}^{25} +75.6 \text{ (c 3.8, CHCl₃);} \)

IR (KBr, neat) \( \nu \) 3451, 2925, 2868, 1694, 1453, 1370, 1190, 956, 747 cm⁻¹;

\(^1\text{H NMR (CDCl₃, 300 MHz)} \)

\( \delta \) 1.12 (d, 3H, \( J = 6.8 \) Hz), 1.24 (d, 3H, \( J = 6.8 \) Hz), 1.41-1.64 (m, 2H), 1.73-1.89 (m, 1H), 2.25 (s, 3H), 2.47 (d, 1H, \( J = 3.0 \) Hz), 2.58-2.69 (m, 2H), 3.21 (dd, 1H, \( J = 3.0 \), 12.8 Hz), 3.89-4.01 (m, 1H), 4.30-4.31 (m, 2H), 4.65-4.75 (m, 1H), 4.82-4.94 (m, 1H), 7.01-7.05 (m, 4H), 7.16-7.35 (m, 5H);
To a stirred solution of 29 (2.5 g, 5.88 mmol), 2,6-lutidine (1.70 mL, 14.7 mmol) in anhydrous DCM (25 mL) at 0 °C, TBSOTf (1.68 mL, 7.3 mmol) was added dropwise. The resulting mixture was stirred at 0 °C for 30 minutes before quenching with saturated aqueous NH₄Cl solution (10 mL). Layers were separated and aqueous layer was extracted with DCM (2 x 10 mL). Combined DCM layer was dried over anhydrous Na₂SO₄ and evaporated. Crude reaction mixture was purified by silica gel column chromatography to obtain compound 30 as colourless oil (3.0 g, 97%); Rf 0.55 (10:1 hexane: ethyl acetate).

**[α]D²⁵** + 51.4 (c 2.5, CHCl₃);

**IR (KBr, neat)**  ν 2935, 2880, 1691, 1435, 1327, 1145, 886, 703 cm⁻¹;

**¹H NMR (CDCl₃, 300 MHz)** δ 0.0 (s, 3H), 0.05 (s, 3H), 0.90 (s, 9H), 1.16 (d, 3H, J = 6.8 Hz), 1.23 (d, 3H, J = 6.8 Hz), 1.32-1.54 (m, 2H), 1.55-1.80 (m, 2H), 2.19 (s, 3H), 2.45 (dd, 1H, J = 3.0, 12.8 Hz), 2.52-2.67 (m, 1H), 3.11 (dd, 1H, J = 3.0, 12.8 Hz), 4.02-4.12 (m, 1H), 4.18-4.24 (m, 2H), 4.76-4.88 (m, 2H), 6.96-7.02 (m, 4H), 7.18 (d, 2H, J = 6.0 Hz), 7.22-7.36 (m, 3H);
(2\S,3\S,6\S)-3-(tert-Butyldimethylsilyloxy)-2-methyl-6-p-tolyheptan-1-ol (31).

To a stirred solution of TBS ether 30 (2.8 g, 5.18 mmol) in MeOH/THF (20 mL, 5:1) was added NaBH₄ (295 mg, 7.77 mmol). The resulting mixture was stirred at room temperature for overnight. After solvent was evaporated completely, water (25 mL) was added and extracted with ethyl acetate (3 x 20 mL). Combined ethyl acetate layer was washed with water (1x 20 mL), brine (1x 20 mL), dried over anhydrous Na₂SO₄ and evaporated. Crude product was purified by silica gel column chromatography to obtain alcohol 31 as colourless oil (1.41g, 78%); Rf 0.15 (20:1 hexane: ethyl acetate).  

$[\alpha]_D^{25} + 13.9$ (c 4.0, CHCl₃);  

IR (KBr, neat)  

\begin{align*}  
\nu & 3423, 2926, 2855, 1462, 1253, 1038, 836, \\
& 773 \text{ cm}^{-1};  
\end{align*}  

\( ^1\text{H NMR (CDCl}_3, 300 \text{ MHz) } \)  

\begin{align*}  
\delta & 0.0 \text{ (s, 3H), 0.0 (s, 3H), 0.71 (d, 3H, J = 6.8 Hz),} \\
& 0.87 \text{ (s, 9H), 1.22 (d, 3H, J = 7.5 Hz), 1.25-1.54 (m, 2H),} \\
& 1.55-1.70 \text{ (m, 1H), 1.78-1.89 (m, 1H), 2.09-2.17 (m, 1H),} \\
& 2.33 \text{ (s, 3H), 2.53-2.64 (m, 1H), 3.38-3.48 (m, 1H),} \\
& 3.58 \text{ (dt, 1H, J = 3.0, 8.3 Hz), 3.70 (dt, 1H, J = 3.0, 6.0 Hz),} \\
& 7.00 \text{ (d, 2H, J = 8.3 Hz),} \\
& 7.05 \text{ (d, 2H, J = 8.3 Hz);}  
\end{align*}  

\( ^{13}\text{C NMR (CDCl}_3, 75 \text{ MHz) } \)  

\begin{align*}  
\delta & -4.59, -4.33, 11.48, 17.98, 20.91, 22.59, 25.85, \\
& 30.95, 34.76, 39.46, 39.65, 65.95, 75.33, 126.72, \\
& 129.0, 135.22, 144.34;  
\end{align*}  

ESIMS m/z  

373 (M+Na).
To a stirred solution of alcohol (1.3 g, 3.71 mmol), Et$_3$N (1.29 mL, 9.28 mmol) in anhydrous DCM (20 mL), recrystallized tosyl chloride (0.88 g, 4.63 mmol) was added. The resulting mixture was stirred at room temperature for three hours. The reaction mixture was diluted with DCM (20 mL), washed with water (1 x 20 mL), brine (1 x 10 mL) dried over anhydrous Na$_2$SO$_4$ and evaporated. Silica gel column chromatography of the crude reaction mixture using hexane/ethyl acetate (19:1) yielded tosylate 32 as light brown oil (1.81 g, 97%); R$_f$ 0.30 (20:1 hexane: ethyl acetate).

$[\alpha]_D^{25}$ +16.6 (c 2.7, CHCl$_3$);

$^1$H NMR (CDCl$_3$, 300 MHz) δ 0.0 (s, 6H), 0.81 (d, 3H, $J$ = 6.8 Hz), 0.87 (s, 9H), 1.27 (d, 3H, $J$ = 6.8 Hz), 1.31-1.39 (m, 1H), 1.41-1.62 (m, 3H), 1.88-2.02 (m, 1H), 2.40 (s, 3H), 2.54 (s, 3H), 2.57-2.69 (m, 1H), 3.71 (dt, 1H, $J$ = 3.0, 6.7 Hz), 3.86 (dd, 1H, $J$ = 6.7, 9.0 Hz), 4.02 (dd, 1H, $J$ = 6.7, 9.0 Hz), 7.06 (d, 2H, $J$ = 8.3 Hz), 7.13 (d, 2H, $J$ = 8.3 Hz), 7.40 (d, 2H, $J$ = 8.3 Hz), 7.85 (d, 2H, $J$ = 8.3 Hz);

(2S,3S)-3-Methyl-2-((S)-3-p-tolylbutyl)oxetane (33)

To a stirred solution of tosylate 32 (1.7 g, 3.36 mmol), in MeOH (20 mL), PTSA (129 mg, 0.67 mmol) was added. The mixture was stirred at room temperature until complete deprotection of TBS ether took place (ca. 6 hours). After evaporating MeOH completely, the residue was dissolved in anhydrous THF (25 mL) and cooled to 0 °C. NaH (55%
dispersion in mineral oil, 220 mg, 5.04 mmol) was added and the resulting mixture was stirred at room temperature for 6 hours before quenching with saturated aqueous NH₄Cl solution (5 mL). Organic layer was separated and aqueous layer extracted with EtOAc (2 x 10 mL). Combined organic layer dried over anhydrous Na₂SO₄ and evaporated under reduced pressure. Silica gel column chromatography of crude product using hexane/ethyl acetate (19:1) yielded oxetane 33 as colourless oil (682 mg, 93%); Rf 0.55 (10:1 hexane: ethyl acetate).

\[ \text{[a]_D}^{25} + 40.4 \quad (c 3.8, \text{CHCl}_3) \]

IR (KBr, neat)
\[ \nu 2960, 2927, 2865, 1513, 1456, 1380, 973, 816 \text{ cm}^{-1} \]

\(^1\)H NMR (CDCl₃, 300 MHz)
\[ \delta 1.07 (d, 3H, J = 7.5 \text{ Hz}), 1.23 (d, 3H, J = 7.5 \text{ Hz}), 1.28-1.40 (m, 2H), 1.54-1.70 (m, 2H), 2.31 (s, 3H), 2.58-2.69 (m, 1H), 2.84-2.99 (m, 1H), 3.97 (t, 1H, \text{J = 6.0 Hz}), 4.62-4.72 (m, 2H), 7.00 (d, 2H, \text{J = 9.0 Hz}), 7.04 (d, 2H, \text{J = 9.0 Hz}) \]

\(^13\)C NMR (CDCl₃, 75 MHz)
\[ \delta 13.1, 20.9, 22.5, 30.1, 31.9, 33.4, 39.7, 75.5, 85.1, 126.8, 129.0, 135.2, 144.3 \]

ESIMS m/z 241 (M+Na).

HRMS Calcd. for C₁₅H₂₂ONa: 241.1568 found 241.1560.

(R)-2-((1R,4S)-4,7-Dimethyl-1,2,3,4-tetrahydronaphthalene-1-yl)propan-1-ol (34).

[Chemical structure image]

A solution of oxetane 33 (550 mg, 2.5 mmol), in anhydrous DCM (26 mL) was cooled to -78 °C. To this freshly distilled BF₃·OEt₂ (0.32 mL, 2.5 mmol) was added dropwise. After stirring for 1 hour at -78 °C, the reaction mixture was allowed to warm up to room temperature and stirred for 3 hours before quenching with half-saturated aqueous NH₄Cl solution (10 mL). DCM layer was separated and the aqueous layer extracted with DCM (2 x 10 mL). Combined DCM layer washed with water (1 x 20 mL), brine (1 x 20 mL), dried over anhydrous Na₂SO₄ and evaporated. The crude product was purified by silica
gel column chromatography using hexane/ethyl acetate (9:1) to obtain alcohol 34 as colourless liquid (445 mg, 81%); Rf 0.15 (10:1 hexane: ethyl acetate).

\[
[a]_D^{25} + 57.4 (c 3.75, CHCl_3);
\]

\[\text{H NMR (CDCl}_3, 200 \text{ MHz)} \]
\[\delta 0.73 (d, 3H, J = 7.0 \text{ Hz}), 1.26 (d, 3H, J = 7.0 \text{ Hz}), 1.31-1.48 (m, 1H), 1.49-1.70 (m, 1H), 1.72-2.04 (m, 2H), 2.16-2.34 (m, 1H), 2.29 (s, 3H), 2.64-2.86 (m, 1H), 2.90-3.06 (m, 1H), 3.46-3.70 (m, 2H), 6.89 (d, 1H, J = 7.8 Hz), 6.97 (s, 1H), 7.07 (d, 1H, J = 7.8 Hz); \]

\[\text{C NMR (CDCl}_3, 75 \text{ MHz)} \]
\[\delta 12.1, 21.0, 21.6, 22.1, 29.6, 32.3, 38.8, 39.8, 66.5, 126.2, 126.8, 128.2, 134.6, 138.9, 140.2; \]

ESIMS \text{ m/z 241 (M+Na).*}

HRMS Calcd. for C_{13}H_{22}ONa: 241.1568 found 241.1576.

(R)-2-((1R,4S)-4,7-Dimethyl-1,2,3,4-tetrahydronaphthalen-1-yl)proyl 4-methylbenzenesulfonate (35).

The tosylation of alcohol 34 (50 mg, 0.229 mmol) was carried out following the same procedure as described for the preparation of tosylate 32. Light brown oil, 79 mg (97%); Rf 0.45 (9:1 hexane: ethyl acetate)

\[
[a]_D^{25} +60.2 (c 1.5, CHCl_3);
\]

\[\text{H NMR (CDCl}_3, 200 \text{ MHz)} \]
\[\delta 0.78 (d, 3H, J = 6.8 \text{ Hz}), 1.27 (d, 3H, J = 6.8 \text{ Hz}), 1.33-1.49 (m, 1H), 1.51-1.73 (m, 1H), 1.75-2.06 (m, 2H), 2.18-2.37 (m, 1H), 2.29 (s, 3H), 2.34 (s, 3H), 2.63-2.88 (m, 1H), 2.92-3.07 (m, 1H), 3.52-3.73 (m, 2H), 6.93 (d, 2H, J = 7.5 Hz), 7.01 (s, 1H), 7.15 (d, 1H, J = 7.5 Hz), 7.45 (d, 2H, J = 7.8 Hz), 7.82 (d, 2H, J = 7.8 Hz), \]
To a stirred solution of tosylate 35 (60 mg, 0.160 mmol) in anhydrous THF (3 mL) at 0 °C under nitrogen atmosphere was added LiAlH₄ (12 mg, 0.32 mmol). The mixture was warmed to room temperature and heated to reflux for 3 hours. After cooling to 0 °C, the reaction mixture was quenched with saturated aqueous Na₂SO₄ solution (1 mL) and diluted with ethyl acetate (5 mL). Filtered through a small pad of celite and washed the celite pad with ethyl acetate (2 x 5 mL). The combined filtrate was dried over anhydrous Na₂SO₄ and evaporated under reduced pressure. The crude reaction mixture was purified by silica gel column chromatography using hexane as eluent to afford 25 mg (80%) of calamenene 36 as colourless oil; Rf 0.50 (hexane).

\[ \alpha \] \text{D}^{25} +29.6 \ (\epsilon 0.75, \text{CHCl}_3) \\
^1\text{H} \text{NMR (CDCl}_3, \text{200 MHz)} \ 5 \ 0.71 \ (d, 3H, J = 6.8 Hz), \ 0.99 \ (d, 3H, J = 6.8 Hz), \ 1.25 \ (d, 3H, J = 6.8 Hz), \ 1.29-1.39 \ (m, 1H), \ 1.50-1.68 \ (m, 1H), \ 1.76-1.87 \ (m, 1H), \ 1.89-2.00 \ (m, 1H), \ 2.15-2.34 \ (m, 1H), \ 2.27 \ (s, 3H), \ 2.62-2.78 \ (m, 2H), \ 6.87 \ (d, 2H, J = 7.5 Hz), \ 6.97 \ (s, 1H), \ 7.06 \ (d, 1H, J = 7.5 Hz); \\
^13\text{C} \text{NMR (CDCl}_3, \text{300 MHz)} \ 17.5, \ 21.3, \ 21.5, \ 21.7, \ 22.5, \ 31.0, \ 32.0, \ 32.7, \ 44.0, \ 126.3, \ 126.9, \ 128.9, \ 134.6, \ 140.1, \ 140.2.

(S,E)-Ethyl 4-(((1R,4S)-4,7-dimethyl-1,2,3,4-tetrahydronaphthalen-1-yl)pent-2-enoate (37).
resulting mixture was stirred for 30 minutes before adding a solution of alcohol 34 (150 mg, 0.68 mmol) in DCM (1 mL). After stirring for 1 hour at -78 °C, Et3N (0.57 mL, 4.12 mmol) was added. The mixture was warm up to room temperature over a period of 1 hour. The reaction mixture was the diluted with DCM (10 mL) and washed with water (2 x 5 mL), brine (1 x 10 mL) and dried over anhydrous Na2SO4. To the crude reaction mixture stabilized two-carbon Wittig ylide (359 mg, 1.03 mmol) was added and stirred overnight. DCM was evaporated and crude reaction mixture was purified by silica gel column chromatography using hexane/ethyl acetate (50:1) to obtain unsaturated ester 37 as colourless oil (165 mg, 84%); Rf 0.35 (20:1 hexane: ethyl acetate).

IR (KBr, neat)  
\[ \text{v} \ 2958, 2925, 1710, 1458, 1268, 1185, 1105, 820 \ \text{cm}^{-1}; \]

\[ ^1\text{H NMR (CDCl}_3, 200 \text{MHz}) \]
\[ \delta \ 0.92 \ (d, 3\text{H}, J = 5.8 \text{ Hz}), 1.24-1.48 \ (m, 7\text{H}), 1.49-1.72 \ (m, 1\text{H}), 1.73-2.42 \ (m, 2\text{H}), 2.31 \ (s, 3\text{H}), 2.68-2.88 \ (m, 1\text{H}), 2.92-3.11 \ (m, 2\text{H}), 4.22 \ (q, 2\text{H}, J = 7.2 \text{ Hz}), 5.81 \ (d, 1\text{H}, J = 15.2 \text{ Hz}), 6.88-7.91 \ (m, 5\text{H}); \]

\[ ^{13}\text{C NMR (CDCl}_3, 75 \text{MHz}) \]
\[ \delta \ 13.1, 14.2, 20.9, 21.1, 22.2, 30.5, 32.4, 40.4, 42.0, 60.1, 120.3, 126.6, 127.1, 128.3, 134.7, 137.5, 140.2, 153.9, 166.7. \]

(S)-Ethyl 4-(((1R,4S)-4,7-dimethyl-1,2,3,4-tetrahydronaphthalen-1-yl)pentaneate (38).

\[
\begin{align*}
\text{(S)-Ethyl} & \quad \text{4-(((1R,4S)-4,7-dimethyl-1,2,3,4-tetrahydronaphthalen-1-yl)pentaneate} \\
\text{38).}
\end{align*}
\]

The unsaturated ester 37 (155 mg) was reduced to the saturated ester 38 following the same procedure as stated for the reduction of compound 6. Colourless oil (155 mg, quantitative); Rf 0.35 (20:1 hexane: ethyl acetate);

\[ [\alpha]_D^{27^\circ} + 38.5 \ (c 3.25, \text{CHCl}_3); \]

IR (KBr, neat)  
\[ \text{v} \ 2957, 2927, 2870, 1735, 1459, 1375, 1174, 1035, 812 \ \text{cm}^{-1}; \]
\[\text{Chapter II, Present Work}\]

\[^1\text{H NMR (CDCl}_3\text{, 300 MHz)}\]

\(\delta 0.69 (d, 3H, J = 6.8 \text{ Hz}), 1.26-1.35 (m, 6H), 1.48-2.00 (m, 6H), 2.04-2.20 (m, 1H), 2.32 (s, 3H), 2.31-2.40 (m, 2H), 2.62-2.81 (m, 1H), 4.16 (q, 2H, J = 7.5 \text{ Hz}), 6.91 (d, 1H, J = 8.3 \text{ Hz}), 6.96 (s, 1H), 7.08 (d, 1H, J = 8.3 \text{ Hz});\]

\[^{13}\text{C NMR (CDCl}_3\text{, 75 MHz)}\]

\(\delta 14.2, 21.0, 21.4, 21.8, 30.1, 31.5, 32.7, 32.8, 36.9, 41.4, 60.1, 126.1, 126.4, 127.9, 134.6, 139.2, 140.3, 173.8;\)

\(\text{ESIMS } m/z\)

311 (M\(^+\)Na).\(^+\)

\(\text{HRMS Calcd. for } C_{15}H_{28}O_2Na: 311.1987 \text{ found 311.1989.}\)

\((S)-4-((1R,4S),4,7-\text{dimethyl}-1,2,3,4-\text{tetrahydronaphthalen}-1-\text{yl})\text{pentanal (39).}\)

\[
\begin{align*}
\text{H} & \quad \text{H} \\
\text{O} & \\
\end{align*}
\]

A solution of saturated ester 38 (100 mg, 0.34 mmol), in anhydrous DCM (3 mL) was cooled to -78 °C. DIBAL-H (1.0 M in toluene, 0.35 mL, 0.35 mmol) was then added dropwise. The resulting mixture was stirred for 15 minutes before quenching with saturated aqueous sodium-potassium tartrate (7 mL). The mixture was warmed to room temperature and stirred for 1 hour. Organic layer was separated and aqueous layer extracted with DCM (3 x 5 mL). Combined organic layer was dried over anhydrous Na\(_2\)SO\(_4\) and evaporated. The crude reaction mixture was purified by silica gel column chromatography using hexane/ethyl acetate (50:1) to obtain aldehyde 39 as colourless oil (68 mg, 80%); \(R_f 0.35\) (20:1 hexane: ethyl acetate).

\([\alpha]_D^{27}\)

+ 54.1 (c 0.55, CHCl\(_3\));

\[^1\text{H NMR (CDCl}_3\text{, 300 MHz)}\]

\(\delta 0.66 (d, 3H, J = 6.8 \text{ Hz}), 1.25 (d, 3H, J = 6.8 \text{ Hz}), 1.46-1.98 (m, 6H), 2.03-2.14 (m, 1H), 2.28 (s, 3H), 2.43-2.54 (m, 2H), 2.62-2.78 (m, 1H), 2.79-2.89 (m, 1H), 6.88 (d, 1H, J = 8.3 \text{ Hz}), 6.90 (s, 1H), 7.06 (d, 1H, J = 8.3), 9.83 (s, 1H).\)

74
Commercial isopropyltriphenylphosphonium iodide (115 mg, 0.26 mmol) was charged into a round bottomed flask equipped with a magnetic bar, nitrogen inlet and a septum. After adding anhydrous THF (3 mL), the mixture was cooled to 0 °C. n-BuLi (0.16 M, 0.15 mL, 0.24 mmol) was added and the resulting deep brown mixture was aged for 30 minutes. A solution of aldehyde 39 (50 mg, 0.20 mmol) in THF (1.5 mL) was added via syringe and resulting mixture was stirred at 0 °C for 3 hours and then warmed to room temperature and stirred for two hours. Quenched with saturated aqueous NH₄Cl solution (3 mL) and extracted with pentane (3 x 10 mL). Combined organic layer washed with water (1 x 10 mL), brine (1 x 5 mL), dried over anhydrous Na₂SO₄ and evaporated. Silica gel column chromatography of the crude product using hexane as eluent yielded 46 mg (80%) of ergorgiaene as colourless liquid; Rf 0.55 (hexane).

[a]_D^27 +23.2 (c 0.75, CHCl₃);

H NMR (CDCl₃, 400 MHz) δ 0.63 (d, 3H, J = 6.6 Hz), 1.26 (d, 3H, J = 7.3 Hz), 1.30-1.38 (m, 2H), 1.39-1.48 (m, 1H), 1.49-1.56 (m, 1H), 1.62 (brs, 3H), 1.70 (brs, 3H), 1.76-1.83 (m, 1H), 1.87-1.93 (m, 1H), 1.99-2.14 (m, 3H), 2.28 (s, 3H), 2.64-2.77 (m, 1H), 2.82-2.88 (m, 1H), 5.12 (brt, 1H, J = 6.6 Hz), 6.86 (d, 1H, J = 8.0 Hz), 6.94 (s, 1H), 7.06 (d, 1H, J = 8.0 Hz);

C NMR (CDCl₃, 75 MHz) δ 14.5, 17.7, 21.1, 21.5, 21.8, 25.7, 26.3, 31.8, 32.8, 35.2, 37.0, 41.5, 124.9, 126.0, 126.4, 128.1, 131.2, 134.7, 139.9, 140.4;

LCMS m/z 270 (M).
References:

Chapter II. Present Work

SPECTRA
$^1$H NMR SPECTRUM OF COMPOUND 5
$^1$H NMR SPECTRUM OF COMPOUND 7

Scan 10  RT: 0:24  No. ions: 420  Rase: 39.4%  TIC=187276

EIMS SPECTRUM OF COMPOUND 7
$^1$H NMR SPECTRUM OF COMPOUND 9
$^1\text{H NMR SPECTRUM OF COMPOUND II}$
HRME Spectrum of Compound 11
$^{13}$C NMR SPECTRUM OF COMPOUND 12
IR SPECTRUM OF COMPOUND 12

Sample Name: JSY-ME
Sample Preparation: NEAT
Collection time: Thu Dec 29 11:46:57 2006 (GMT+05:30)
Instruments: Thermo Nicolet Nexus 670 Spectrometer
Resolution: 4 cm⁻¹

Detector: DTGS KBr
Beam splitter: KBr
Source: IR

Analyzed Name:
$^1$H NMR SPECTRUM OF COMPOUND 13
Indian Institute of Chemical Technology, Hyderabad
FTIR Analysis Report

Sample Name: JSY-ALC
Sample Preparation: HEAT
Collection time: Tue Dec 29 16:48:45 2008 (GMT+05:30)
Infrachrome: Thermo Nicolet Nexus 670 Spectrometer
Resolution: 4 cm-1

IR SPECTRUM OF COMPOUND 13

Detector: DTGS KBr
Beam splitter: KBr
Source: IR
Analyst Name:

Wavenumbers (cm⁻¹)

4000 3500 3000 2500 2000 1500 1000 500
88 86 84 82 80 78 76 74 72
Sample Name: JSI-ALO
Sample Preparation: NLA1
Collection time: Wed Jan 10 14:50:32 2011 (311m+53.3)
Bench: Thermo Nicolet NEXUS 870 Spectrometer
Resolution: 4 cm⁻¹

IR SPECTRUM OF COMPOUND 14

Detector: DTGS KBr
Refractor: KBr
Source: IR
Analyzer Name
$^1$H NMR SPECTRUM OF COMPOUND 16
$^1$H NMR SPECTRUM OF COMPOUND 18
$^1$H NMR SPECTRUM OF COMPOUND 19
$^1$H NMR SPECTRUM OF COMPOUND 20
Indian Institute of Chemical Technology, Hyderabad
FTIR Analysis Report

IR SPECTRUM OF COMPOUND 21

Sample Name: JSY-WT
Sample Preparation: neat
Collection time: Fri Jan 05 14:30 4/2001 (GMT+06:30)
Instrument: Thermo Nicolet Nexus 670 Spectrometer
Resolution: 4 cm⁻¹

Detector: DTGS KBr
Beam splitter: KBr
Source: IR
Analyst Name:
$^1$H NMR SPECTRUM OF COMPOUND 22
Display Report - Selected Window Selected Analysis

Analysis Name: SK87792.D
Method: Copy of OLYMPUS.M
Sample Name: blank 213
Analysis Info:

ESIMS SPECTRUM OF COMPOUND 27
IR SPECTRUM OF COMPOUND 27

Name: JSY-ALC
Preparation: NEAT

Thu Dec 28 11:48:35 2006 (GMT+05:30)

4 cm⁻¹
HRES SPECTRUM OF COMPOUND 29
IR SPECTRUM OF COMPOUND 29

Sample Name: JSY-ALDOL

Preparation: NEAT

Action time: Tue Oct 17 12:28:02 2008 (GMT+05:30)

Instrument: Thermo Nicolet Nexus 670 Spectrometer

Solution: 4 cm-1

Detector: DTGS KBr

Beamsplitter: KBr

Source: IR

Analyst Name:
$^1$H NMR SPECTRUM OF COMPOUND 30
$^1$H NMR SPECTRUM OF COMPOUND 30
HRMS SPECTRUM OF COMPOUND 30
$^1$H NMR SPECTRUM OF COMPOUND 31
HRMS SPECTRUM OF COMPOUND 31
Indian Institute of Chemical Technology, Hyderabad
FTIR Analysis Report

IR SPECTRUM OF COMPOUND 31

Sample Name: JSY-ALCA
Sample Preparation: NEAT
Collection time: Tue Dec 28 16:56:48 2008 (GMT+05:30)
Instrument: Thermo Nicolet Nexus 670 Spectrometer
Resolution: 4 cm⁻¹

Detector: DTGS KBr
Beam splitter: KBr
Source: IR
Analyst Name: 
$^{13}$C NMR SPECTRUM OF COMPOUND 33
HRMS SPECTRUM OF COMPOUND 33
Indian Institute of Chemical Technology, Hyderabad
FTIR Analysis Report

Sample Name: JSY-OXE
Sample Preparation: NEAT
Collection time: Tue Oct 17 12:36:48 2006 (GMT+05:30)

IR Spectrum of Compound 33

Detector: DTGS KBr
Beam splitter: KBr
Source: IR
Analyst Name:
$^{13}$C NMR SPECTRUM OF COMPOUND 34
$^{13}$C NMR SPECTRUM OF COMPOUND 37
"H NMR SPECTRUM OF COMPOUND 38
Sample Name: JSY-ES1LR
Sample Preparation: easel
Collection time: Fri Jan 06 14:44:15 2007 (GMT+05 30)
Bench: Thermo Nicolet Nexus 670 Spectrometer
Resolution: 4 cm⁻¹

IR SPECTRUM OF COMPOUND 38

Detector: DTGS KBr
Beam splitter: KBr
Source: IR
Analyst Name:
$^1$H NMR SPECTRUM OF (+)-EROGORIAENE