CHAPTER – 2

Terpenes to Ionic Liquids: Synthesis and Characterization of Citronellal-Based Chiral Ionic Liquids
2.1 Introduction

Ionic liquids are a fascinating class of compounds with unique properties, which have recently attracted the attention of a wide number of researchers. Numerous works have been published in the last couple of years reporting the possibility to perform several organic reactions and catalyzed processes in these new media. They represent a new class of non-molecular, ionic solvents with a tremendous potential to replace conventional solvents. They are also considered as greener alternatives to conventional organic solvents in chemical transformations due to their low vapor pressure and high boiling points.\(^1\) Particularly, their property of reusability and tolerance for flammability has prompted their use in chromatographic separation\(^2\) and extraction techniques.\(^3\) There has been a flurry of activity on the synthesis, properties and applications of several ionic liquids in the last decade culminating in several publications and reviews.\(^4\)\(^-\)\(^9\)

Ionic liquids have the potential to play a significant role in asymmetric synthesis possibly due to their difference in thermodynamic and kinetic behavior, selectivity and process performance as compared to conventional organic solvents. Although synthesis, characterization and application of ionic liquids have gained more popularity, literature available on chiral ionic liquids is very limited.
Terpenes are an important part of the “chiral pool” and can be used in the synthesis of chiral ionic liquids. However, the literature available on the use of terpenes as a chiral pool in ionic liquids is limited. Tosoni et al. have reported one of the first chiral ionic liquids derived from citronellol, 1,3-dicitronellyl-1H-imidazolium bromide, Scheme-2.1.

Scheme: 2.1 Synthesis of Citronellyl bromide.

Chiral citronellol has been converted into the corresponding citronellyl bromide followed by alkylation with 1-alkylimidazoles to give chiral ionic liquid, Scheme-2.2.

Scheme: 2.2 Synthesis of CILs derived from (3R)-Citronellol.

Similarly alkylation of citronellyl bromide with pyridine gives chiral pyridinium ionic liquid, Scheme–2.3.
Scheme: 2.3 Synthesis of chiral pyridinium ionic liquids.

Another interesting C2-symmetric 1,3-dicitronellyl-1H-imidazolium bromide was produced via deprotonation with tetrabutylammonium hydroxide and then reacted with 2 equivalents of the citronellyl bromide, Scheme-2.4.

Scheme: 2.4 Synthesis of CIL derived from (3R)-Citronellol.

Wang et al. investigated chiral pinene-based ionic liquids using (1S)-a pinene. The cis amino alcohol obtained from a-pinene was converted into chiral oxazoline, followed by alkylation with suitable alkyl halide to furnish the chiral ionic liquid, Scheme-2.5. The counter ion could be exchanged with different counter ions like PF$_6^-$ and BF$_4^-$. 
Both the above mentioned examples used imidazolium, pyridinium, oxazolium moieties to construct chiral ionic liquids.

Chirality in these ionic liquids can arise from the anion or from the cation counterpart of the ionic liquids. Ionic liquids with chiral anion counterparts have been reported in the literature. However, application of the same in Diels-Alder reaction did not result in enantioselectivity. Modifications to the cation counterpart of room temperature chiral ionic liquids have been reported with ammonium, pyridinium, oxazolium, thiazolium and imidazolium moieties. The
following work gives the detailed uses of terpene chiral pool for the preparation of chiral ionic liquids through simple chemical transformations.

Citronellal is an easily accessible, less expensive chiral starting material with an aldehyde functionality, which can be conveniently used for the several chemical transformations to design the desired carbon framework. It is extensively used in the field of organic synthesis and an important chiral precursor in the synthesis of several natural products. The major advantage of citronellal as chiral precursor is its commercial accessibility in both the chiral forms. The low boiling point of citronellal is expected to provide a useful chiral carbon chain to the ionic liquid under study with low melting points or offer liquid state at room temperature, thus enabling them to open new opportunities in the field of asymmetric synthesis.

The chiral ionic liquids can be envisaged from citronellal 18, using a reductive amination strategy with dimethylamine or diethylamine followed by treatment with an alkyl halide to give the corresponding chiral ionic liquids 19a-e and 20a-e respectively, as mentioned in the Figure 2.1.
Figure: 2.1 Retrosynthesis of Citronellal-based chiral ionic liquids.
2.2 Results and Discussion

As mentioned in the retro synthetic analysis Figure-2.1, the citronellal \((S)-18\) is treated with dimethylamine in the presence of Raney-nickel in hydrogen environment to give the corresponding amine \((S)-21\) in excellent yields. The dimethylamine \(21\), thus obtained, is treated with different alkyl halides for eg., methyl iodide, ethyl iodide, \(n\)-propyl bromide, iso-propyl bromide, \(n\)-butyl bromide, etc., to give the corresponding quaternary ammonium salts \((S)-19a-e\) in good yields. Although the reaction proceeded smoothly with methyl and ethyl halides, the reactivity with iso-propyl bromide was observed to be sluggish with longer reaction time. Similarly, the other commercially available isomer, \((R)\)-citronellal, was also reacted with dimethylamine in presence of Raney-nickel and hydrogen to give the corresponding amine \((R)-21\), which on further treatment with the alkyl halides furnished the desired chiral ammonium salts \((R)-19a-e\) in good yields, Scheme-2.6.
a) Dimethylamine, MeOH, Raney-nickel, H₂ balloon, RT- overnight.

b) Acetonitrile, R-X, RT- overnight.

**Scheme: 2.6** Synthesis of chiral ionic liquids starting from citronellal and dimethylamine as amine source.

The scope of the reaction was extended to diethylamine to understand the physical properties of the resulting ionic liquids with citronellal. Thus, citronellal (S)-18 was treated with diethylamine in the presence of Raney-nickel and hydrogen to give the corresponding diethylamine (S)-22. The diethylamine derivative (S)-22 was further treated with different alkyl halides for eg., methyl iodide, ethyl iodide, n-propyl bromide, iso-propyl bromide, n-butyl bromide, etc., to give the corresponding quaternary ammonium salts (S)-20a-e in good yields. Similar observations were experienced in the reaction of iso-propyl bromide with diethyl substrate, in which the reaction was observed to be sluggish. Similarly, the chemistry was repeated with (R)-citronellal and diethylamine in presence of Raney-nickel and
hydrogen to give the corresponding amine (R)-22, which on further treatment with alkyl halides yielded the chiral ammonium salts (R)-20a-e in good yields, Scheme-2.7. All the chiral ionic liquids prepared using reductive amination with dimethylamine were found as liquid at room temperature except (S) and (R)-19a. Similarly, all the new chiral ionic liquids were prepared using reductive amination with diethylamine were found to be liquids at room temperature, table-2.1.

a) Diethylamine, MeOH, Raney-nickel, H₂ balloon, RT- overnight
b) Acetonitrile, R-X, RT-overnight.

**Scheme: 2.7** Synthesis of chiral ionic liquids starting from citronellal and diethylamine as amine source.
Table: 2.1

Preparation of compounds (S)-19a-e, (R)-19a-e, (S)-20a-e, and (R)-20a-e

<table>
<thead>
<tr>
<th>Compound No.</th>
<th>R</th>
<th>X</th>
<th>SOR (C= 1, MeOH)</th>
<th>M.P.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(S)-19a</td>
<td>Me</td>
<td>I−</td>
<td>3.09</td>
<td>Yellow Solid</td>
</tr>
<tr>
<td>(S)-19b</td>
<td>Et</td>
<td>I−</td>
<td>2.96</td>
<td>Liquid</td>
</tr>
<tr>
<td>(S)-19c</td>
<td>n-Pr</td>
<td>Br−</td>
<td>3.96</td>
<td>Liquid</td>
</tr>
<tr>
<td>(S)-19d</td>
<td>Iso-Pr</td>
<td>Br−</td>
<td>3.55</td>
<td>Liquid</td>
</tr>
<tr>
<td>(S)-19e</td>
<td>n-Bu</td>
<td>Br−</td>
<td>3.28</td>
<td>Liquid</td>
</tr>
<tr>
<td>(R)-19a</td>
<td>Me</td>
<td>I−</td>
<td>-1.26</td>
<td>Yellow Solid</td>
</tr>
<tr>
<td>(R)-19b</td>
<td>Et</td>
<td>I−</td>
<td>-1.34</td>
<td>Liquid</td>
</tr>
<tr>
<td>(R)-19c</td>
<td>n-Pr</td>
<td>Br−</td>
<td>-2.27</td>
<td>Liquid</td>
</tr>
<tr>
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<td>Iso-Pr</td>
<td>Br−</td>
<td>-2.43</td>
<td>Liquid</td>
</tr>
<tr>
<td>(R)-19e</td>
<td>n-Bu</td>
<td>Br−</td>
<td>-2.08</td>
<td>Liquid</td>
</tr>
<tr>
<td>(S)-20a</td>
<td>Me</td>
<td>I−</td>
<td>3.32</td>
<td>Liquid</td>
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<td>Br−</td>
<td>3.22</td>
<td>Liquid</td>
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<tr>
<td>(R)-20a</td>
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<td>I−</td>
<td>-1.52</td>
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<tr>
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<td>I−</td>
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<tr>
<td>(R)-20c</td>
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<td>Br−</td>
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<tr>
<td>(R)-20e</td>
<td>n-Bu</td>
<td>Br−</td>
<td>-3.22</td>
<td>Liquid</td>
</tr>
</tbody>
</table>
Reductive amination product dimethylamine (21) was confirmed from the $^1$H NMR study, absence of aldehyde proton at δ 9.7 ppm and appearance of a new peak at δ 2.2 (S, 6H) corresponds to dimethylamine protons, peak at δ 2.2 (t, 2H) corresponds to N-CH$_2$. The quaternization of 21 with methyl iodide product (19a) was confirmed from the $^1$H NMR peak at δ 3.4-3.5 (S, 9H) which corresponds to trimethylamine (N-(CH$_3$)$_3$), peak at δ 3.5-3.7 (m, 2H) corresponds to N-CH$_2$ protons as seen from $^1$H NMR study.

Reductive amination product diethylamine (22) was confirmed from $^1$H NMR study. The aldehyde peak at δ 9.7 ppm disappeared in the product, and appeared of a new peak at δ 2.5-2.6 (q, 4H) corresponds to the methylene group of N-(CH$_2$)-CH$_3$$_2$ and a singlet at δ 1.7 ppm (6H, 2-CH$_3$ of N-(CH$_2$-CH$_3$)$_2$. The other peak of the product appeared at δ 2.3-2.4 (m, 2H) of N-CH$_2$. The quaternization of 22 was carried out using methyl iodide, product 20a was confirmed from $^1$H NMR study. The peak at δ 3.5-3.6 (m, 4H) corresponded to N-(CH$_2$-CH$_3$)$_2$, while the peaks at δ 3.3-3.5 (dd, 2H) of N-CH$_2$-CH$_2$ and δ 3.21 (S, 3H) corresponded to N-CH$_3$, confirming the product.
2.3 Conclusion

In summary, several new chiral ionic liquids were prepared starting from both the chiral isomers of citronellal as the chiral starting material and dialkylamine as the amine source. The Schiff base thus obtained was reduced and further reacted with alkyl halides containing different carbon chains. The strategy could be generalized with other dialkylamines to design a chiral ionic liquid for any specific use. Most of the ionic liquids isolated were liquids at room temperature and amenable for the application in asymmetric synthesis.
2.4 Experimental Section

All the chemicals and reagents of LR grade were used. $^1$H NMR spectra were recorded on Varian Gemini 2000 model 400 MHz instrument using TMS as an internal standard in CDCl$_3$ (Chemical shifts in ppm) and mass spectrum was recorded on HP 5989A spectrometer. Optical Rotation of the compounds were recorded on Polari meter (Jasco) in methanol (c=1).

**General procedure for synthesis of compounds (21 & 22):**

To a stirred solution of compound (S) or (R)-18 (1.0 mmol), in methanol (10 vol) was added appropriate alkylamine (1.5 mmol) and Raney-nickel (30% w/v) at room temperature. Reaction was left to stir for 20 hrs at room temperature in hydrogen environment, the catalyst was filtered and the solvent was evaporated under reduced pressure. The resulting crude (pale greenish liquid) was subjected to column chromatography to give pure desired products (21& 22).

**Preparation of (3S or 3R)-3,7-dimethyl-6-octenyl (dimethyl) amine (21):**

To a stirred solution of (3S) or (3R)-3,7-dimethyl-6-octenal (18) (5.0 g, 32.4 mmol) in methanol (50 mL) was added 40% aqueous solution of dimethylamine (2.4 mL, 48.6 mmol) and Raney-nickel (30% w/v) at room temperature. Reaction was left to stir for 20 hrs at room temperature in hydrogen environment. After completion of reaction, the catalyst was filtered and the solvent was evaporated under reduced pressure. The resulting crude (pale greenish liquid) was subjected to column chromatography using a mixture of ethyl acetate
and pet ether as an eluent to yield 4.2 g (70%) of the pure desired product (3S) or (3R) -3,7-dimethyl-6-octenyl (dimethyl) amine (21).

\[ ^1H \text{ NMR (400 MHz, CDCl}_3): \delta 5.0-5.2 \ (m, \ 1H), \ 2.2-2.3 \ (t, \ J=7.8 \ Hz, \ 2H), \ 2.0 \ (s, \ 6H), \ 1.9-2.1 \ (m, \ 2H), \ 1.7 \ (s, \ 3H), \ 1.6 \ (s, \ 3H), \ 1.4-1.6 \ (m, \ 1H), \ 1.2-1.4 \ (m, \ 2H), \ 1.1-1.2 \ (m, \ 2H), \ 0.8-0.9 \ (d, \ J=6.4 \ Hz, \ 3H); \ \ ^{13}C \text{ NMR (200 MHz, CDCl}_3): \delta 130.51, \ 124.59, \ 57.51, \ 45.17, \ 45.17, \ 37.01, \ 34.47, \ 30.78, \ 25.37, \ 25.20, \ 19.35, \ 17.27. \]

Mass: m/z = 183

**Preparation of (3S or 3R)-3,7-dimethyl-6-octenyl (diethyl)amine (22):** To a stirred solution of (3S) or (3R)-3,7-dimethyl-6-octenal (18) (5.0 g, 32.4 mmol) in methanol (50 mL) was added diethylamine (5.0 mL, 48.6 mmol) and Raney nickel (30% w/v) at room temperature. The reaction was left to stir for 20 hrs at room temperature in hydrogen environment. After completion of the reaction, the catalyst was filtered and the solvent was evaporated under reduced pressure. The resulting crude (pale greenish liquid) was subjected to column chromatography using a mixture of ethyl acetate and pet ether as an eluent to yield 5.1 g (75%) of the pure desired product (3S) or (3R)-3,7-dimethyl-6-octenyl (diethyl) amine (22).

\[ ^1H \text{ NMR (400 MHz, CDCl}_3): \delta 5.0-5.2 \ (m, \ 1H), \ 2.5-2.6 \ (q, \ 4H), \ 2.3-2.4 \ (m, \ 2H), \ 1.9-2.1 \ (m, \ 2H), \ 1.6-1.7 \ (s, \ 6H), \ 1.4-1.5 \ (m, \ 2H), \ 1.2-1.4 \ (m, \ 2H), \ 1.1-1.2 \ (m, \ 1H), \ 1.0 \ (t, \ J=6.8 \ Hz, \ 6H), \ 0.8 \ (d, \ J=6.4 \ Hz, \ 3H); \ \ ^{13}C \text{ NMR (200 MHz, CDCl}_3): \delta 130.51, \ 124.59, \ 50.43, \ 46.55, \ 36.98, \ 33.47, \ 30.77, \ 25.34, \ 25.21, \ 19.41, \ 17.24, \ 11.29. \]

Mass: m/z = 212
General procedure for synthesis of compounds (S) or (R)-19a-e and 20a-e:

To a stirred solution of compound (S) or (R)-3 (1.0 mmol) in acetonitrile (10 vol), alkyl halide (1.2 mmol) was added at room temperature. The reaction was allowed to stir for 12 hrs at room temperature and the solvent was removed under reduced pressure, followed by drying under high vacuum to afford the desired product.

Preparation of (3S or 3R)-3,7-dimethyl-6-octenyl (trimethyl) ammonium iodide (19a): To a stirred solution of compound (S) or (R)-21 (2.0 g, 10.9 mmol) in acetonitrile (20 mL), methyl iodide (2.0 mL, 13.1 mmol) was added at room temperature. The reaction was allowed to stir for 12 hrs at room temperature and the solvent was removed under reduced pressure followed by further drying under high vacuum to afford 3.2 g (90%) of the desired product as a yellow solid.

$^1$H NMR (400 MHz, CDCl$_3$) : δ 5.0-5.2 (m, 1H), 3.5-3.7 (m, 2H), 3.4-3.5 (s, 9H), 1.9-2.1 (m, 2H), 1.7-1.8 (m, 1H), 1.6-1.7 (s, 6H), 1.5-1.6 (m, 2H), 1.2-1.4 (m, 2H), 0.9-1.0 (d, $J=6.4$ Hz, 3H); $^{13}$C NMR (200 MHz, CDCl$_3$) : δ 131.32, 123.56, 65.51, (3C, 53.43), 36.36, 29.91, 29.39, 25.32, 24.85, 18.99, 17.39.

Mass: m/z =198

Preparation of (3S or 3R)-3,7-dimethyl-6-octenyl (ethyl) dimethyl ammonium iodide (19b): To a stirred solution of compound (S) or (R)-21 (2.0 g, 10.9 mmol) in acetonitrile (20 mL), ethyl iodide (1.1 mL, 13.1 mmol) was added at room temperature. The reaction was
allowed to stir for 12 hrs at room temperature, and the solvent was removed under reduced pressure followed by drying under high vacuum to afford 3.3 g (90%) of the desired product as a liquid.

$^1$H NMR (400 MHz, CDCl$_3$) : δ 5.0-5.2 (m, 1H), 3.7-3.8 (q, 2H), 3.4-3.6 (m, 2H), 3.39 (s, 6H), 1.9-2.1 (m, 2H), 1.7-1.8 (m, 1H), 1.6-1.7 (s, 6H), 1.5-1.6 (m, 2H), 1.4 (t, J=7.2 Hz, 3H), 1.2-1.3 (m, 2H), 1.0 (d, J=6.4 Hz, 3H); $^{13}$C NMR (200MHz, CDCl$_3$) : δ 131.19, 123.42, 62.11, 59.20, 50.65, 50.65, 36.19, 29.84, 28.83, 25.18, 24.72, 18.87, 17.26, 8.28.

Mass: m/z = 212

**Preparation of (3S or 3R)-3,7-Dimethyl-6-octenyl (dimethyl) propyl ammonium bromide (19c) :** To a stirred solution of compound (S) or (R)-21 (2.0 g, 10.9 mmol) in acetonitrile (20 mL), n-propyl bromide (1.2 mL, 13.1 mmol) was added at room temperature. The reaction was allowed to stir for 12 hrs at room temperature and the solvent was evaporated under reduced pressure followed by further drying under high vacuum yielding 2.3 g (70%) of the desired product as a liquid.

$^1$H NMR (400 MHz, CDCl$_3$) : δ 5.0-5.2 (m, 1H), 3.4-3.6 (m, 4H), 3.4 (s, 6H), 1.9-2.1 (m, 2H), 1.7-1.8 (m, 1H), 1.6-1.7 (s, 6H), 1.6 (m, 2H), 1.5-1.6 (m, 2H), 1.2-1.4 (m, 2H), 1.1 (t, J=7.2 Hz, 3H), 0.9 (d, J=6.4 Hz, 3H); $^{13}$C NMR (200MHz, CDCl$_3$) : δ 131.48, 123.63, 64.87, 62.45, 51.14, 36.45, 30.09, 29.10, 25.39, 24.94, 18.96, 17.42, 16.00, 10.40.

Mass: m/z = 226

**Preparation of (3S or 3R)-3,7-dimethyl-6-octenyl (isopropyl) dimethyl ammonium bromide (19d) :** To a stirred solution of
compound (S) or (R)-21 (2.0 g, 10.9 mmol) in acetonitrile (20 mL), iso-
propyl bromide (1.6 mL, 13.1 mmol) was added at room temperature. The reaction was allowed to stir for 12 hrs at room temperature and the solvent was removed under reduced pressure. The crude product was purified by column chromatography to yield 1.3 g (40%) of the desired product as a liquid.

$^1$H NMR (400 MHz, CDCl$_3$) : $\delta$ 5.0-5.2 (m, 1H), 3.7-4.0 (m, 1H), 3.4-3.6 (m, 2H), 3.3-3.4 (s, 6H), 1.9-2.0 (m, 2H), 1.7-1.8 (m, 1H), 1.6-1.7 (s, 6H), 1.4-1.5 (m, 2H), 1.2-1.4 (m, 2H), 1.0-1.1 (m, 6H), 0.9 (d, $J$=4.8 Hz, 3H); $^{13}$C NMR (200MHz, CDCl$_3$) : $\delta$ 131.44, 123.63, 64.16, 61.51, 48.04, 36.42, 29.00, 28.87, 25.37, 24.94, 18.93, 17.41, 16.46.

Mass: m/z = 226

**Preparation of butyl [(3S or 3R)-3,7-dimethyl-6-octenyl] dimethyl ammonium bromide (19e)** : To a stirred solution of compound (S) or (R)-21 (2.0 g, 10.9 mmol) in acetonitrile (20 mL), n-butyl bromide (1.4 mL, 13.1 mmol) was added at room temperature. The reaction was allowed to stir for 12 hrs at room temperature and the solvent was removed under reduced pressure. The obtained crude was subjected to column chromatography to yield 2.1 g (60%) of the desired product as a liquid.

$^1$H NMR (400 MHz, CDCl$_3$) : $\delta$ 5.0-5.2 (m, 1H), 3.4-3.6 (m, 4H), 3.38 (s, 6H), 1.9-2.1 (m, 2H), 1.8-1.9 (m, 1H), 1.6-1.7 (s, 6H), 1.4-1.5 (m, 4H), 1.39 (m, 2H), 1.2-1.3 (m, 2H), 1.0 (t, $J$=7.2 Hz, 3H), 0.9 (d, $J$=6.4 Hz, 3H); $^{13}$C NMR (200MHz, CDCl$_3$) : $\delta$ 131.67, 123.68, 63.42, 62.43,
Preparation of (3S or 3R)-3,7-dimethyl-6-octenyl (diethyl) methyl ammonium iodide (20a): To a stirred solution of compound (S) or (R)-22 (2.0 g, 9.5 mmol) in acetonitrile (20 mL), methyl iodide (1.8 mL, 11.4 mmol) was added at room temperature. The reaction was allowed to stir for 12 hrs at room temperature and the solvent was removed under reduced pressure followed by drying under high vacuum to yield 3.0 g (90%) of the desired product as a liquid.

\[ ^1H \text{ NMR (400 MHz, CDCl}_3): \delta 5.0-5.2 (m, 1H), 3.5-3.7 (m, 4H), 3.3-3.5 (m, 2H), 3.2 (s, 3H), 1.9-2.1 (m, 2H), 1.7 (m, 2H), 1.6 (s, 6H), 1.4-1.5 (m, 2H), 1.3-1.4 (t, \text{ J}=7.4 \text{ Hz}, 6H), 1.2-1.3 (m, 1H), 1.0 (d, \text{ J}=6.4 \text{ Hz}, 3H); \]

\[ ^{13}C \text{ NMR (200MHz, CDCl}_3): \delta 130.93, 123.14, 58.73, 56.15, 47.54, 35.89, 29.62, 28.20, 24.93, 24.46, 18.62, 17.00, 7.75. \]

Mass: m/z = 240

Preparation of (3S or 3R)-3,7-dimethyl-6-octenyl (triethyl) ammonium iodide (20b): To a stirred solution of compound (S) or (R)-22 (2.0 g, 9.5 mmol) in acetonitrile (20 mL), ethyl iodide (0.9 mL, 11.4 mmol) was added at room temperature. The reaction was allowed to stir for 12 hrs at room temperature and the solvent was removed under reduced pressure followed by drying under high vacuum to yield 2.8 g (80%) of the desired product as a liquid.

\[ ^1H \text{ NMR (400 MHz, CDCl}_3): \delta 5.0-5.2 (m, 1H), 3.4-3.5 (q, 6H), 3.1-3.3 (m, 2H), 1.9-2.1 (m, 2H), 1.7-1.8 (m, 2H), 1.6-1.7 (s, 6H), 1.5-1.6 (m,
2H), 1.4 (t, J=7.2 Hz, 9H), 1.2-1.3 (m, 1H), 1.0 (d, J=6.0 Hz, 3H); $^{13}$C NMR (200MHz, CDCl$_3$): δ 129.97, 122.45, 54.62, 52.07, 35.05, 28.84, 27.07, 24.19, 23.71, 17.91, 16.26, 6.80.

Mass: m/z = 240

**Preparation of (3S or 3R)-3,7-dimethyl-6-octenyl (diethyl) propyl ammonium bromide (20c):** To a stirred solution of compound (S) or (R)-22 (2.0 g, 9.5 mmol) in acetonitrile (20 mL), n-propyl bromide (1.0 mL, 11.4 mmol) was added at room temperature. The reaction was allowed to stir for 12 hrs at room temperature and the solvent was removed under reduced pressure. The obtained crude was subjected to column chromatography to yield 1.3 g (50%) of the desired product as a liquid.

$^1$H NMR (400 MHz, CDCl$_3$) : δ 5.0-5.2 (m, 1H), 3.5-3.6 (q, 4H), 3.2-3.4 (m, 4H), 1.9-2.1 (m, 2H), 1.8-1.9 (m, 2H), 1.7-1.8 (m, 2H), 1.6-1.7 (s, 6H), 1.5-1.6 (m, 2H), 1.3-1.5 (t, J=7.0 Hz, 6H), 1.2-1.3 (m, 1H), 1.1 (t, J=7.2 Hz, 3H), 1.0 (d, J=6.8 Hz, 3H); $^{13}$C NMR (200MHz, CDCl$_3$) : δ 131.71, 123.59, 59.25, 56.40, 53.86, 36.47, 30.26, 28.47, 25.49, 25.06, 19.14, 17.53, 15.54, 10.71, 7.88.

Mass: m/z = 254

**Preparation of (3S or 3R)-3,7-dimethyl-6-octenyl (diethyl) isopropyl ammonium bromide (20d):** To a stirred solution of compound (S) or (R)-22 (2.0 g, 9.5 mmol) in acetonitrile (20 mL), isopropyl bromide (1.1 mL, 11.4 mmol) was added at room temperature. The reaction was allowed to stir for 12 hrs at room temperature and the solvent was removed under reduced pressure. The obtained crude
was subjected to column chromatography to yield 0.8 g (25%) of the desired product as a liquid.

$^1$H NMR (400 MHz, CDCl$_3$) : $\delta$ 5.0-5.2 (m, 1H), 3.5 (q, 4H), 3.2-3.3 (m, 2H), 2.6-2.7 (m, 1H), 1.8-2.2 (m, 6H), 1.6-1.7 (s, 6H), 1.4 (t, $J$=7.2 Hz, 3H), 1.2 (t, $J$=7.2 Hz, 3H), 1.0 (d, $J$=6.4 Hz, 3H), 0.9 (d, $J$=6.4 Hz, 6H).

Mass: m/z = 254

**Preparation of Butyl [(3$S$ or 3$R$)-3,7-dimethyl-6-octenyl] diethyl ammonium bromide (20e)**: To a stirred solution of compound (S) or (R)-22 (2.0 g, 9.5 mmol) in acetonitrile (20 mL), n-butyl bromide (1.2 mL, 11.4 mmol) was added at room temperature. The reaction was allowed to stir for 12 hrs at room temperature and the solvent was removed under reduced pressure. The obtained crude was subjected to column chromatography to yield 1.6 g (50%) of the desired product as a liquid.

$^1$H NMR (400 MHz, CDCl$_3$) : $\delta$ 5.0-5.2 (m, 1H), 3.5-3.6 (q, 4H), 3.2-3.4 (m, 2H), 3.1 (t, $J$=7.2 Hz, 2H), 1.9-2.1 (m, 2H), 1.7-1.8 (m, 6H), 1.6-1.7 (s, 6H), 1.5 (m, 2H), 1.3-1.4 (t, $J$=7.2 Hz, 6H), 1.2-1.3 (m, 1H), 1.1 (t, $J$=7.4 Hz, 3H), 0.9 (d, $J$=6.8 Hz, 3H); $^{13}$C NMR (200MHz, CDCl$_3$) : $\delta$ 131.50, 123.45, 57.38, 56.18, 53.64, 36.32, 30.09, 28.28, 25.32, 24.89, 23.59, 19.36, 18.99, 17.36, 13.31, 7.71.

Mass: m/z = 268
2.5 Spectral data

$^1$H NMR spectrum (400MHz, CDCl$_3$) of compound 18:

![Spectral data of compound 18]

$^1$H NMR spectrum (400MHz, CDCl$_3$) of compound 21:

![Spectral data of compound 21]
$^{13}\text{C}$ NMR spectrum (400MHz, CDCl$_3$) of compound 21:

![C NMR spectrum](image)

Mass spectrum of compound 21:

![Mass spectrum](image)
\[ ^1H \text{NMR spectrum (400MHz, CDCl}_3 \text{) of compound } 19a: \]

\[ ^{13}C \text{NMR spectrum (400MHz, CDCl}_3 \text{) of compound } 19a: \]
DEPT spectrum of compound 19a:

Mass spectrum of compound 19a:
$^1$H NMR spectrum (400MHz, CDCl$_3$) of compound 19b:

$^{13}$C NMR spectrum (400MHz, CDCl$_3$) of compound 19b:
DEPT spectrum (400MHz, CDCl₃) of compound 19b:

Mass spectrum of compound 19b:
$^1$H NMR spectrum (400MHz, CDCl$_3$) of compound 19c:

DEPT spectrum (400MHz, CDCl$_3$) of compound 19c:
$^{13}$C NMR spectrum of compound 19c:

Mass spectrum of compound 19c:
$^1$H NMR spectrum (400MHz, CDCl$_3$) of compound 19d:

DEPT spectrum of compound 19d:
Mass Spectrum of compound 19d:

\[ <31.33 \text{ to } 12.93 \text{ min from Sample 3 BLANK of 140685. eff (Carbo Sorb), authentic 15.55 to 11} > \]

\[ S<483.0 \text{ at } 80.1 \text{ min} \text{ from Analysis sample} \]

\[ 546.5 \text{ at } 10.1 \text{ min} \text{ from Analysis sample} \]

\[ \text{Analysis sample} \]

\[ (R)-19d \]

\[ \text{Mass Spectrum of compound 19d:} \]

\[ \text{H NMR spectrum of compound 19e:} \]

\[ 81.6 \text{ at } 1 \text{ ppm} \]

\[ 84.5 \text{ at } 1 \text{ ppm} \]

\[ 84.5 \text{ at } 1 \text{ ppm} \]

\[ 84.5 \text{ at } 1 \text{ ppm} \]

\[ 84.5 \text{ at } 1 \text{ ppm} \]

\[ (R)-19e \]
DEPT spectrum of compound 19e:

Mass spectrum of compound 19e:
$^{13}$C NMR spectrum of compound 19e:

$^1$H NMR spectrum of compound 22:
DEPT spectrum of compound 22:

\[
\text{Chemical Shift, ppm}
\]

\[
\text{On carbon}
\]

\[
\text{All prominent carbon}
\]

\[
\text{13C NMR spectrum of compound 22:}
\]

\[
\text{Chemical Shift, ppm}
\]
$^1$H NMR spectrum of compound 20a:

$^{13}$C NMR spectrum of compound 20a:
Mass spectrum of compound 20a:

(R)-20a

$^{1}H$ NMR spectrum of compound 20b:

(R)-20b
DEPT spectrum of compound 20b:

\[ \text{\textsuperscript{13}C NMR spectrum of compound 20b:} \]
Mass spectrum of compound 20b:

\[ \text{Mass spectrum of compound 20b:} \]

\[ \text{1H NMR spectrum of compound 20c:} \]
DEPT spectrum of compound 20c:

\[ (R)-20c \]

\[ H \quad N \quad Br \quad (R) - 20c \]

\[ \text{all protons, CH/CH}_2 \text{sp} \]

\[ 13C \text{ NMR spectrum of compound 20c:} \]
$^1$H NMR spectrum of compound 20d:

Mass spectrum of compound 20d:
$^1$H NMR spectrum of compound 20e:

![H NMR spectrum of compound 20e]

DEPT spectrum of compound 20e:

![DEPT spectrum of compound 20e]
$^{13}$C NMR spectrum of compound 20e:

Mass spectrum of compound 20e:
2.6 References


2. Visser, A. E.; Swatlowski, R. P.; Rogers, R. D. pH-Dependent partitioning in room temperature ionic liquids provides a link to


