

Task-Specific Boronium Ionic Liquids as Ashless Lubricant Additives

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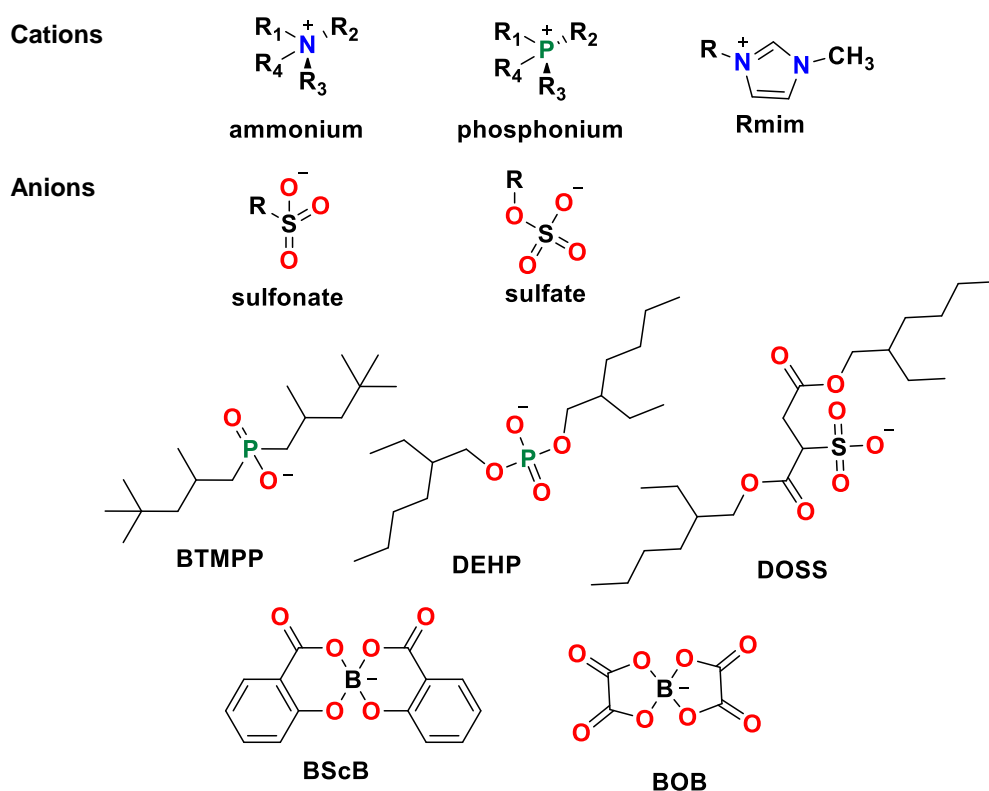


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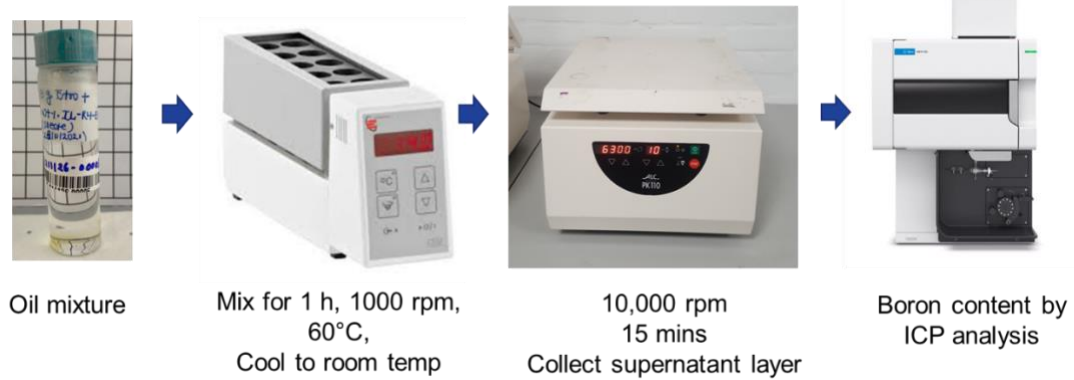


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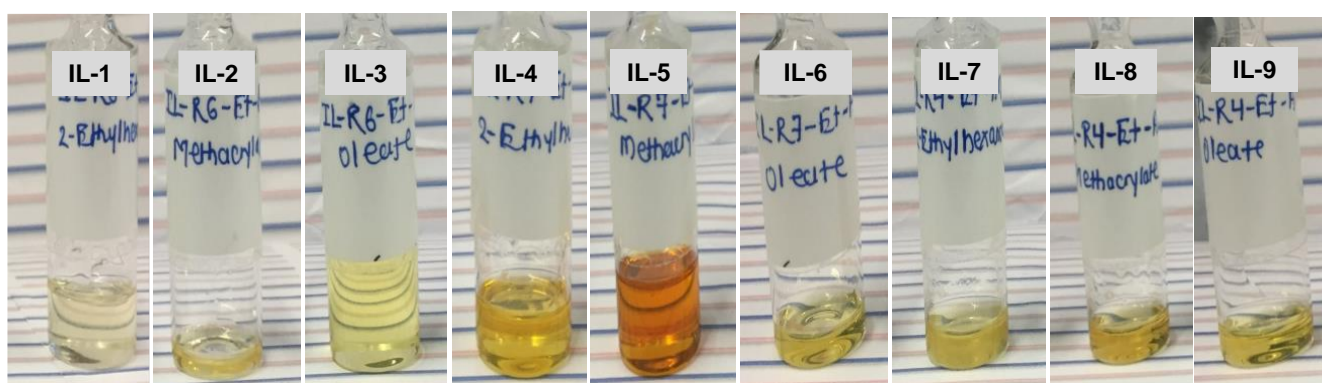


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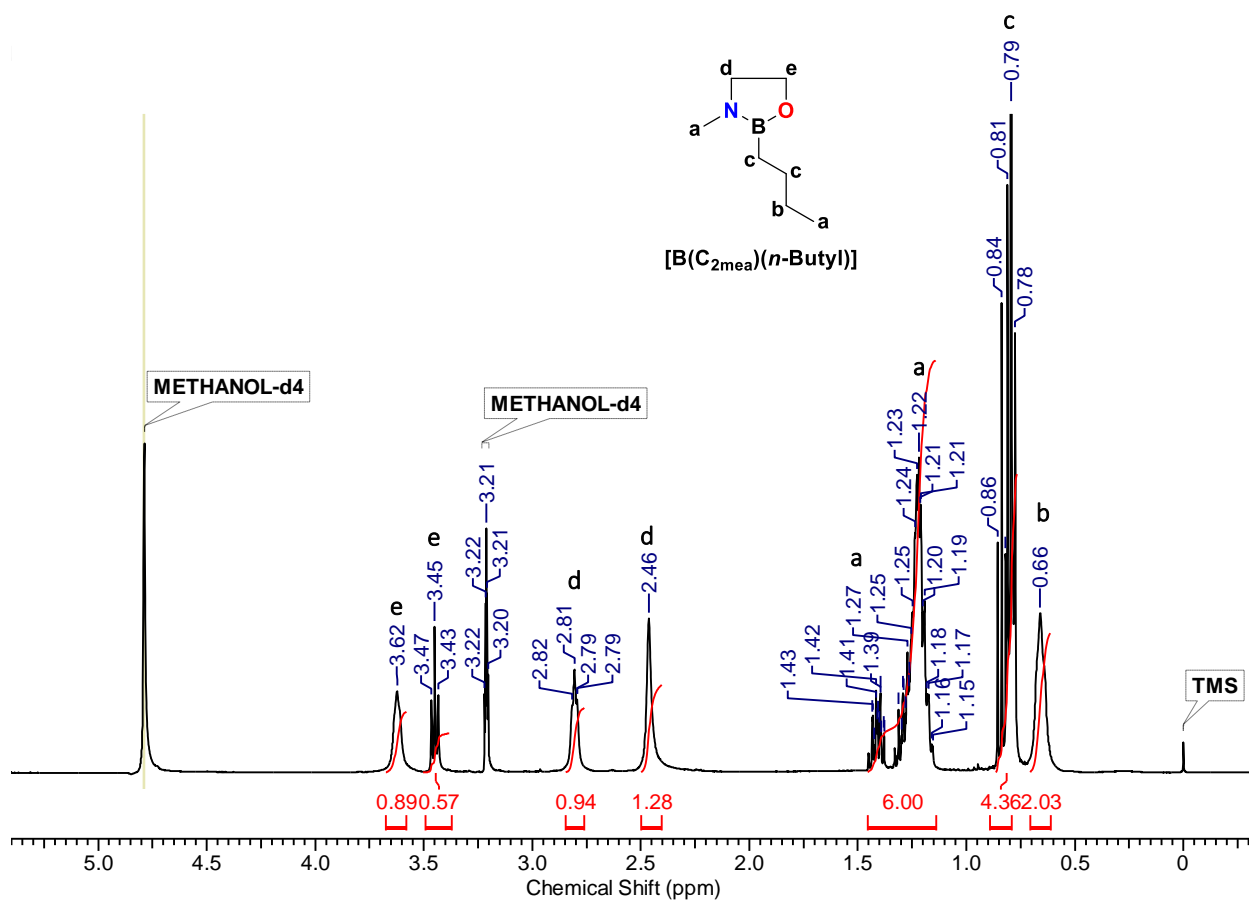


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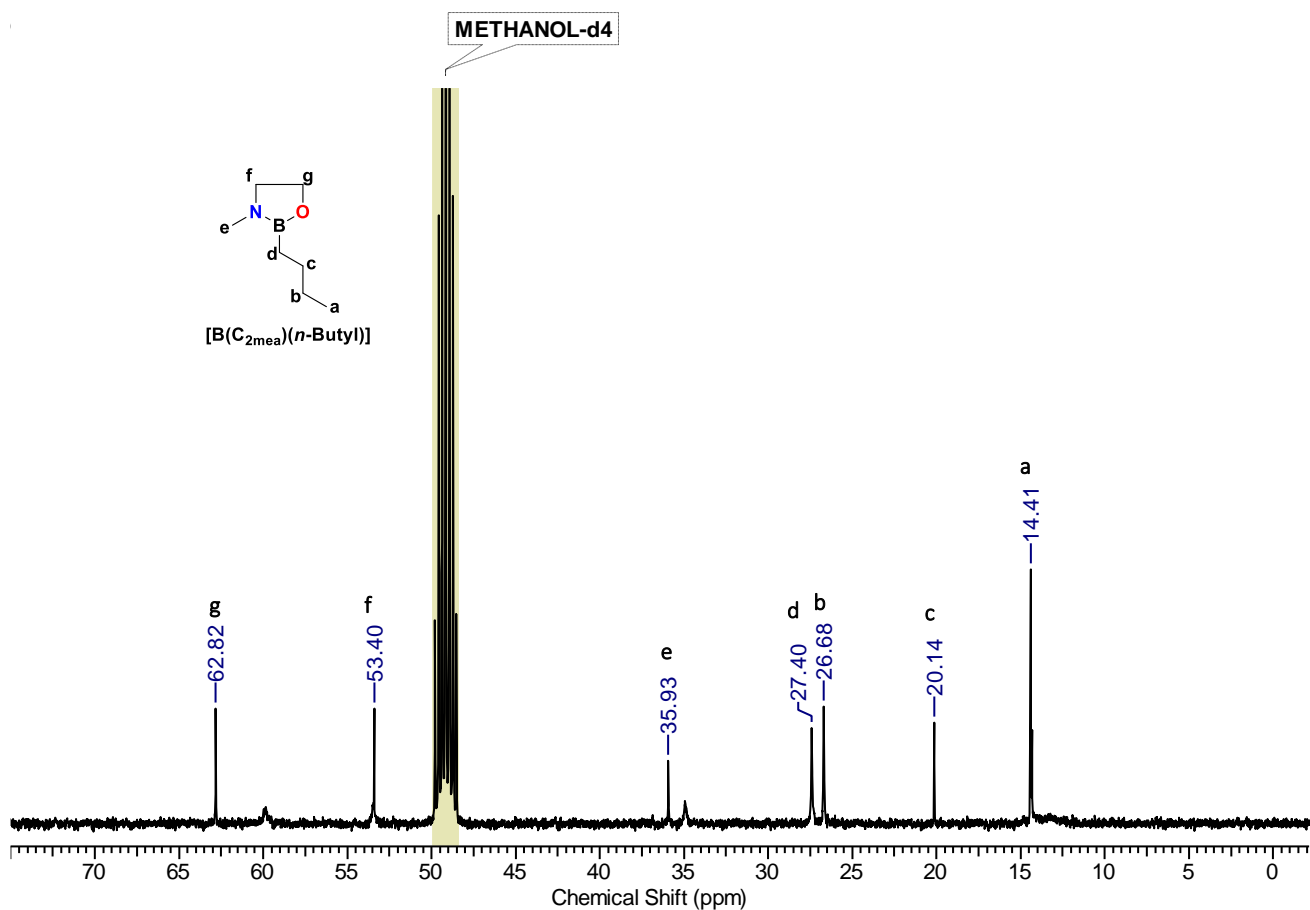


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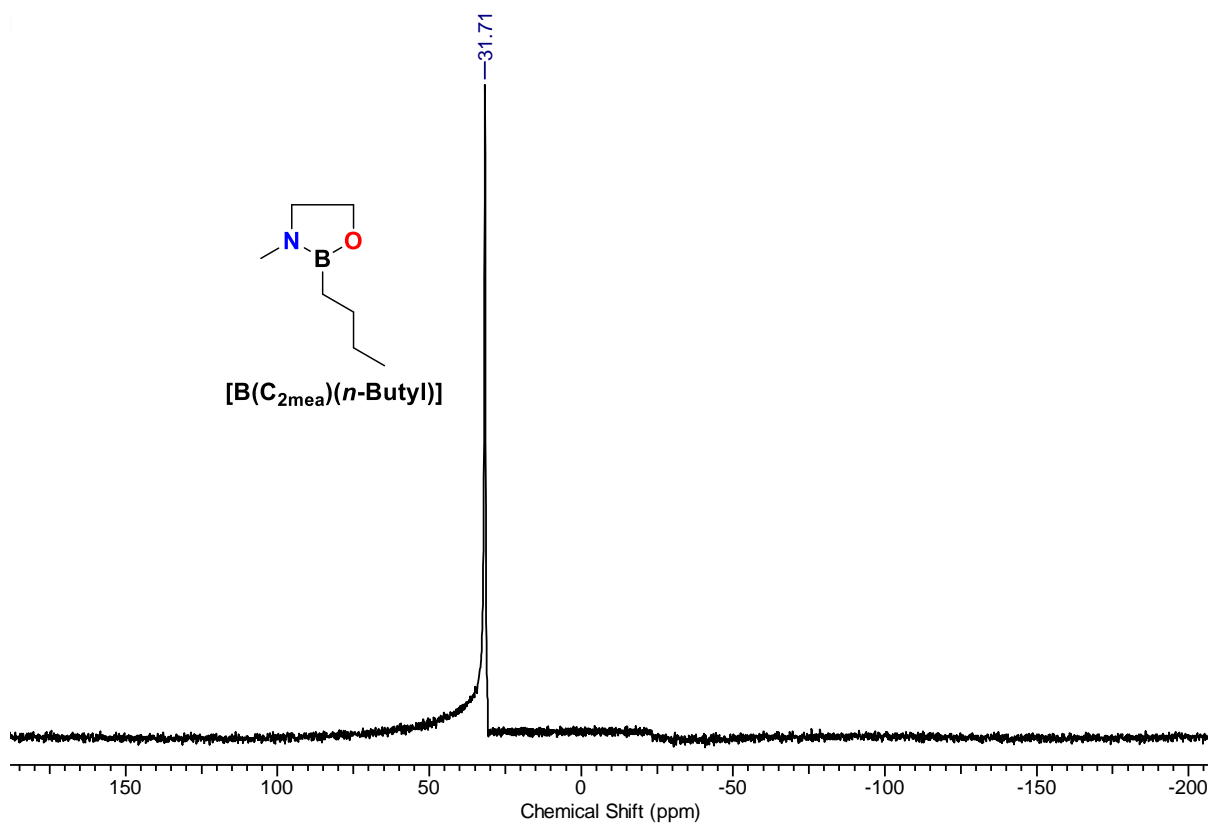


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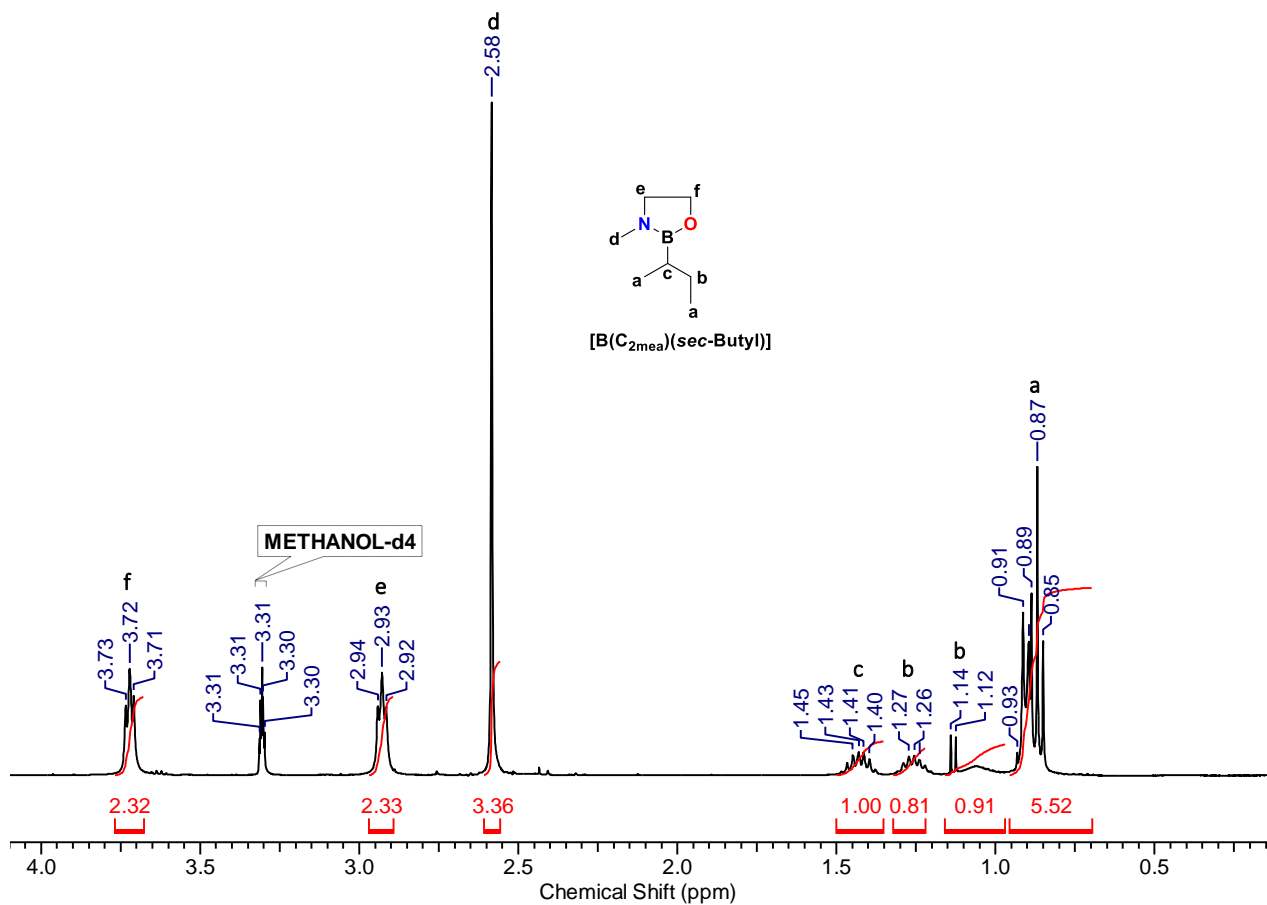


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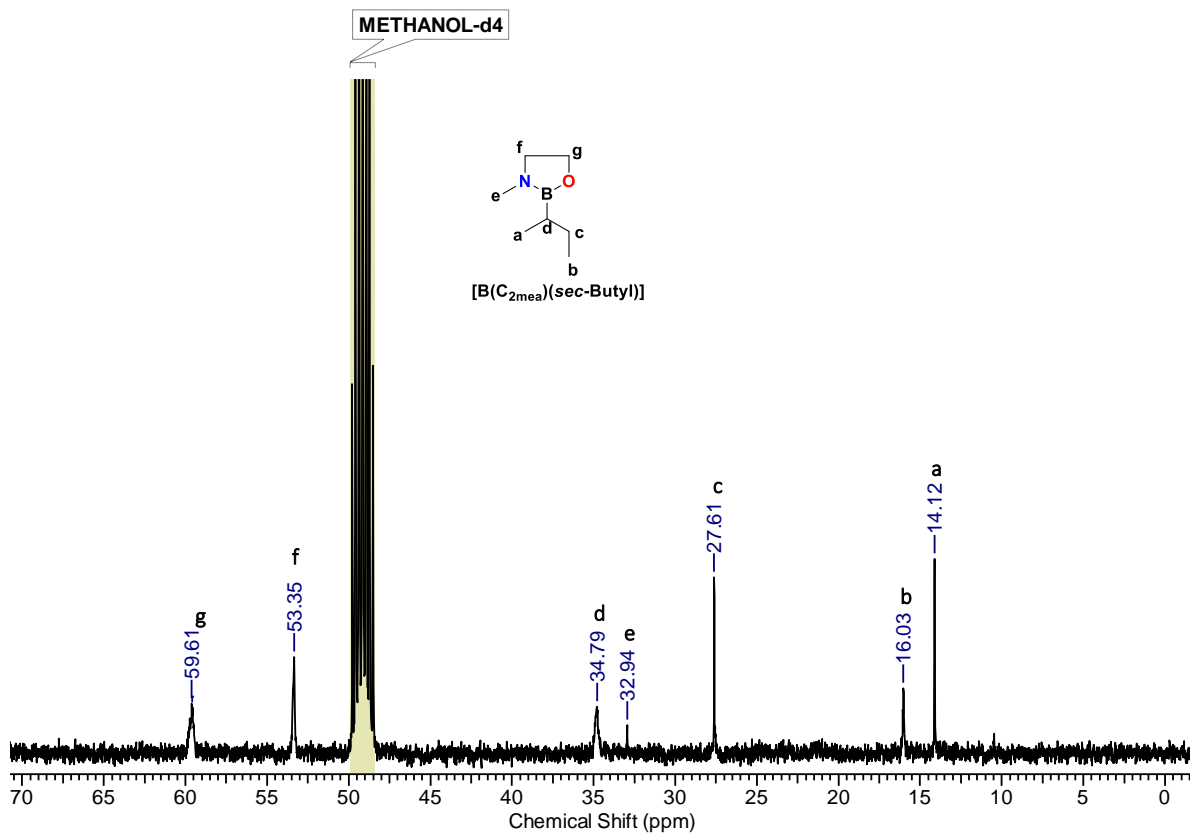


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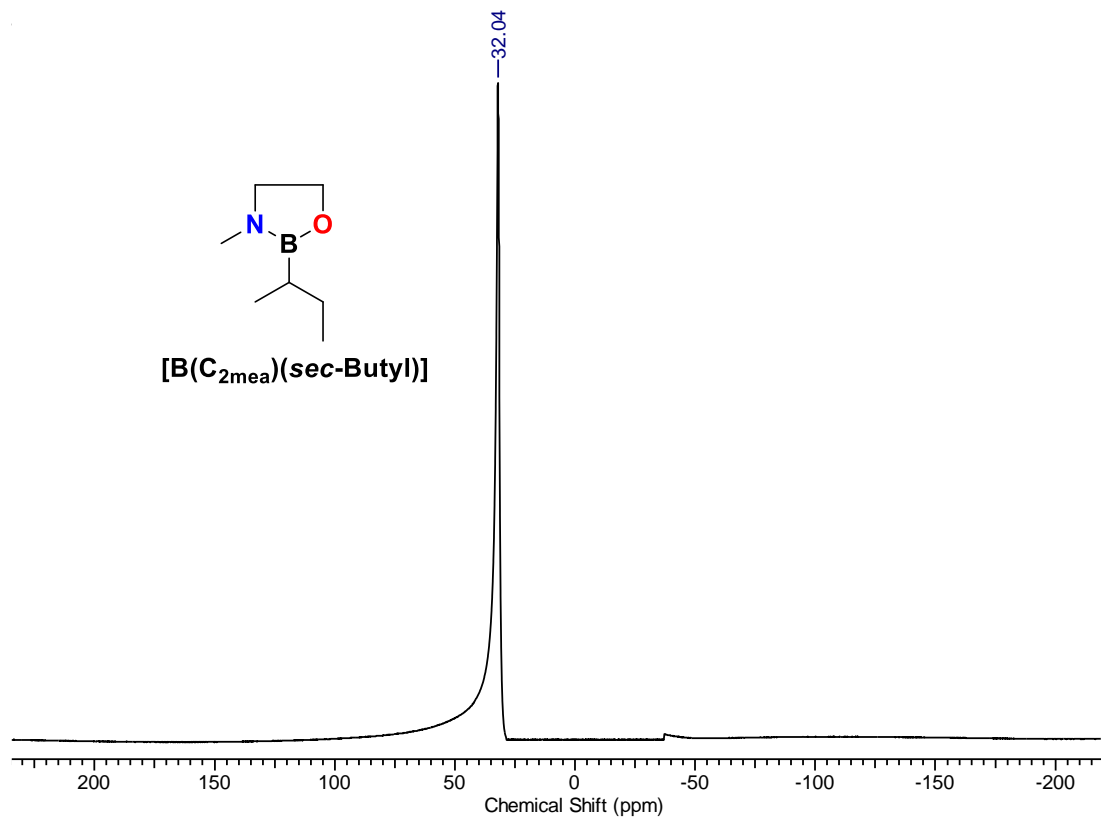


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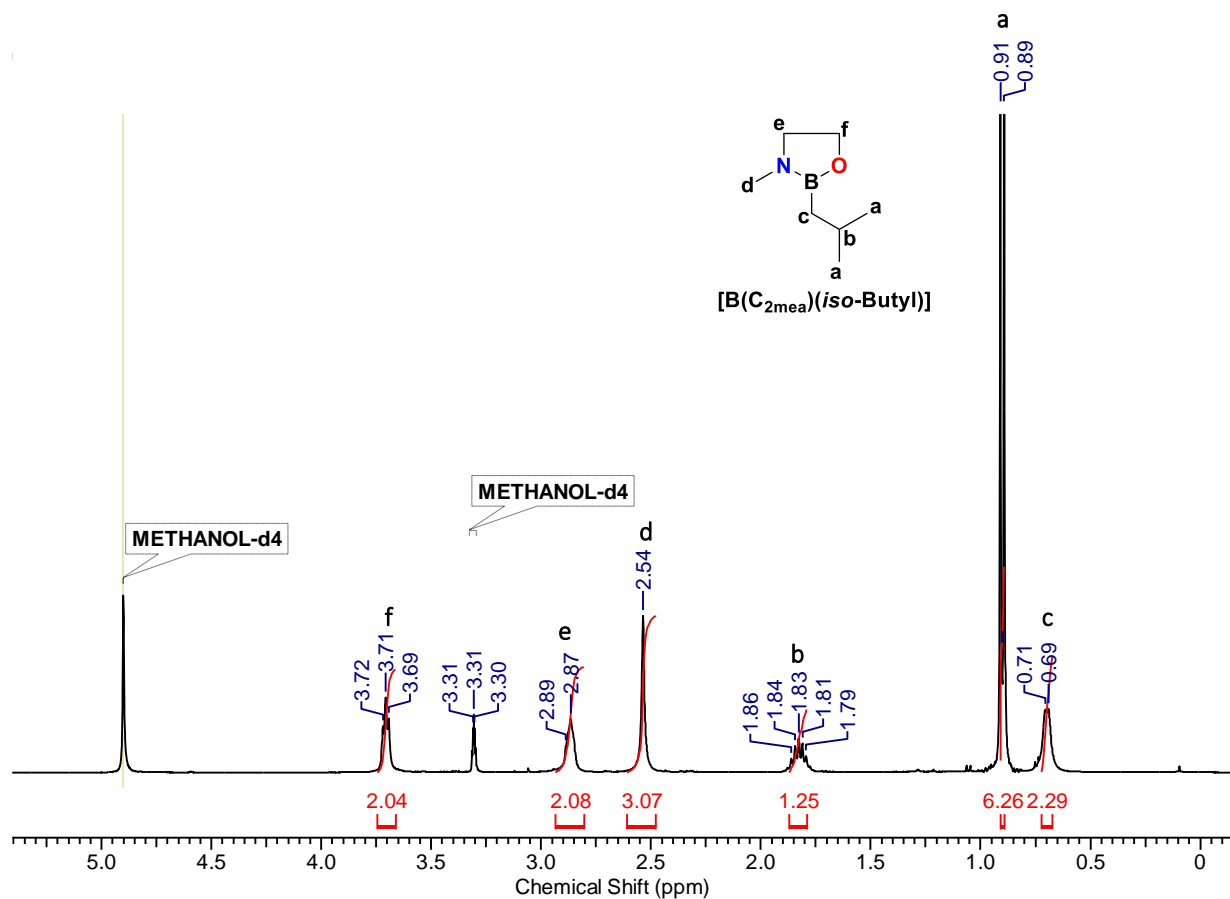


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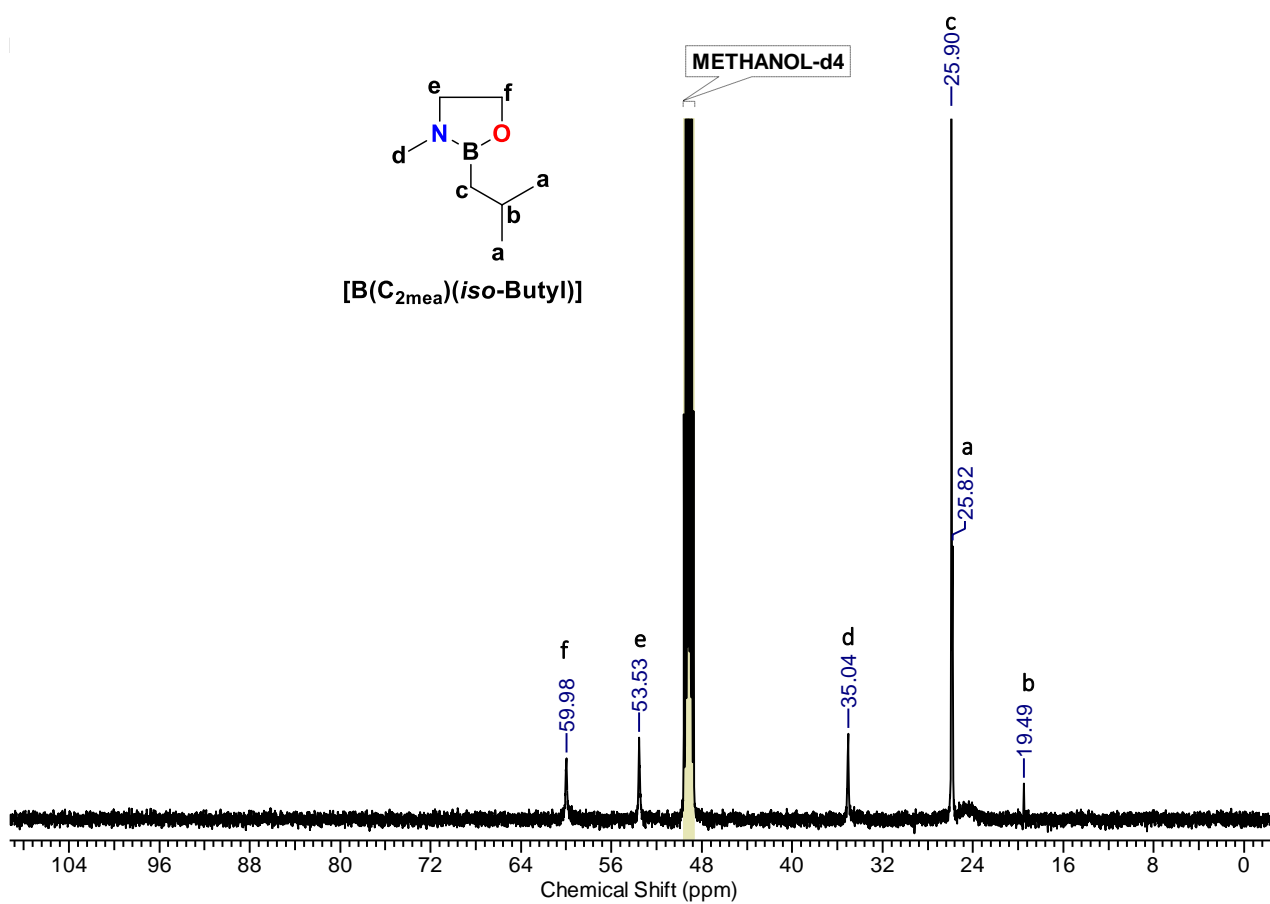


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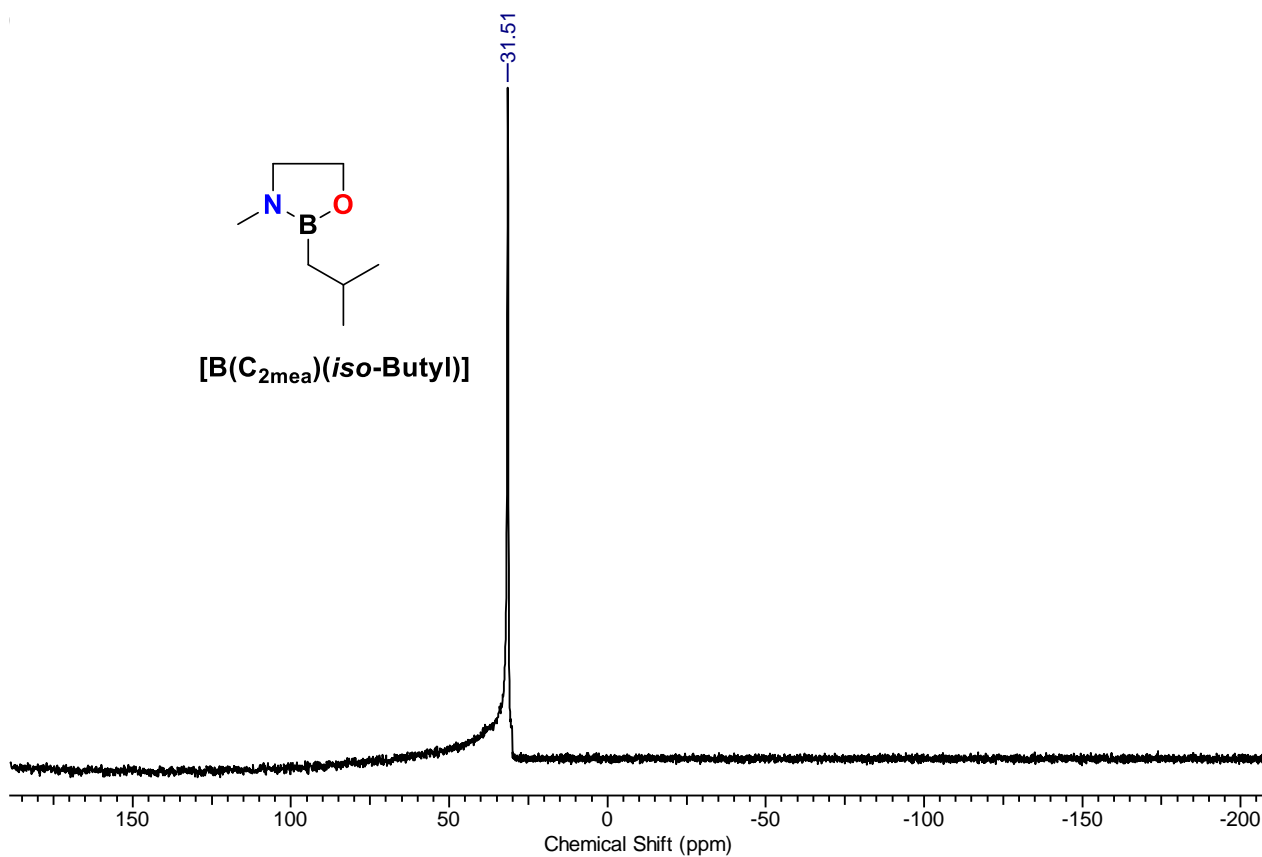


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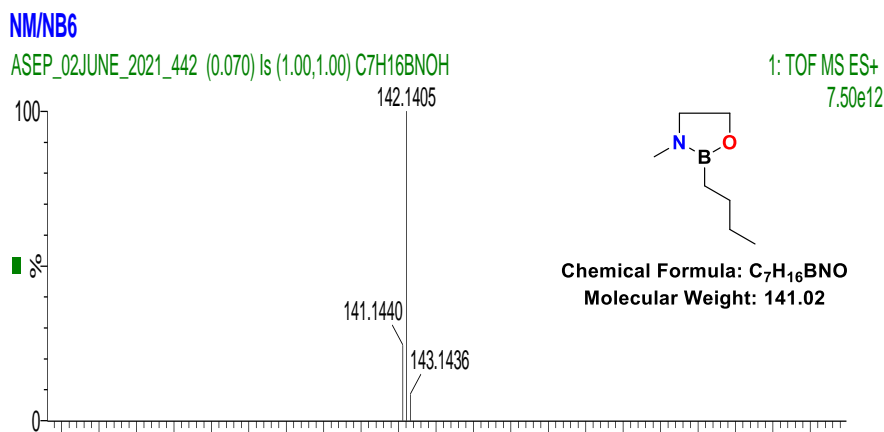


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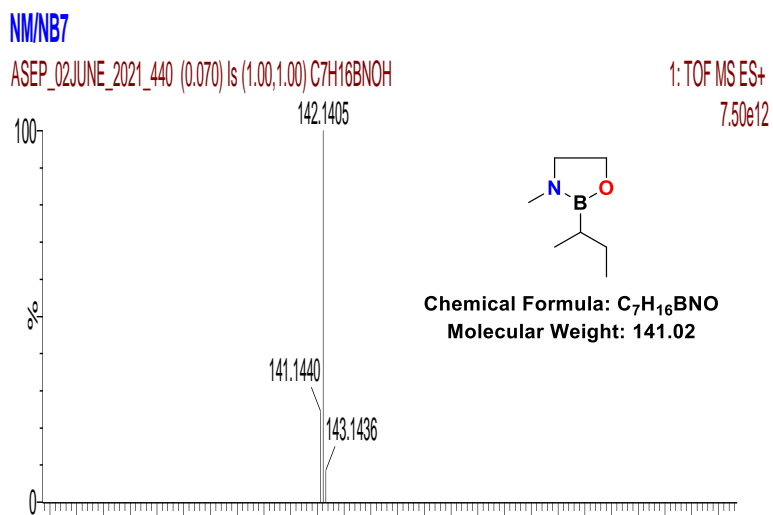


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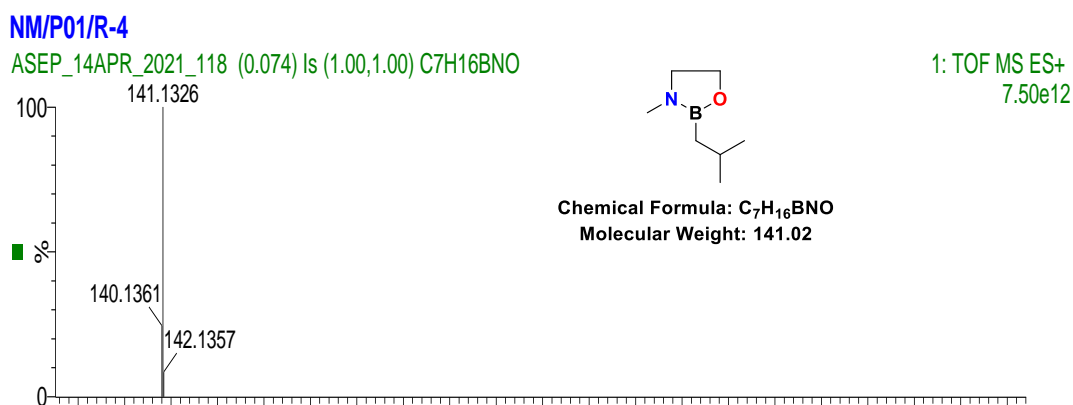


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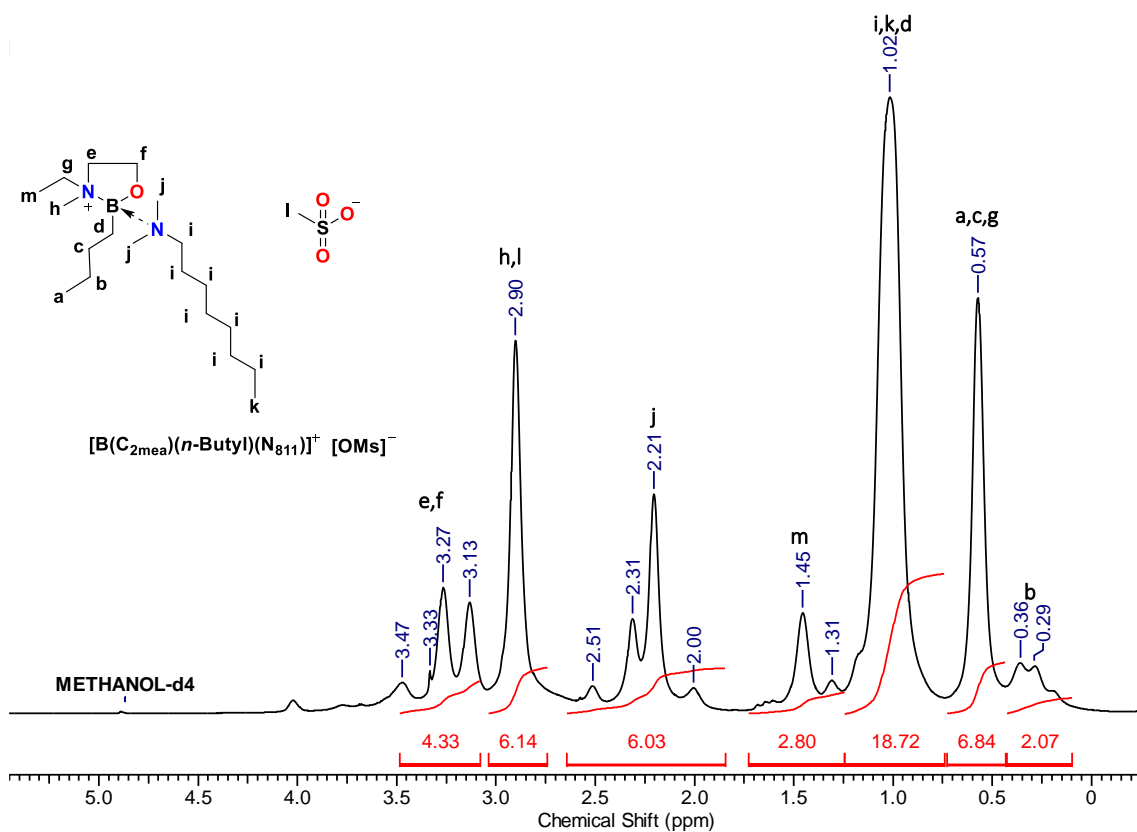


Figure S 16. ^1H NMR spectrum of $[\text{B}(\text{C}_{2\text{mea}})(n\text{-butyl})(\text{N}_{811})][\text{OMs}]$.

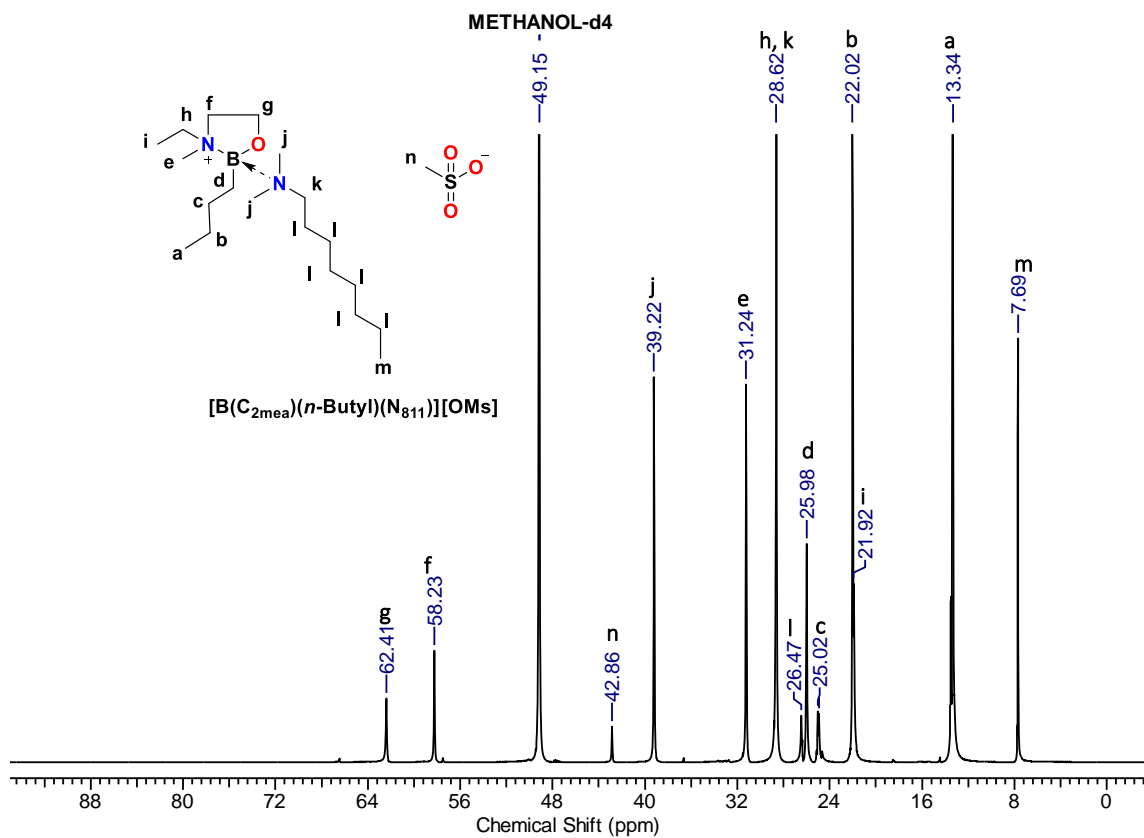


Figure S 17. ^{13}C NMR spectrum of $[\text{B}(\text{C}_{2\text{mea}})(n\text{-butyl})(\text{N}_{811})][\text{OMs}]$.

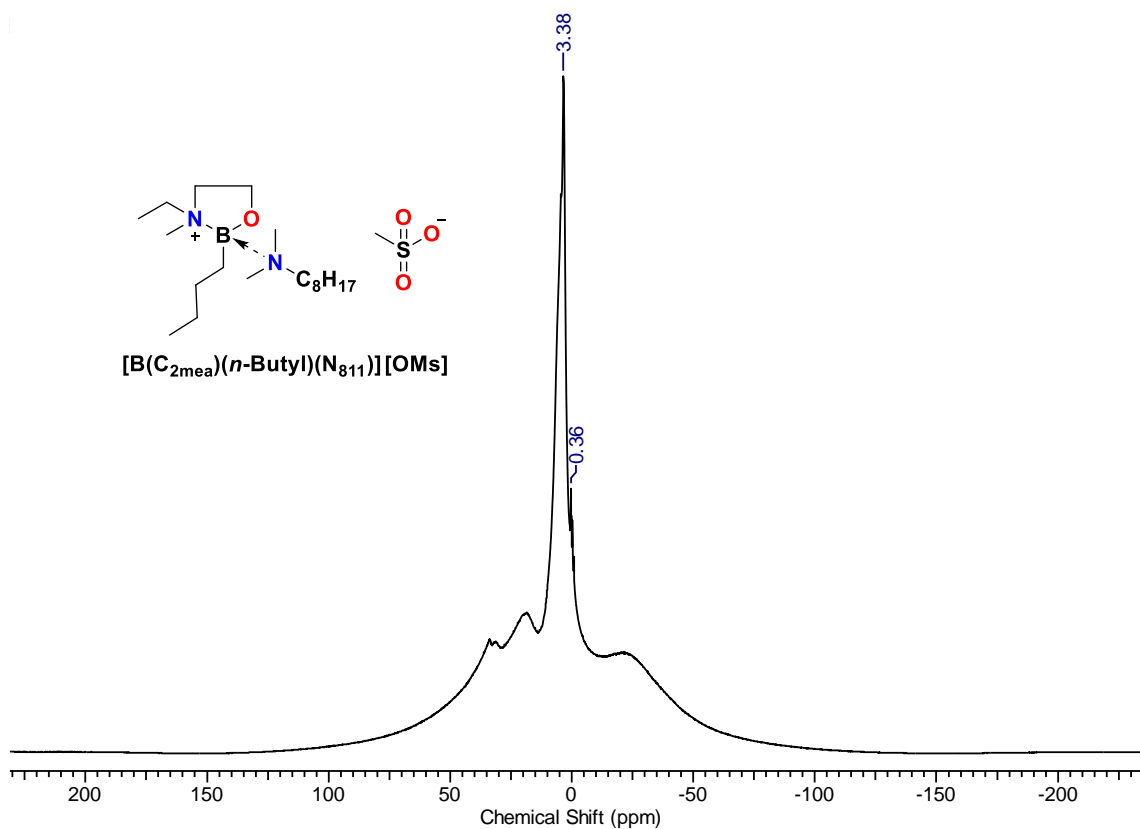


Figure S 18. ^{11}B NMR spectrum of $[B(C_{2mea})(n\text{-butyl})(N_{811})][OMs]$.

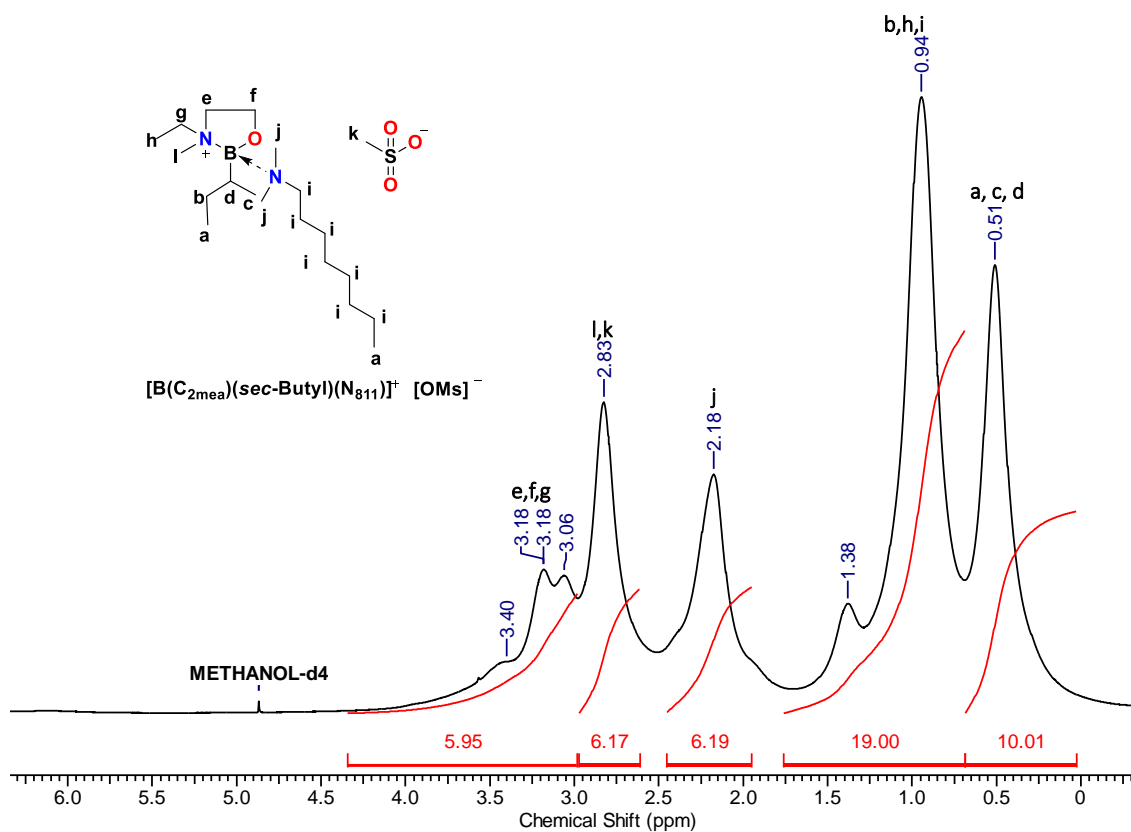


Figure S 19. 1H NMR spectrum of $[B(C_{2mea})(sec\text{-butyl})(N_{811})][OMs]$.

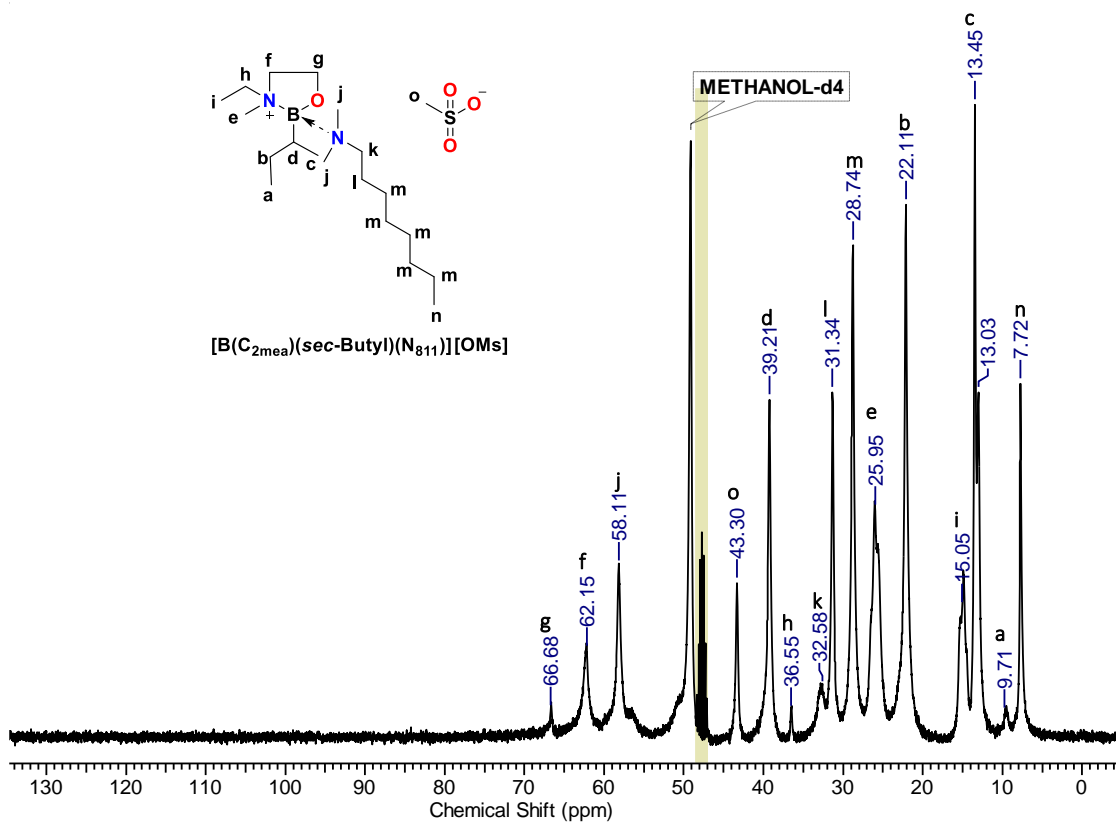


Figure S 20. ^{13}C NMR spectrum of $[B(C_{2mea})(sec\text{-butyl})(N_{811})][OMs]$.

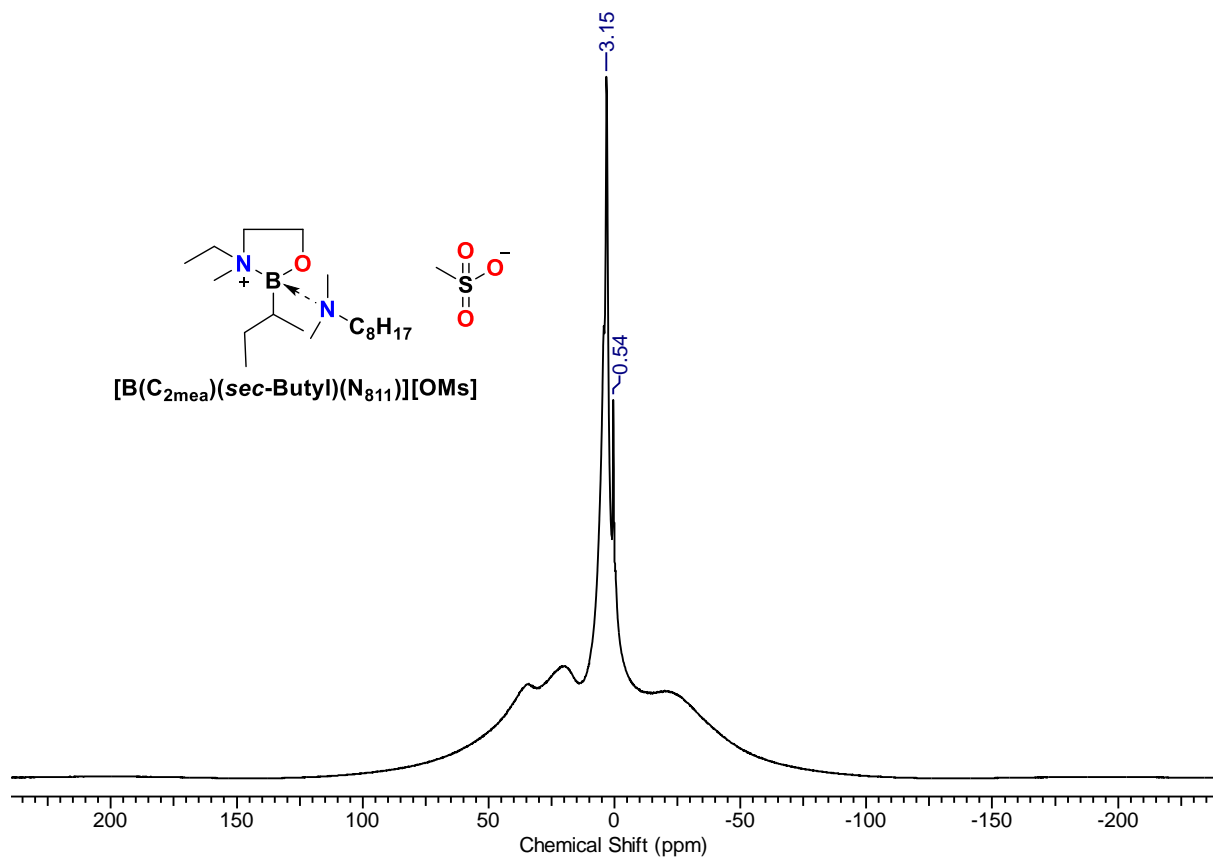


Figure S 21. ^{11}B NMR spectrum of $[B(C_{2mea})(sec\text{-butyl})(N_{811})][OMs]$.

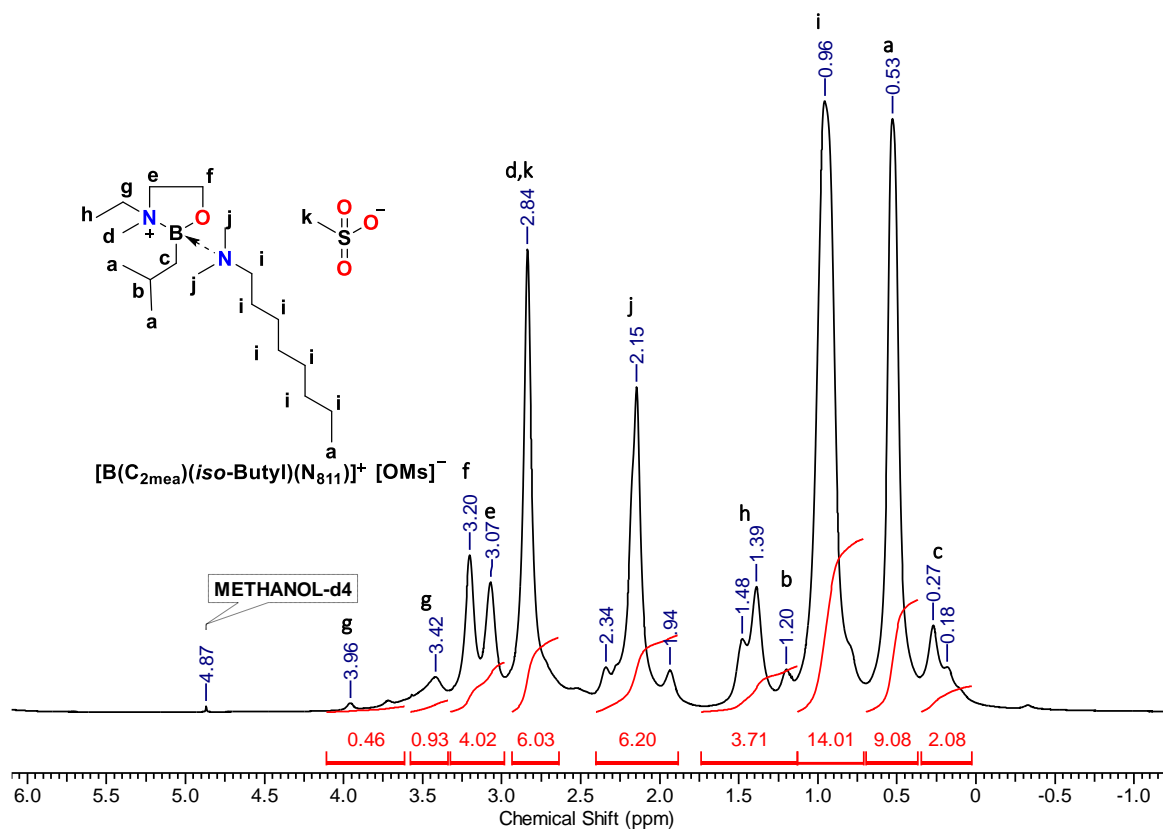


Figure S 22. ¹H NMR spectrum of [B(C₂mea)(iso-butyl)(N₈₁₁)]⁺[OMs]⁻.

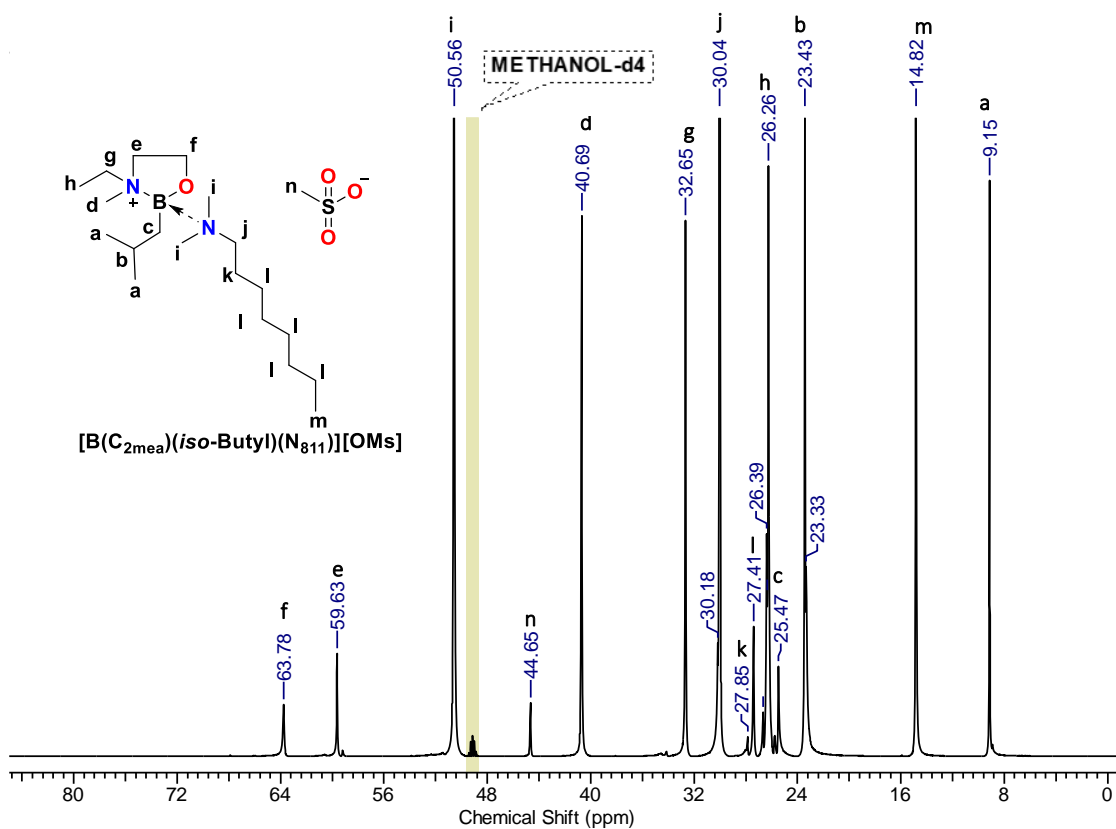


Figure S 23. ¹³C NMR spectrum of [B(C₂mea)(iso-butyl)(N₈₁₁)]⁺[OMs]⁻.

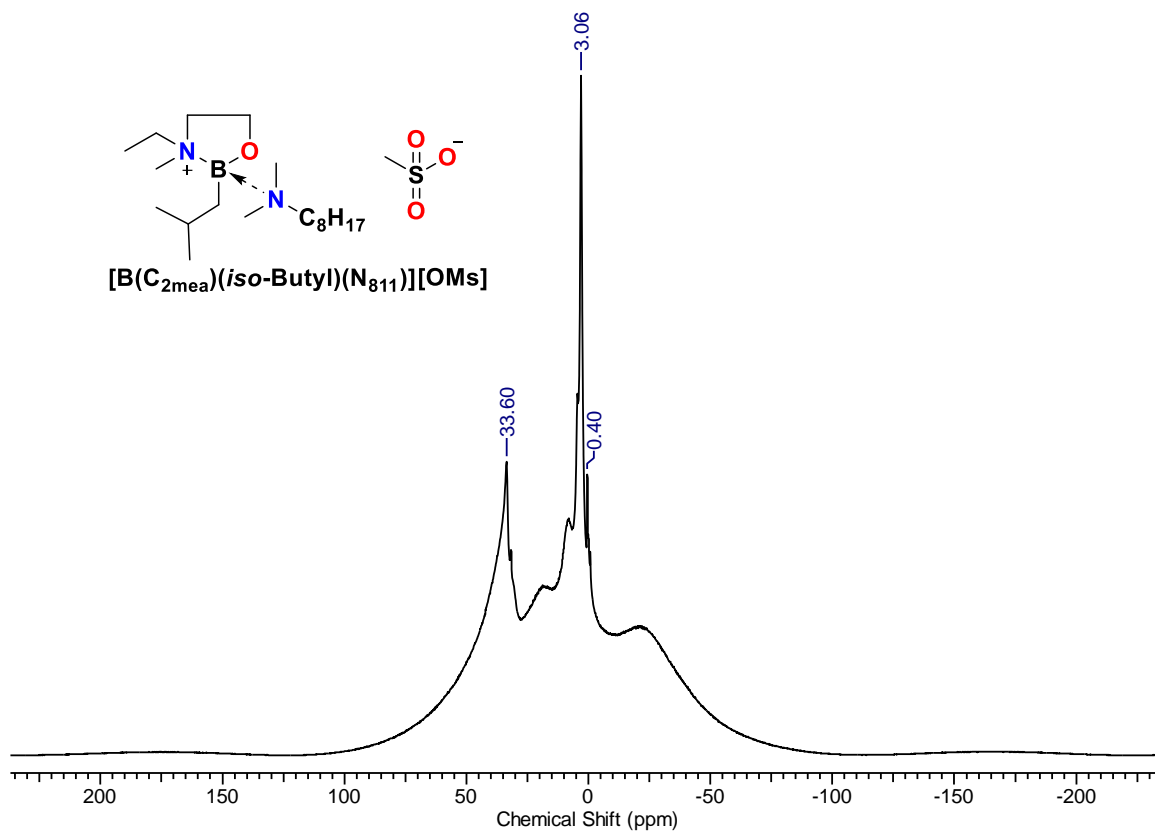


Figure S 24. ¹¹B NMR spectrum of [B(C₂mea)(iso-butyl)(N₈₁₁)] [OMs].

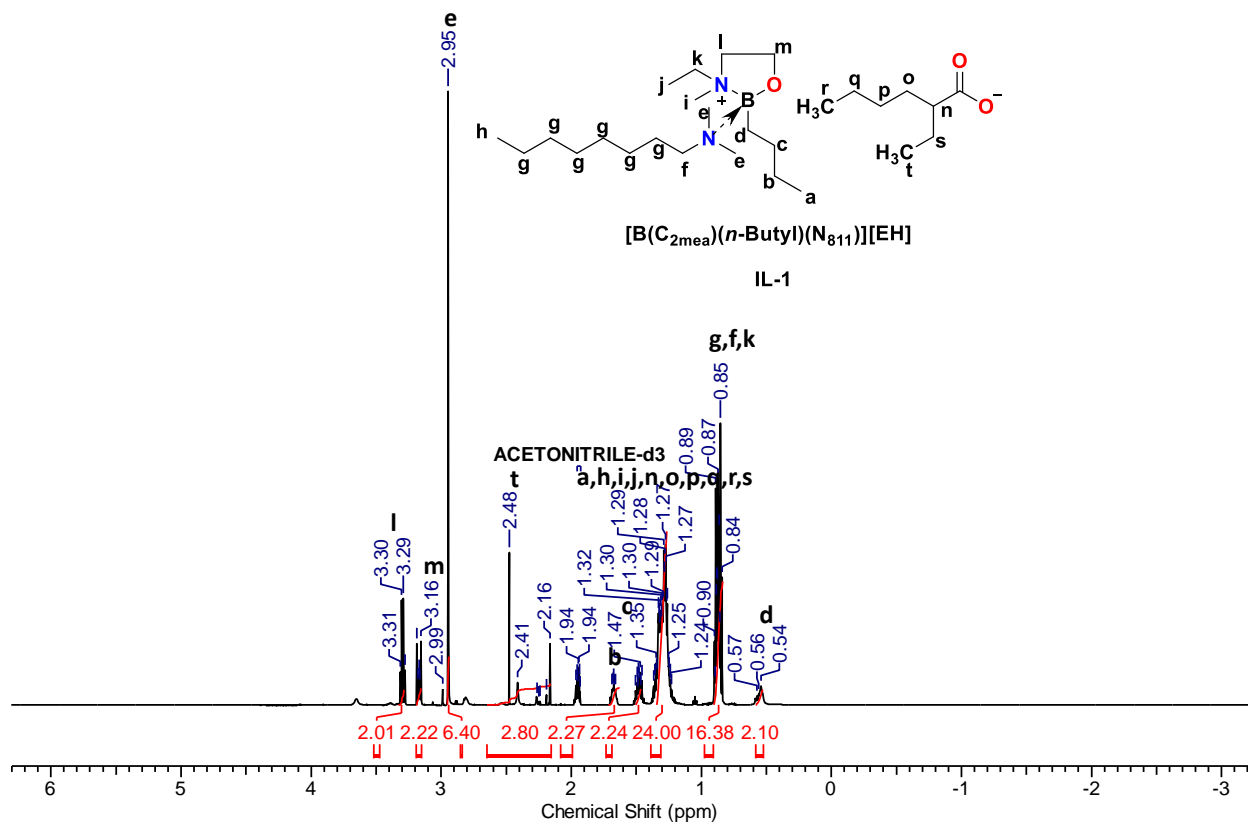


Figure S 25. ¹H NMR spectrum of IL-1 [B(C₂mea)(n-butyl)(N₈₁₁)] [EH].

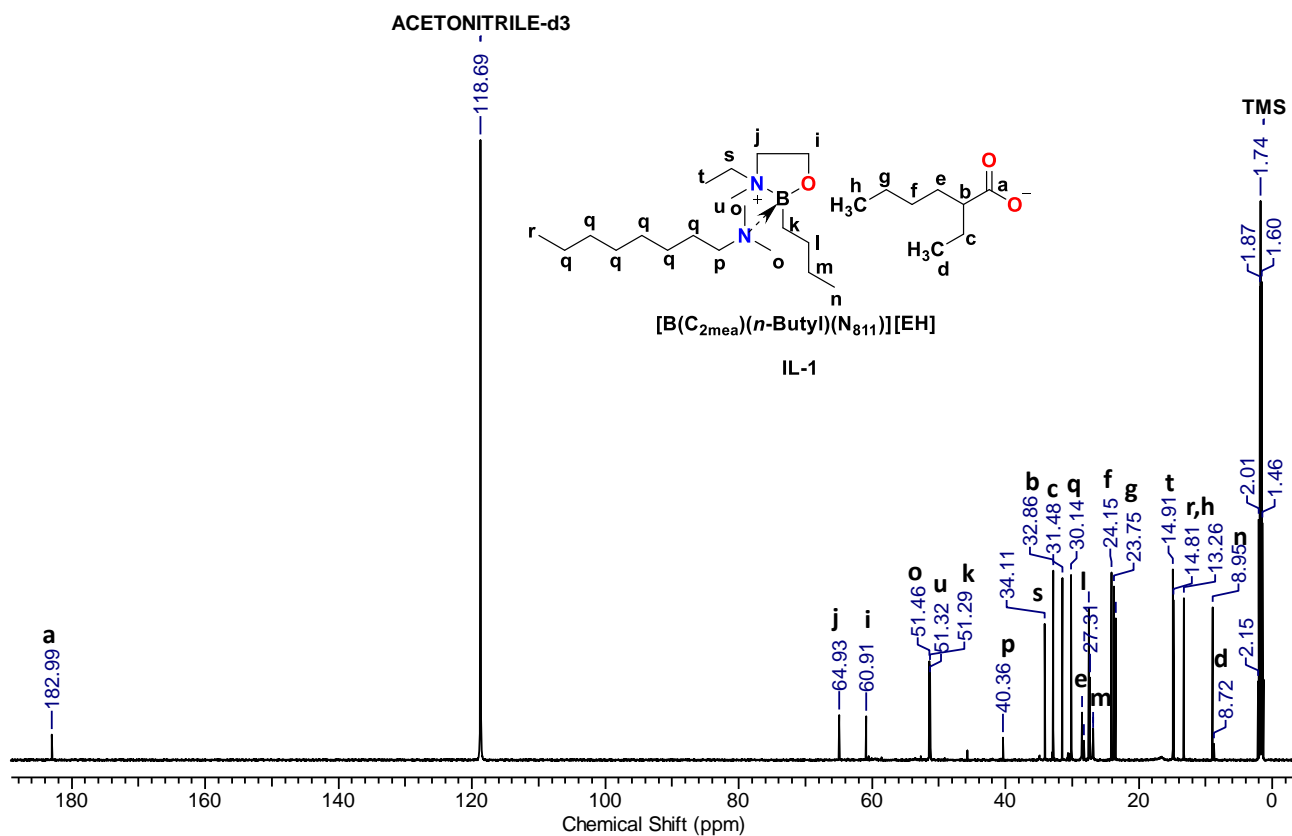


Figure S 26. ¹³C NMR spectrum of IL-1 $[B(C_{2mea})(n\text{-butyl})(N_{811})][EH]$.

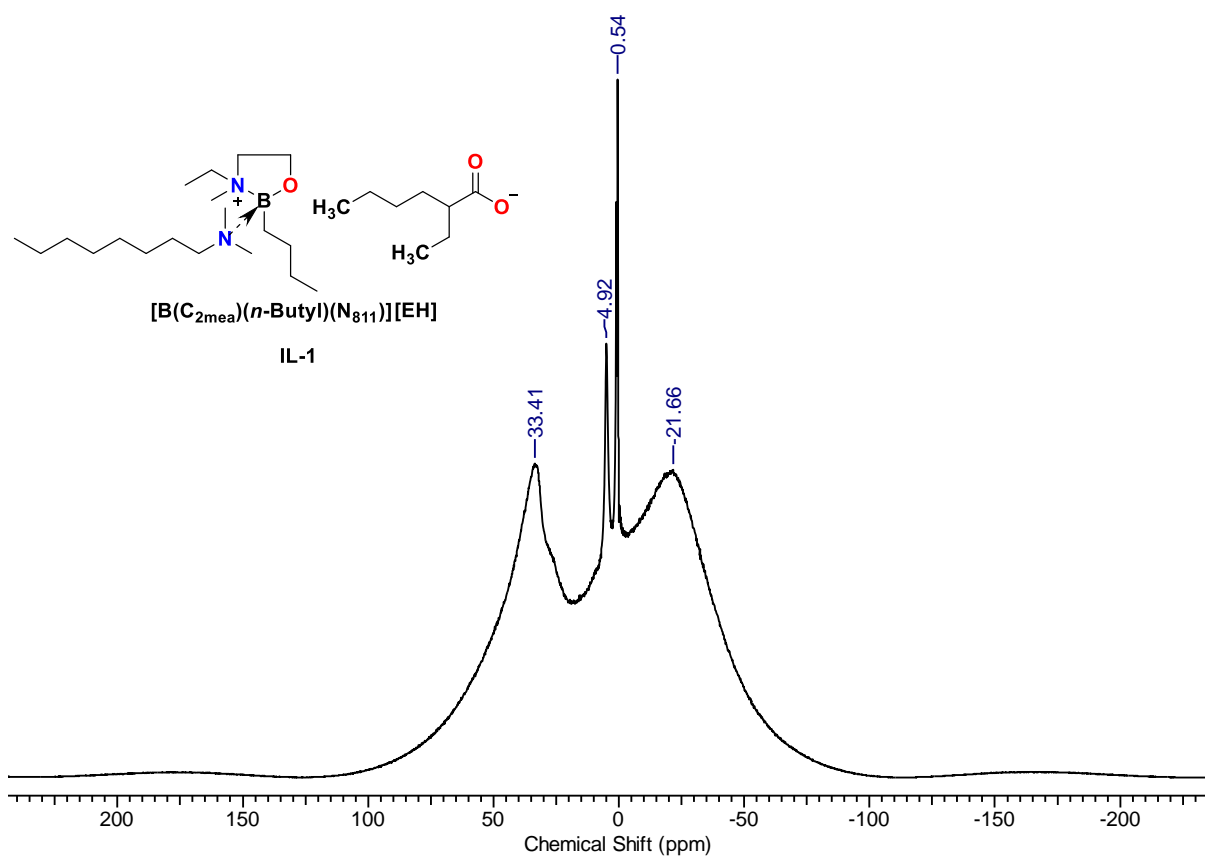


Figure S 27. ¹¹B NMR spectrum of IL-1 $[B(C_{2mea})(n\text{-butyl})(N_{811})][EH]$.

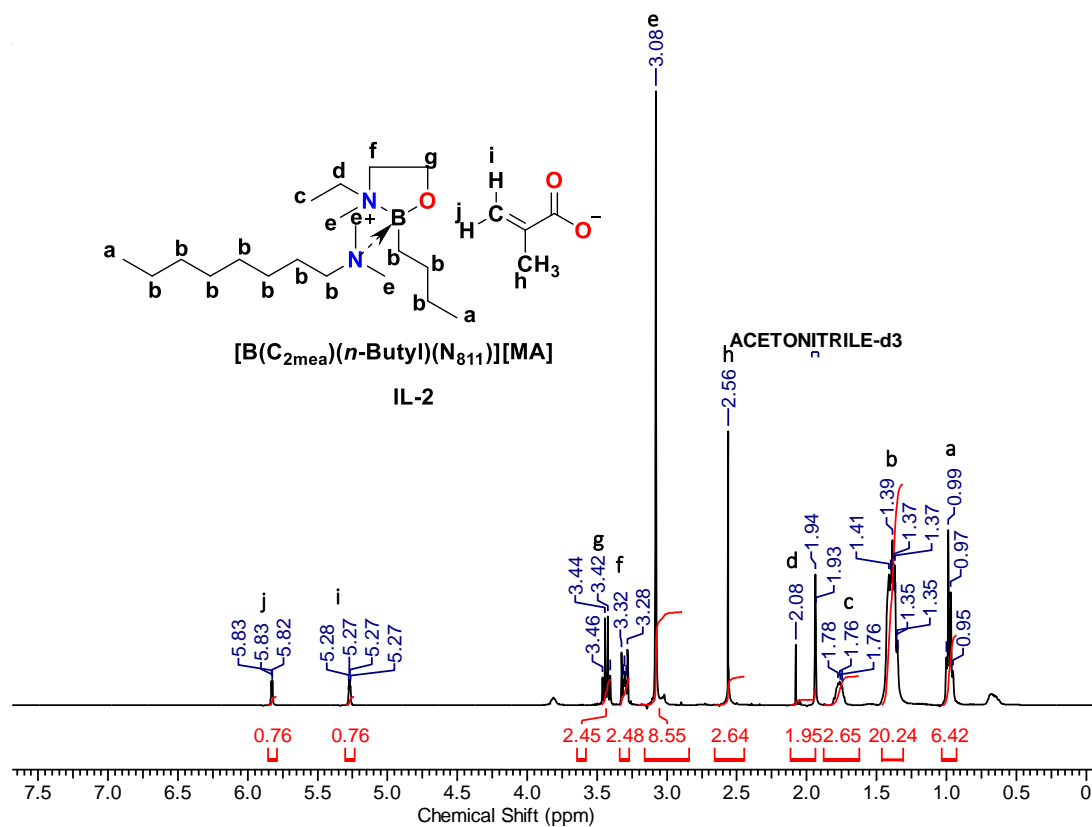


Figure S 28. ^1H NMR spectrum of IL-2 $[\text{B}(\text{C}_{2\text{mea}})(n\text{-butyl})(\text{N}_{811})][\text{MA}]$.

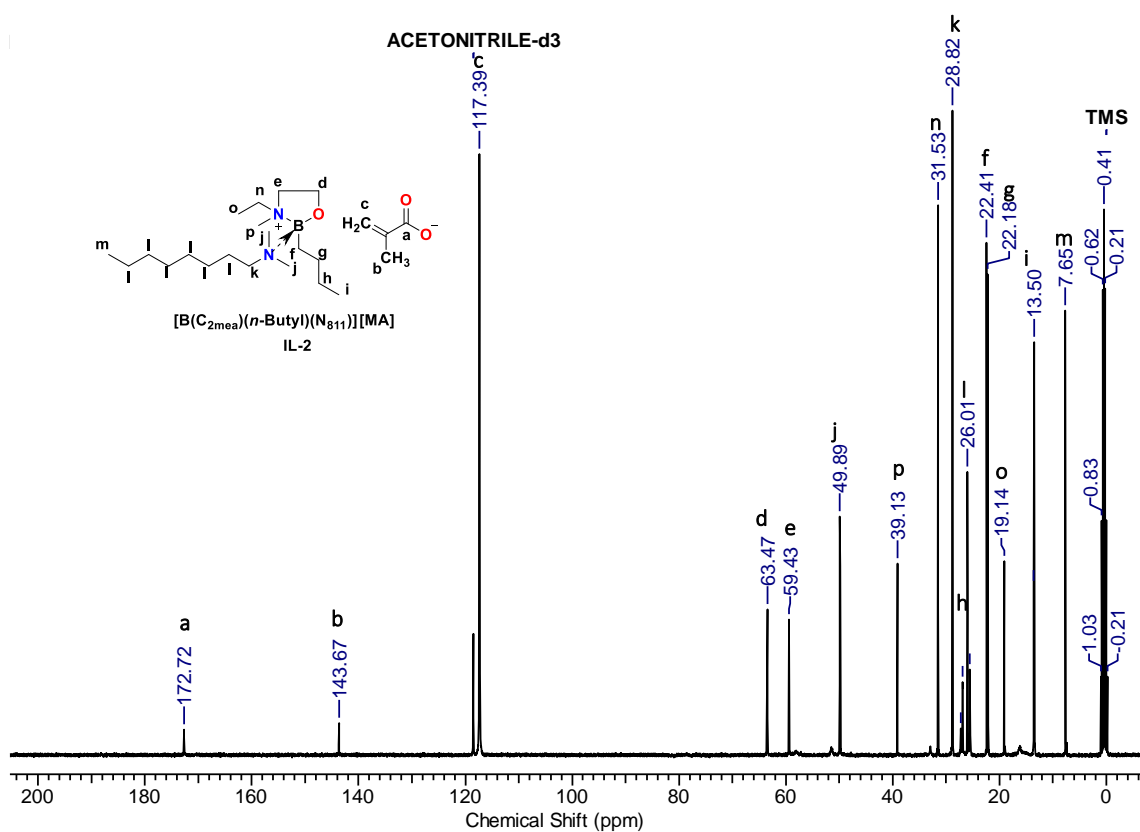


Figure S 29. ^{13}C NMR spectrum of IL-2 $[\text{B}(\text{C}_{2\text{mea}})(n\text{-butyl})(\text{N}_{811})][\text{MA}]$.

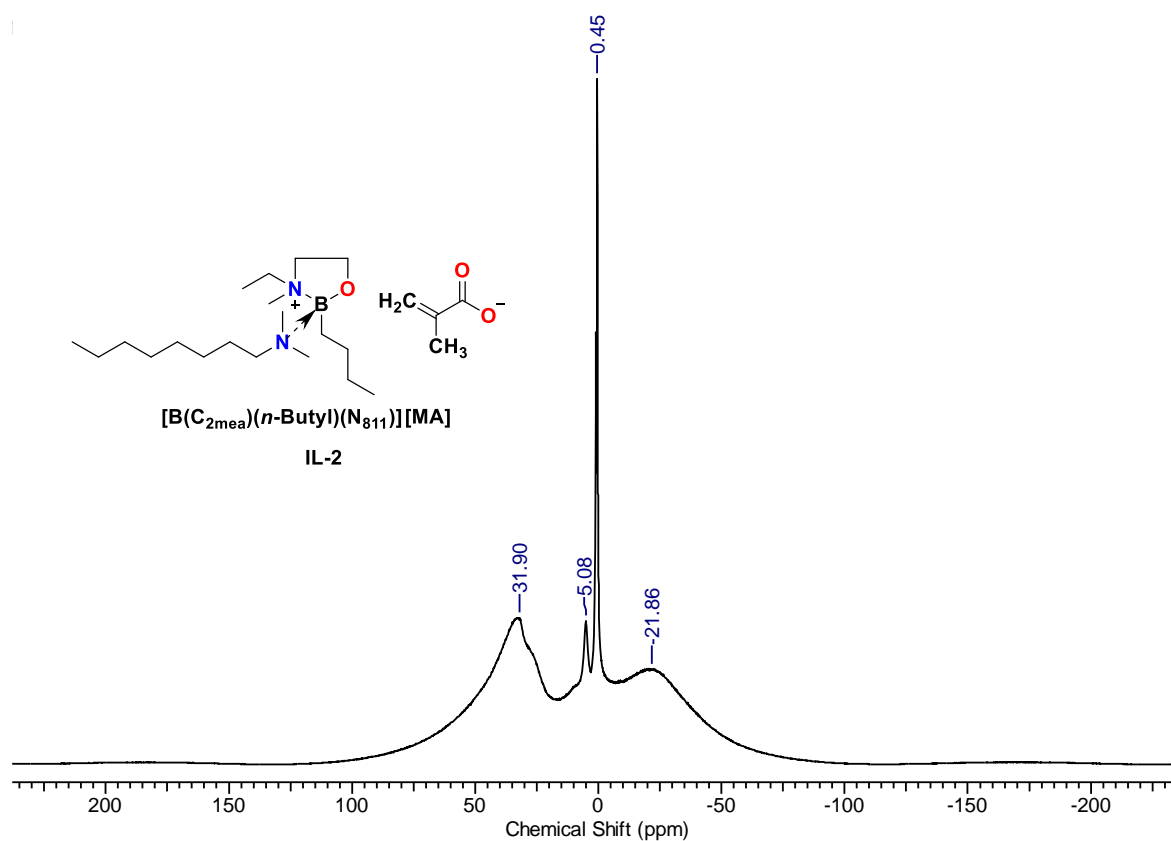


Figure S 30. ^{11}B NMR spectrum of IL-2 $[B(C_{2mea})(n\text{-butyl})(N_{811})][MA]$.

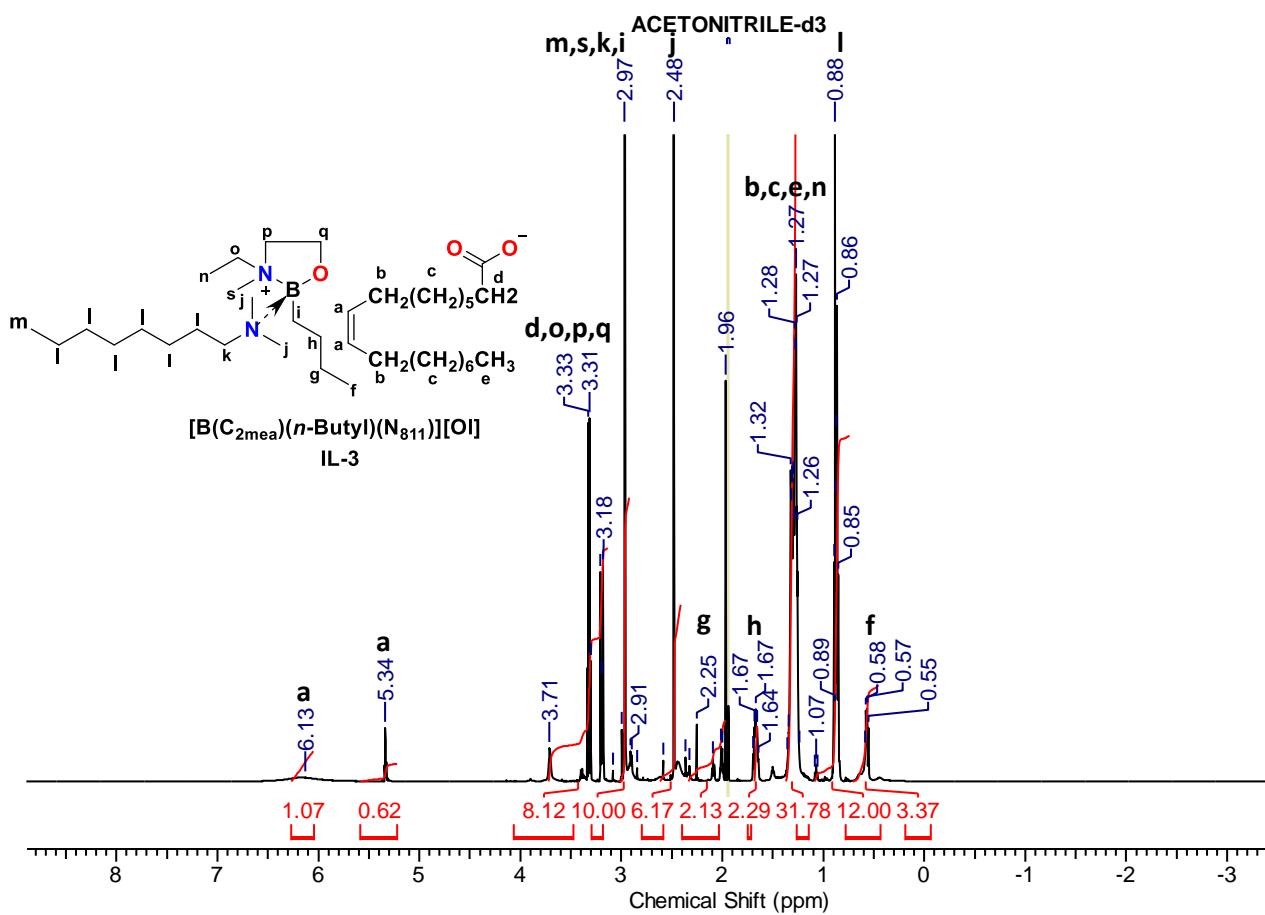


Figure S 31. 1H NMR spectrum of IL-3 $[B(C_{2mea})(n\text{-butyl})(N_{811})][OI]$.

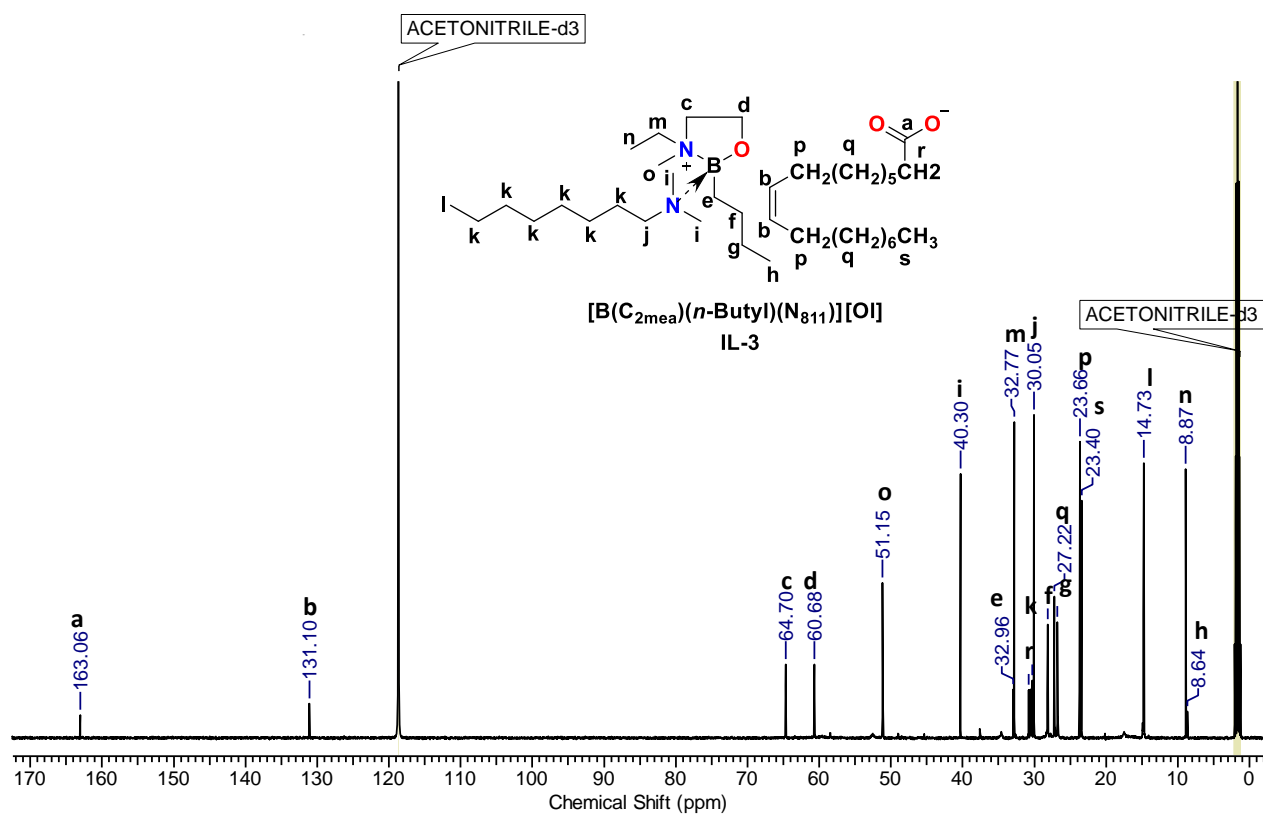


Figure S 32. ^{13}C NMR spectrum of IL-3 $[\text{B}(\text{C}_{2\text{mea}})(n\text{-butyl})(\text{N}_{811})][\text{OI}]$.

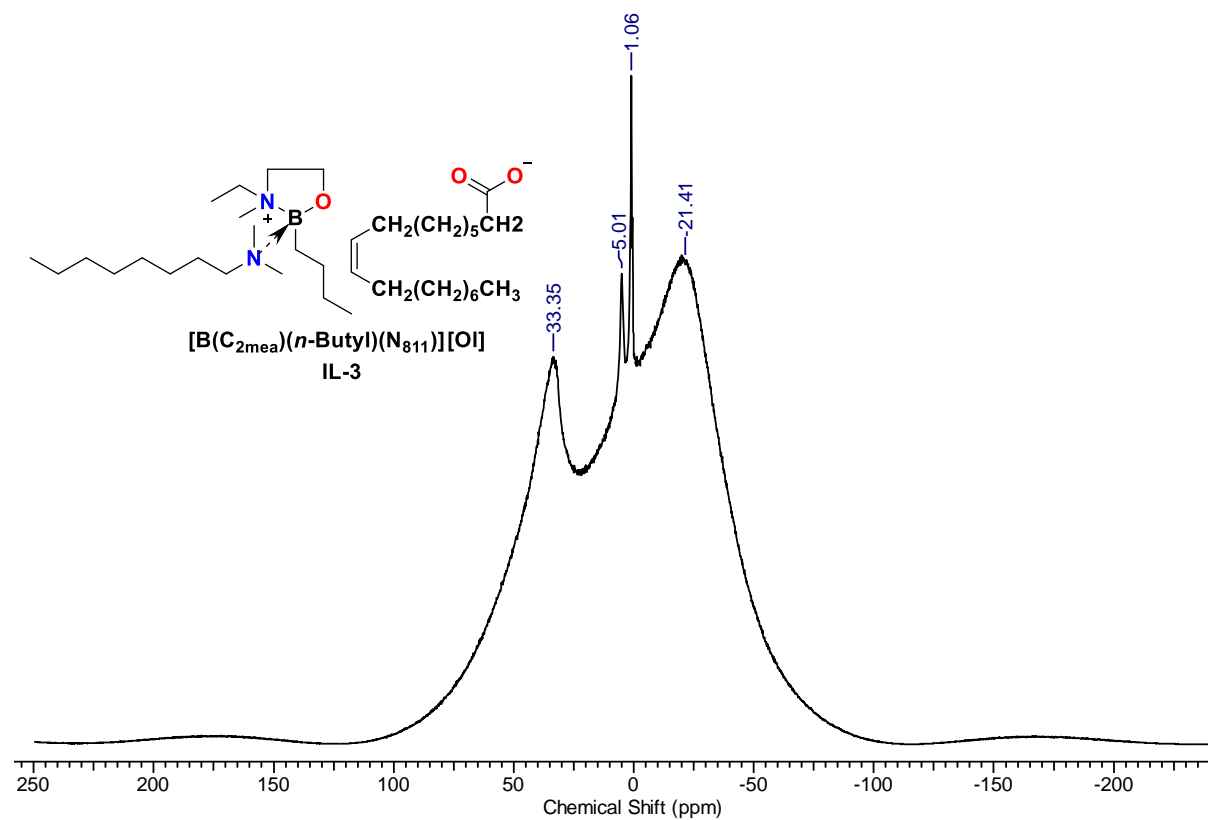


Figure S 33. ^{11}B NMR spectrum of IL-3 $[\text{B}(\text{C}_{2\text{mea}})(n\text{-butyl})(\text{N}_{811})][\text{OI}]$.

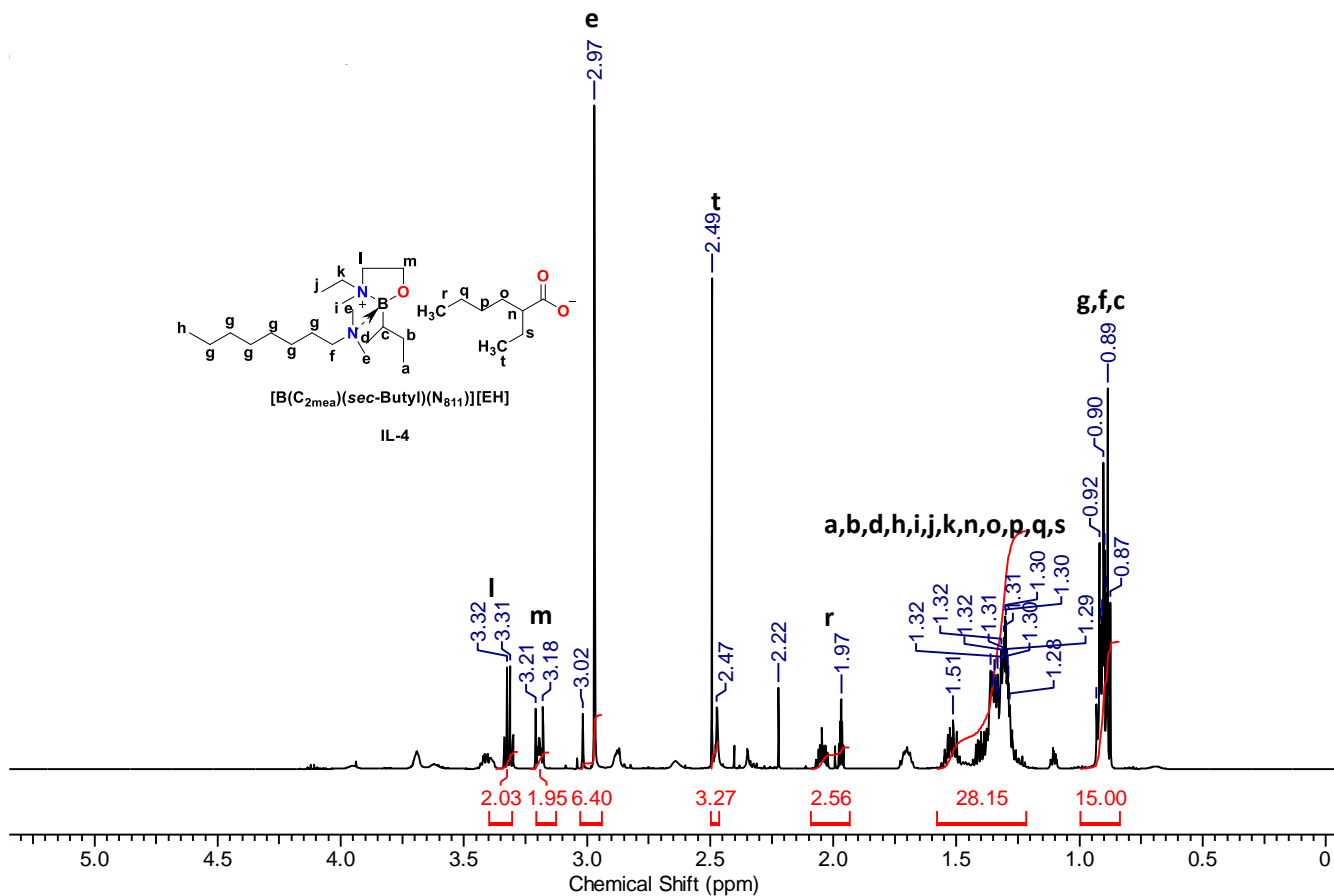


Figure S 34. ¹H NMR spectrum of IL-4 $[B(C_{2mea})(sec-butyl)(N_{811})][EH]$.

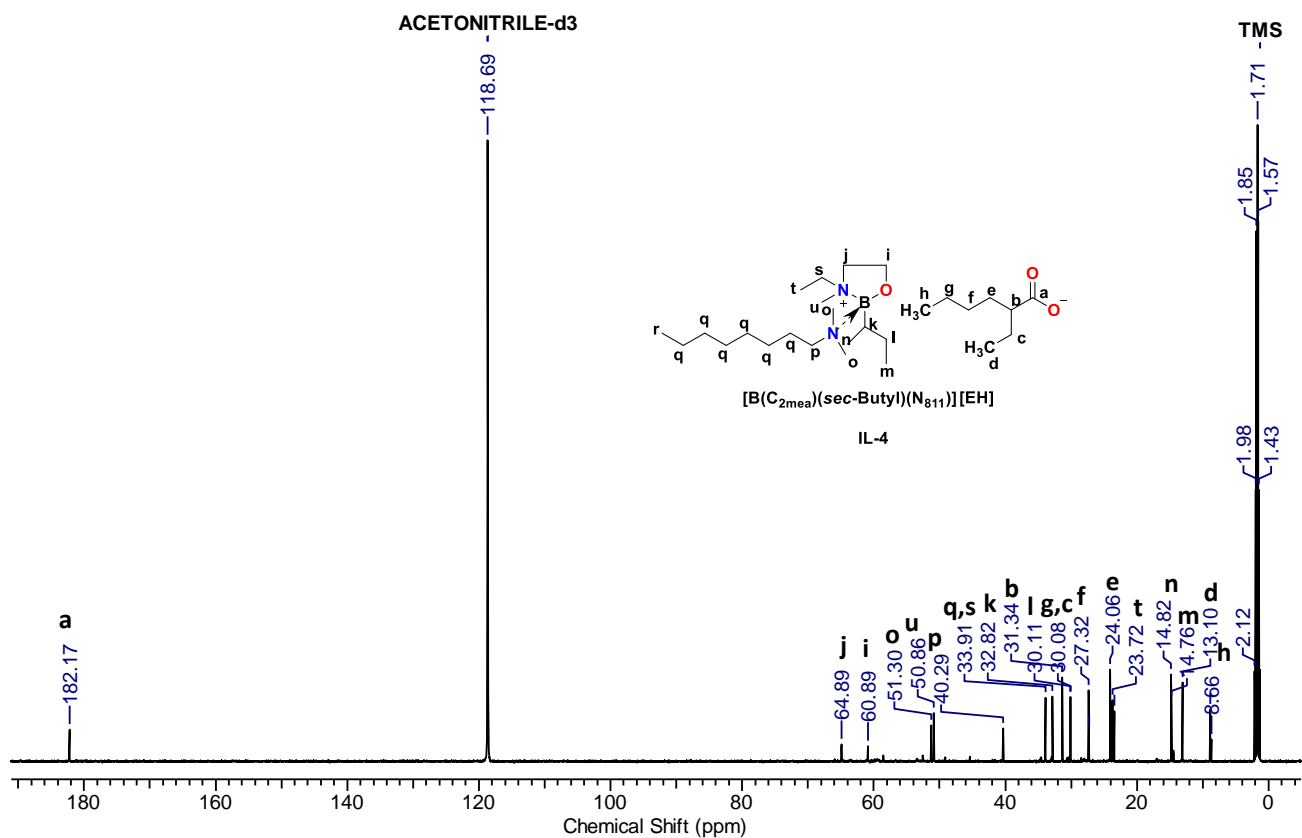


Figure S 35. ^{13}C NMR spectrum of IL-4 $[\text{B}(\text{C}_{2\text{mea}})(\text{sec-butyl})(\text{N}_{811})][\text{EH}]$.

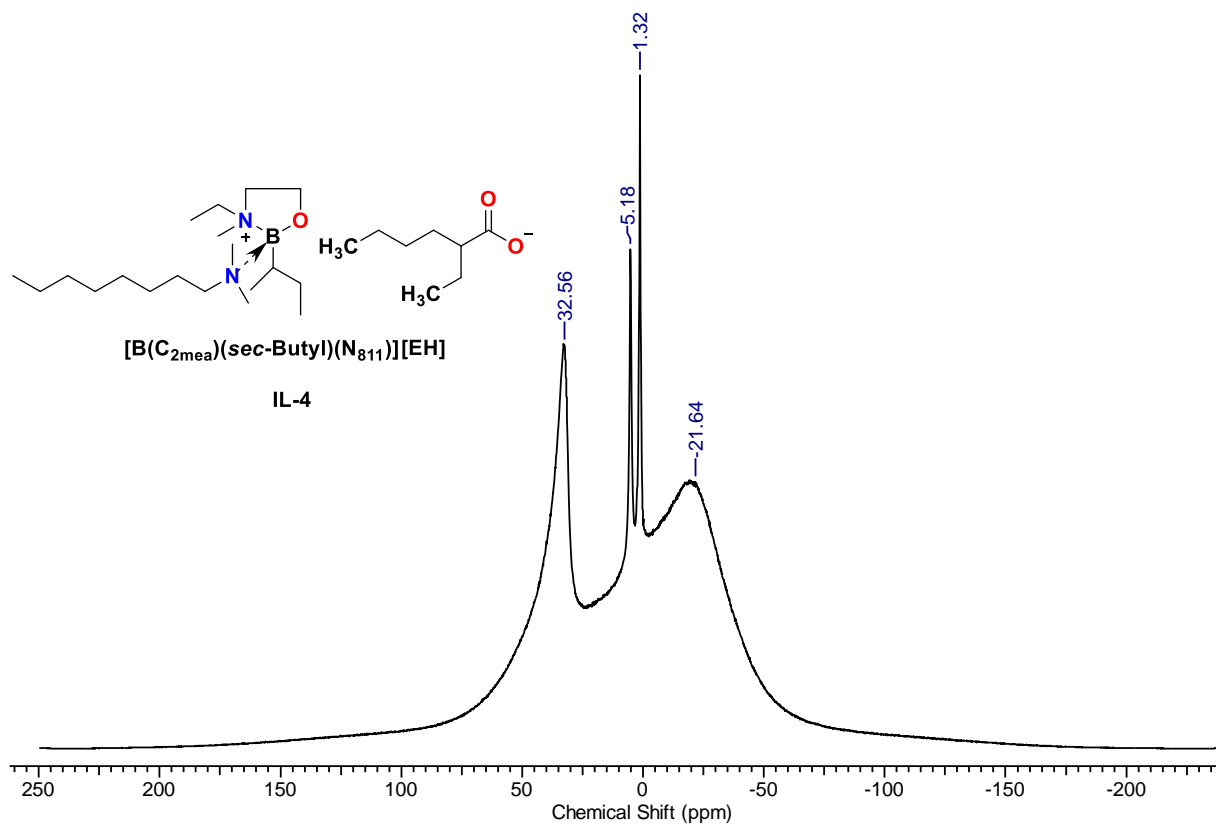


Figure S 36. ^{11}B NMR spectrum of IL-4 $[\text{B}(\text{C}_{2\text{mea}})(\text{sec-butyl})(\text{N}_{811})][\text{EH}]$.

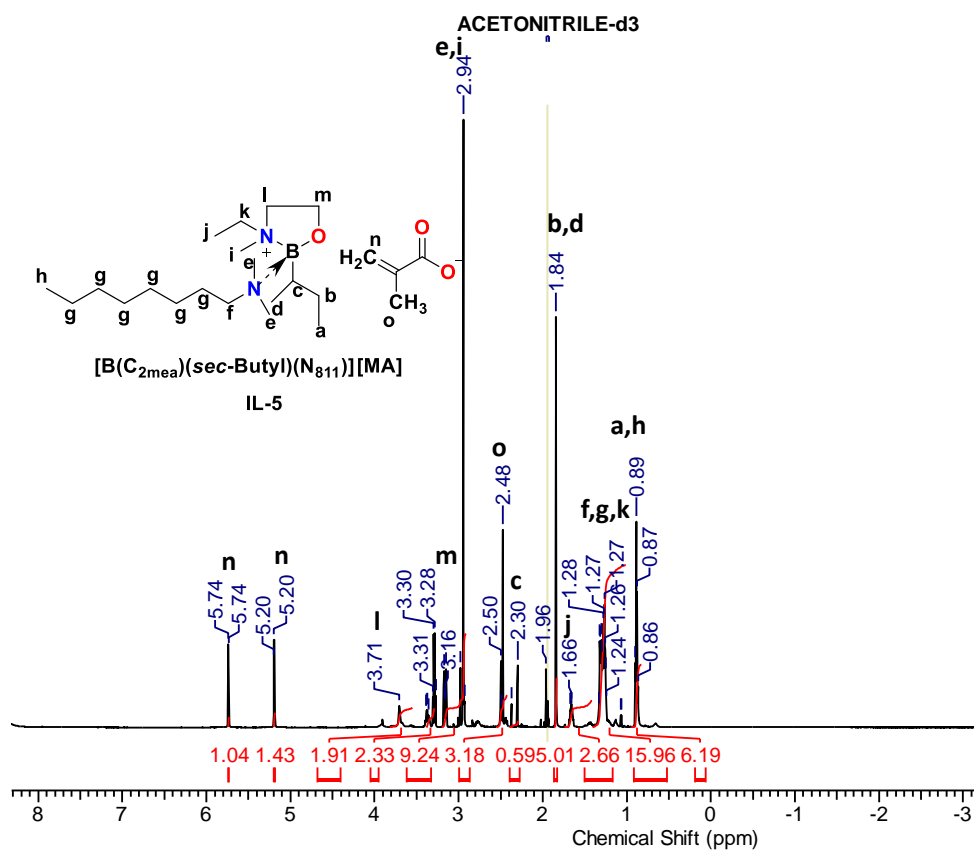


Figure S 37. ^1H NMR spectrum of IL-5 $[\text{B}(\text{C}_{2\text{mea}})(\text{sec-butyl})(\text{N}_{811})][\text{MA}]$.

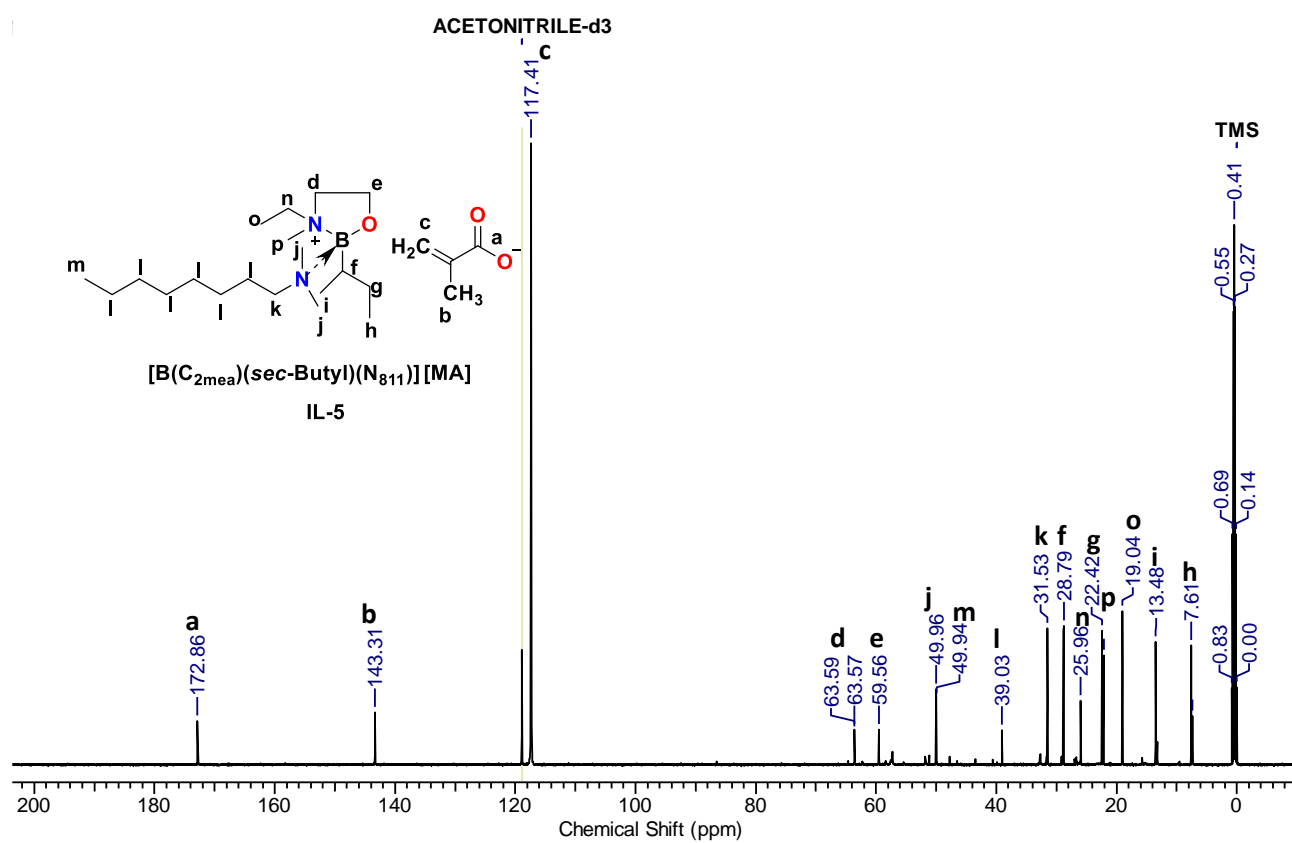


Figure S 38. ^{13}C NMR spectrum of IL-5 $[B(C_{2mea})(sec\text{-}butyl)(N_{811})][MA]$.

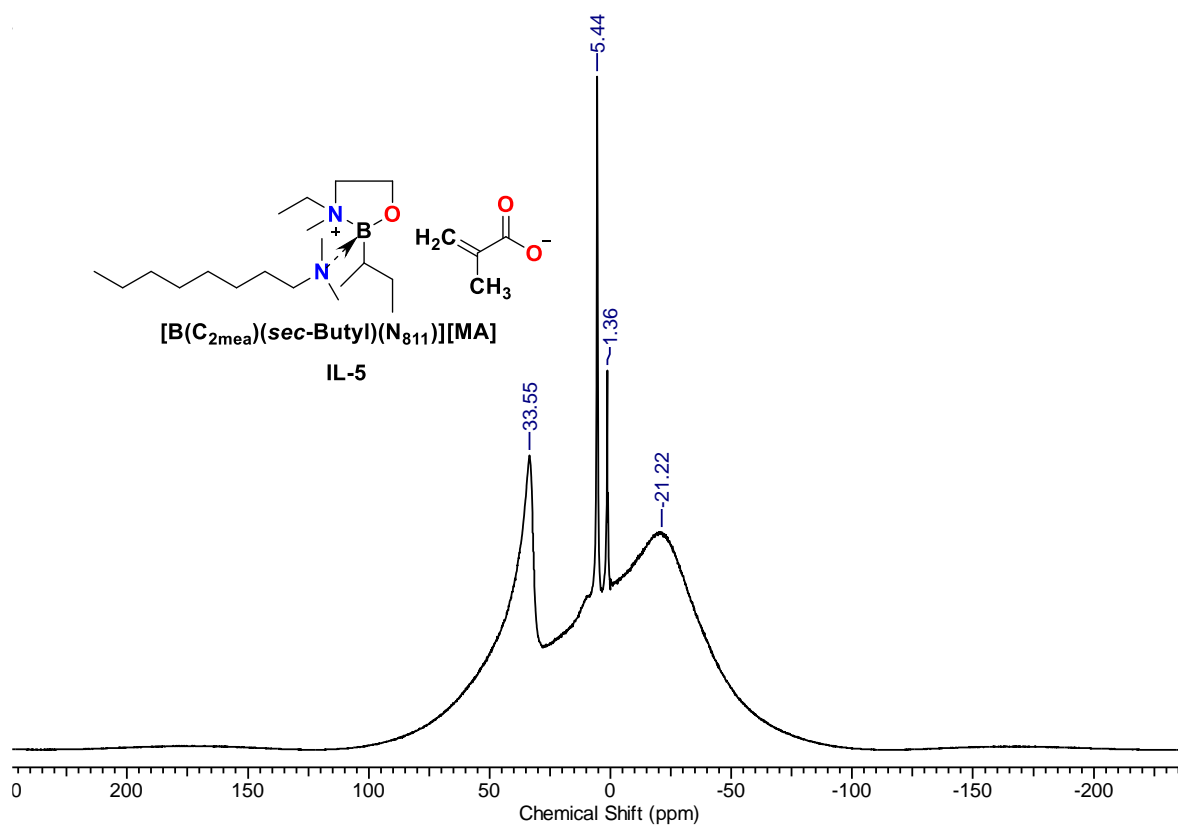


Figure S 39. ^{11}B NMR spectrum of IL-5 $[B(C_{2mea})(sec\text{-}butyl)(N_{811})][MA]$.

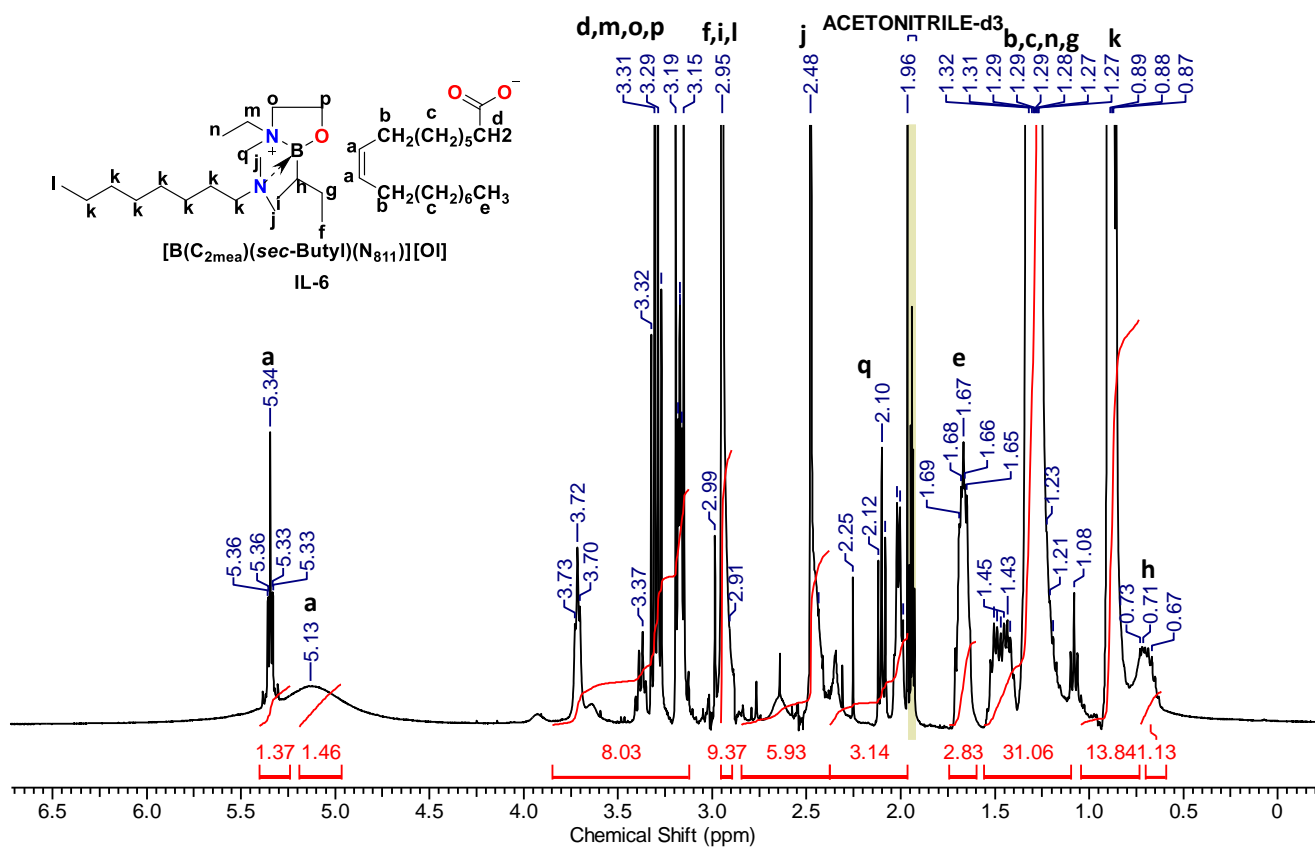


Figure S 40. ¹H NMR spectrum of IL-6 [B(C₂mea)(sec-butyl)(N₈₁₁)] [OI].

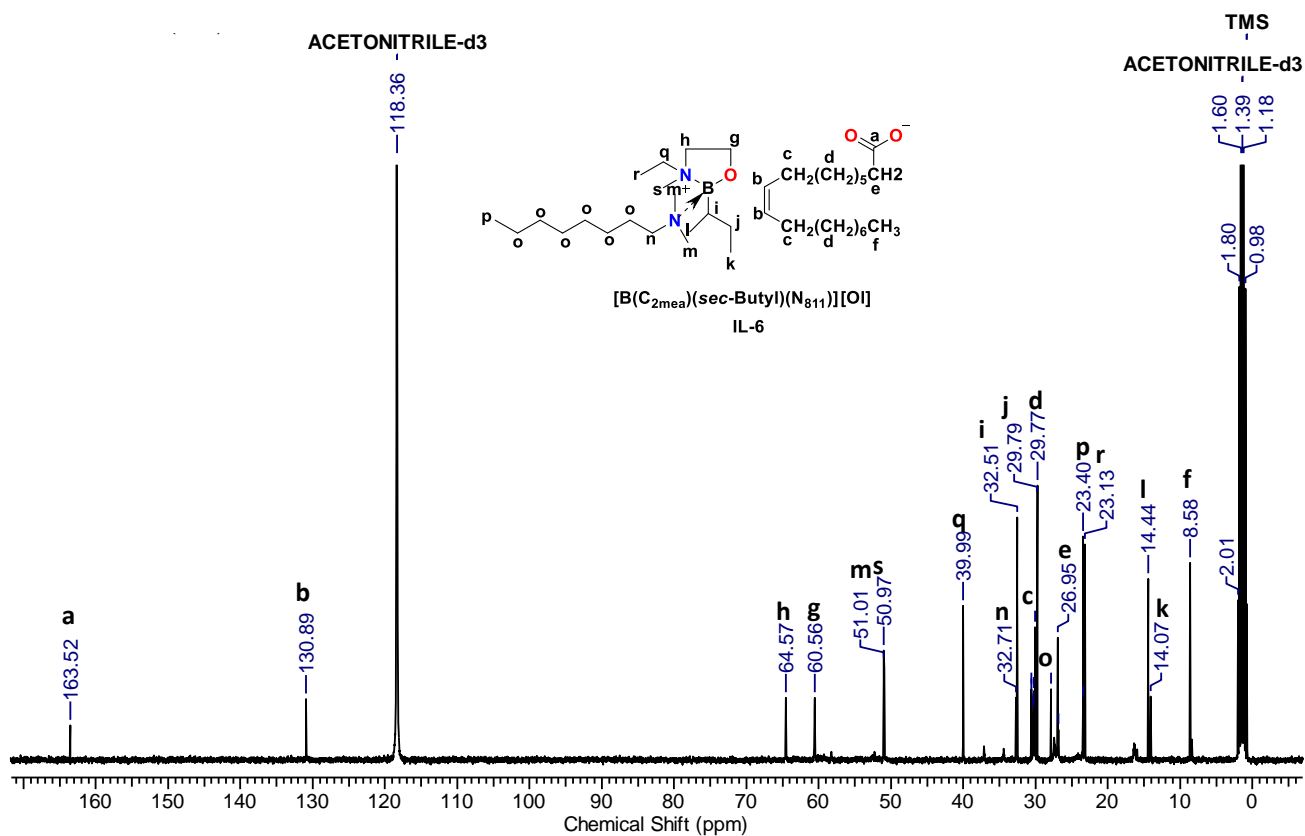


Figure S 41. ¹³C NMR spectrum of IL-6 [B(C₂mea)(sec-butyl)(N₈₁₁)] [OI].

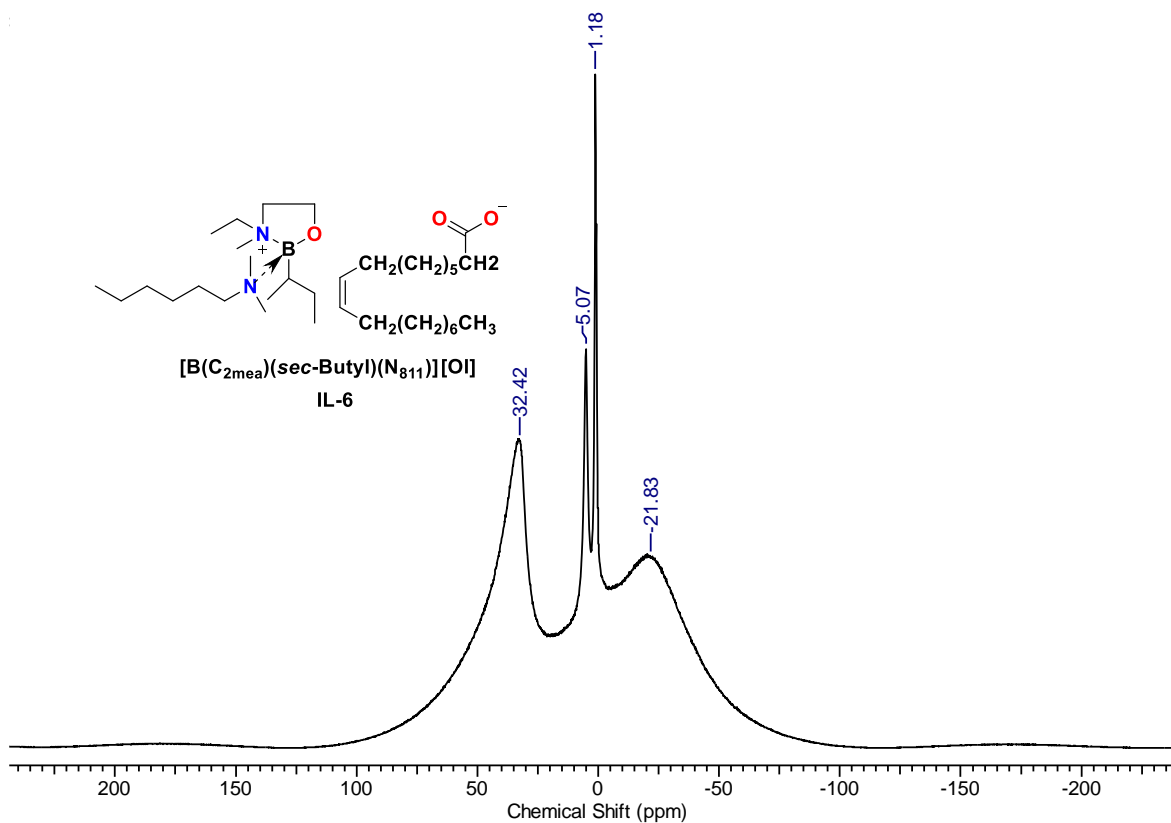


Figure S 42. ¹¹B NMR spectrum of IL-6 [B(C₂mea)(*sec*-butyl)(N₈₁₁)] [OI].

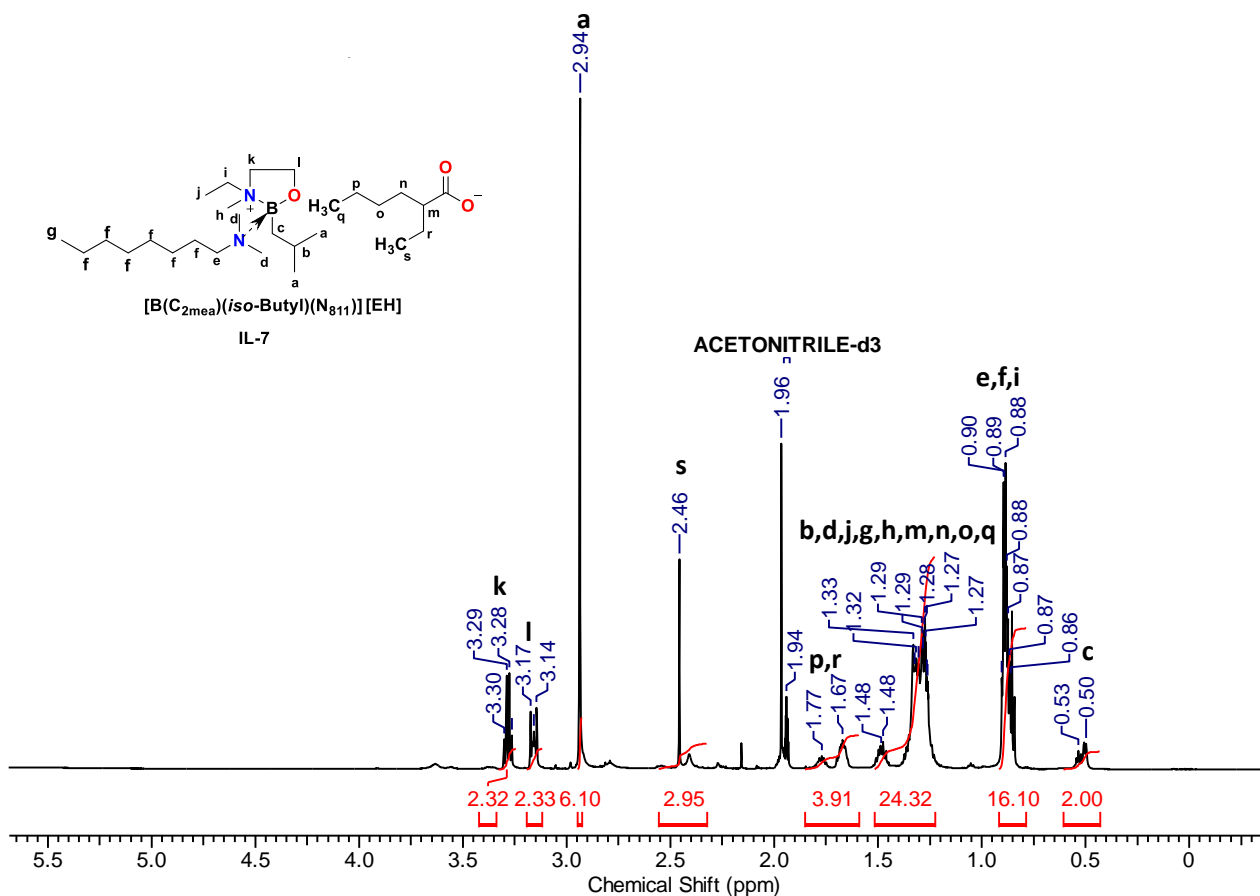


Figure S 43. ¹H NMR spectrum of IL-7 [B(C₂mea)(*iso*-butyl)(N₈₁₁)] [EH].

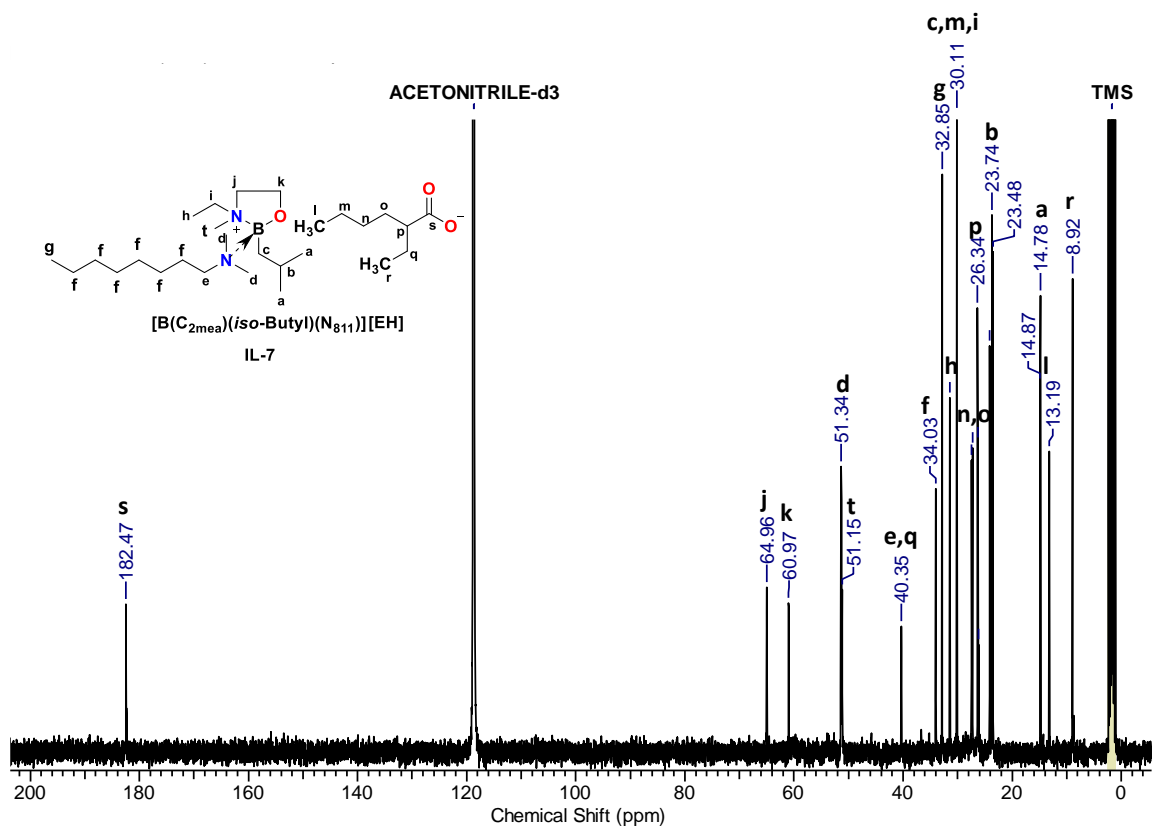


Figure S 44. ¹³C NMR spectrum of IL-7 [B(C₂mea)(iso-butyl)(N₈₁₁)] [EH].

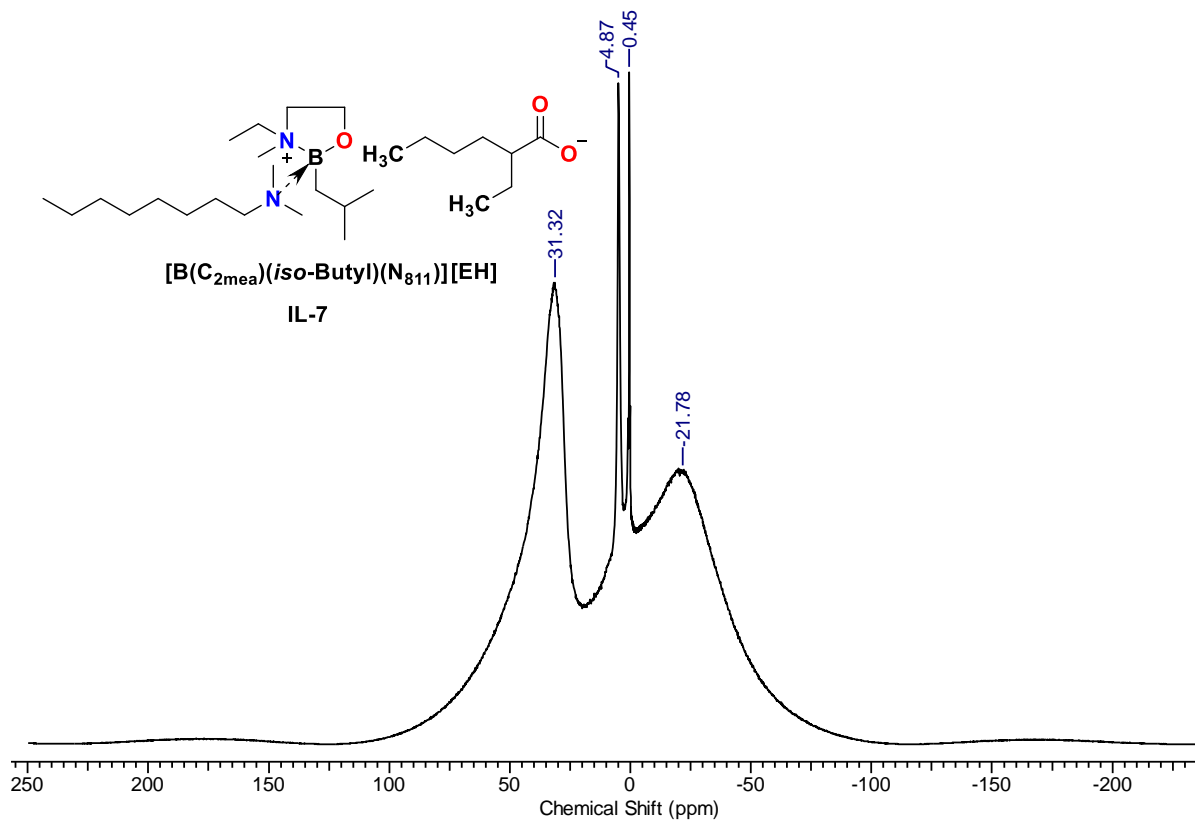


Figure S 45. ¹¹B NMR spectrum of IL-7 [B(C₂mea)(iso-butyl)(N₈₁₁)] [EH].

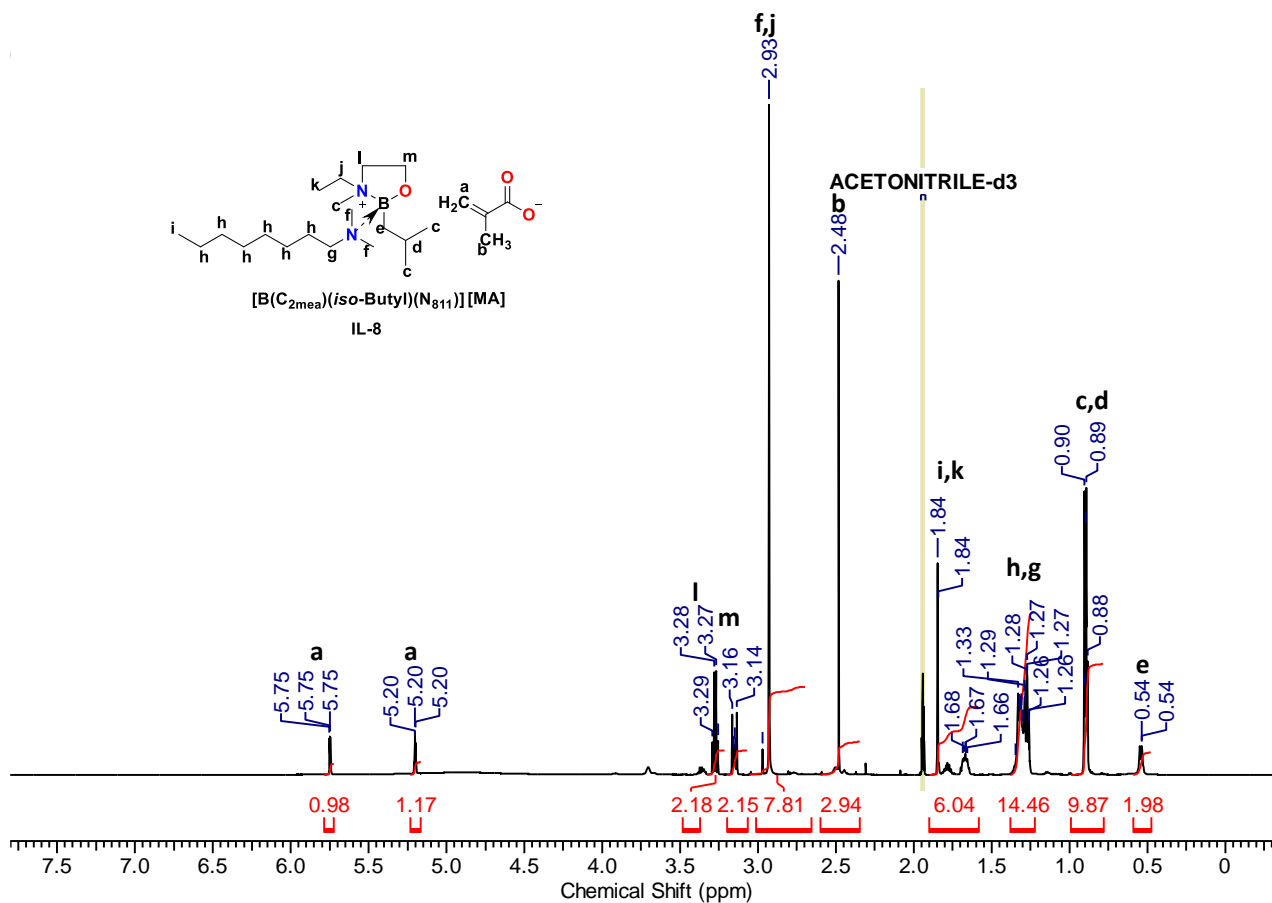


Figure S 46. ^1H NMR spectrum of IL-8 $[\text{B}(\text{C}_{2\text{mea}})(\text{iso-butyl})(\text{N}_{811})][\text{MA}]$.

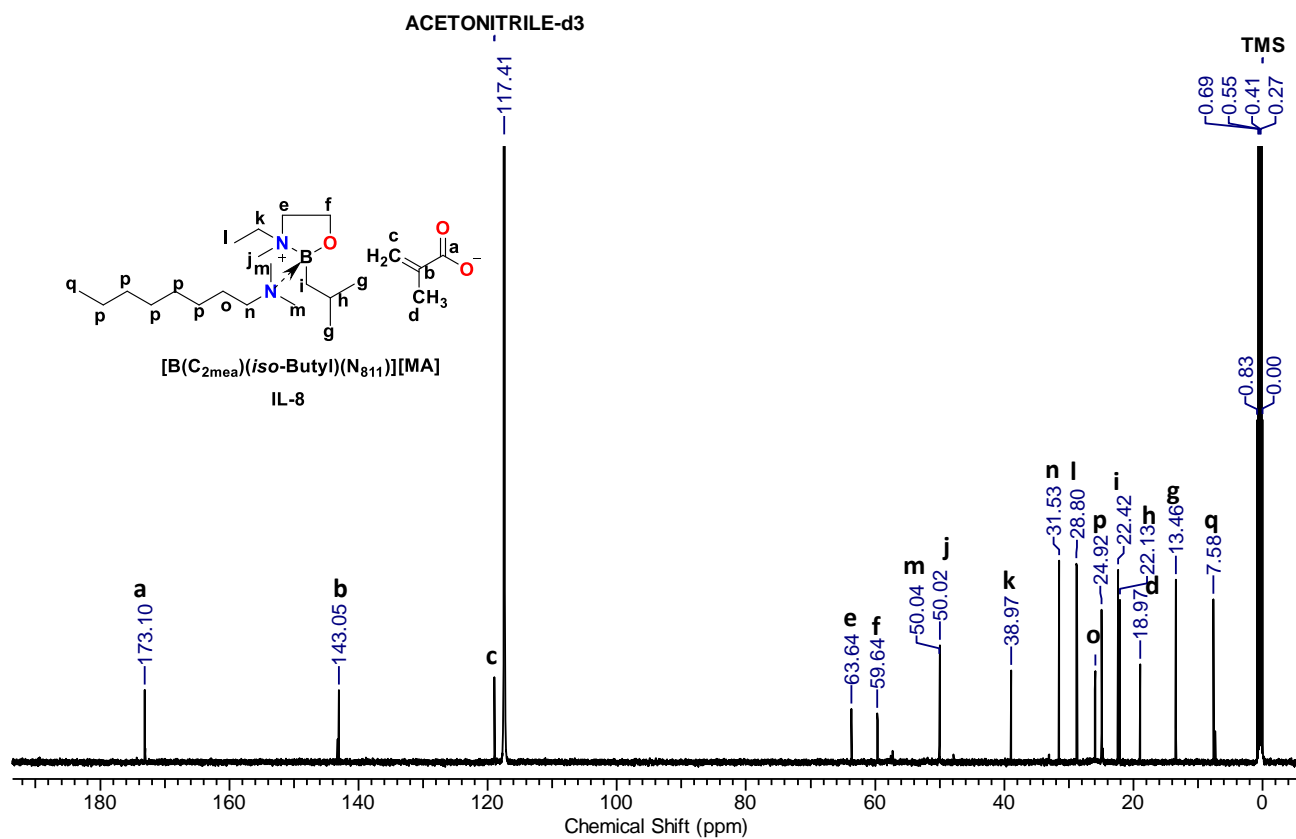


Figure S 47. ^{13}C NMR spectrum of IL-8 $[\text{B}(\text{C}_{2\text{mea}})(\text{iso-butyl})(\text{N}_{811})][\text{MA}]$.

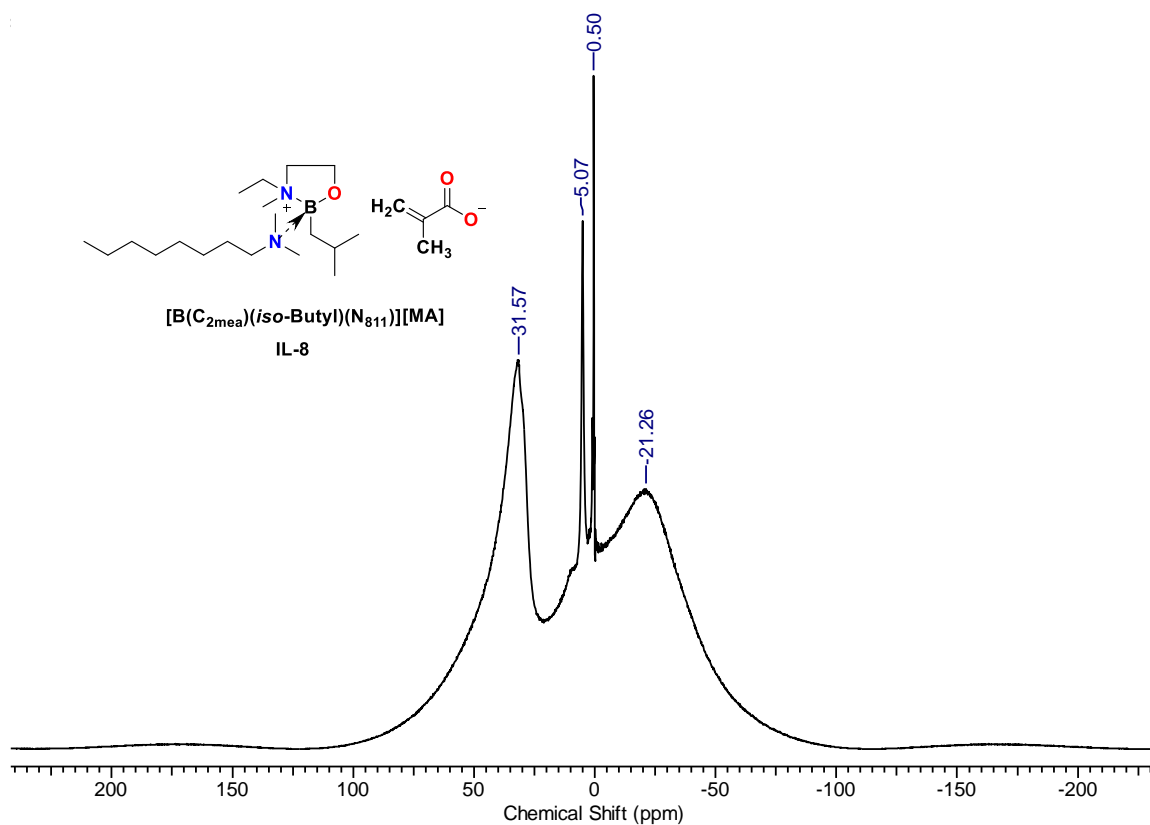


Figure S 48. ^{11}B NMR spectrum of IL-8 $[B(C_{2mea})(iso-butyl)(N_{811})][MA]$.

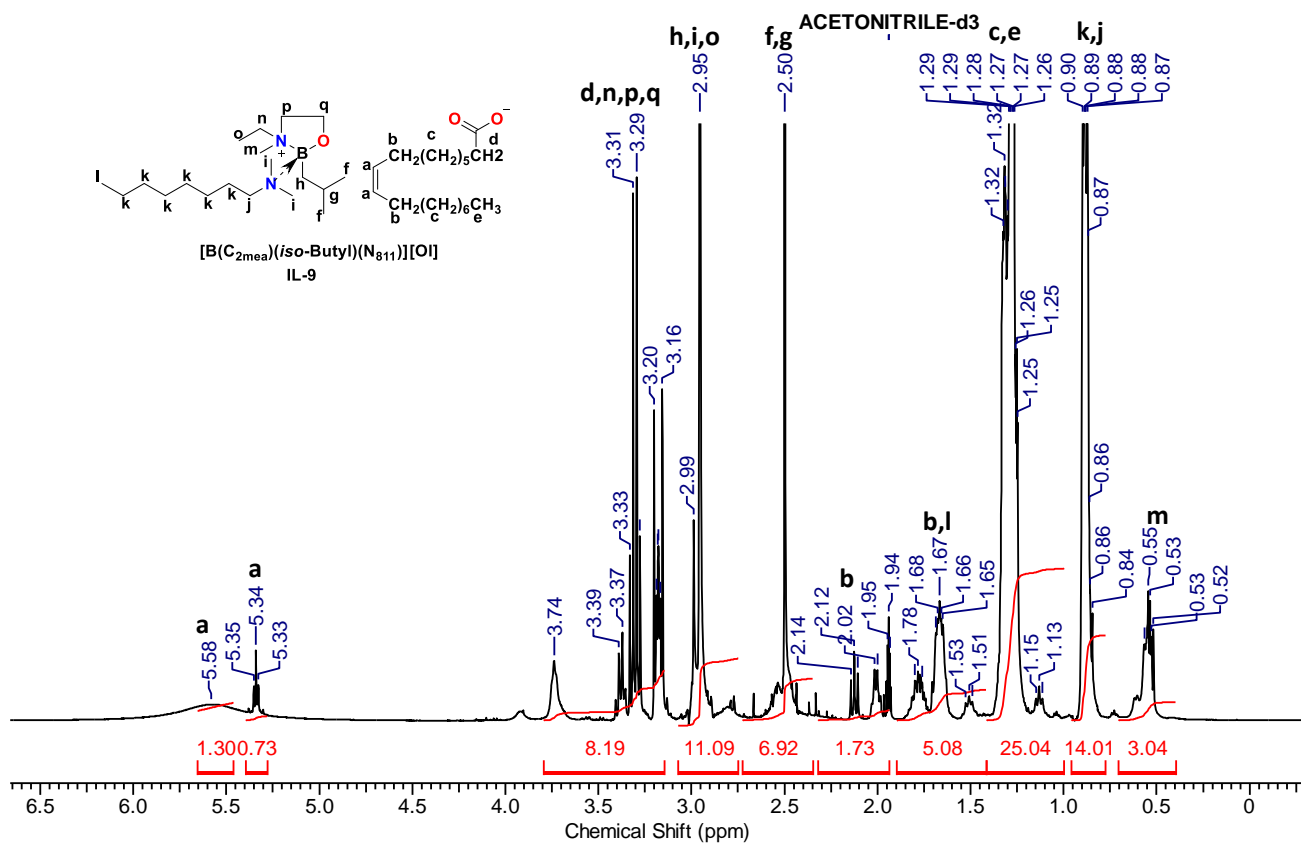


Figure S 49. 1H NMR spectrum of IL-9 $[B(C_{2mea})(iso-butyl)(N_{811})][OI]$.

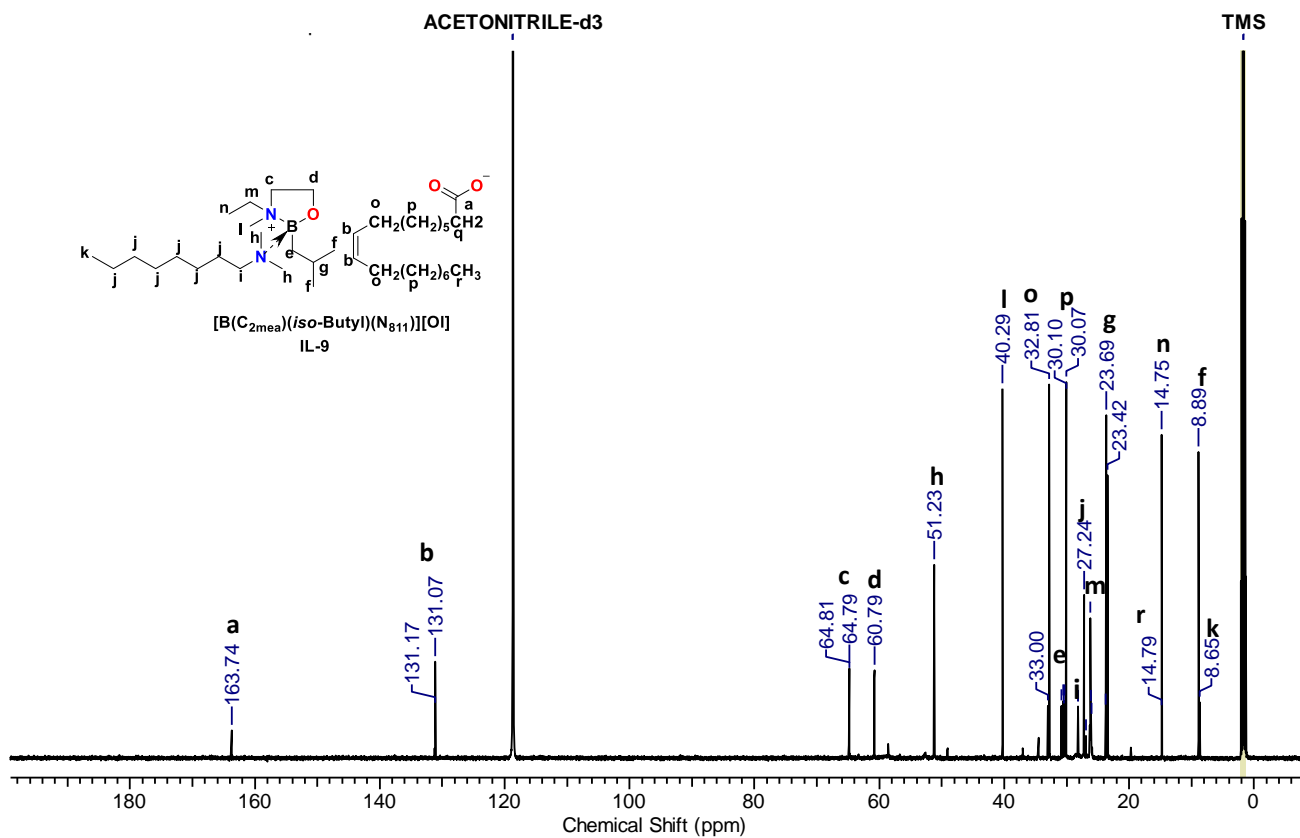


Figure S 50. ¹³C NMR spectrum of IL-9 [B(C₂mea)(*iso*-butyl)(N₈₁₁)] [OI].

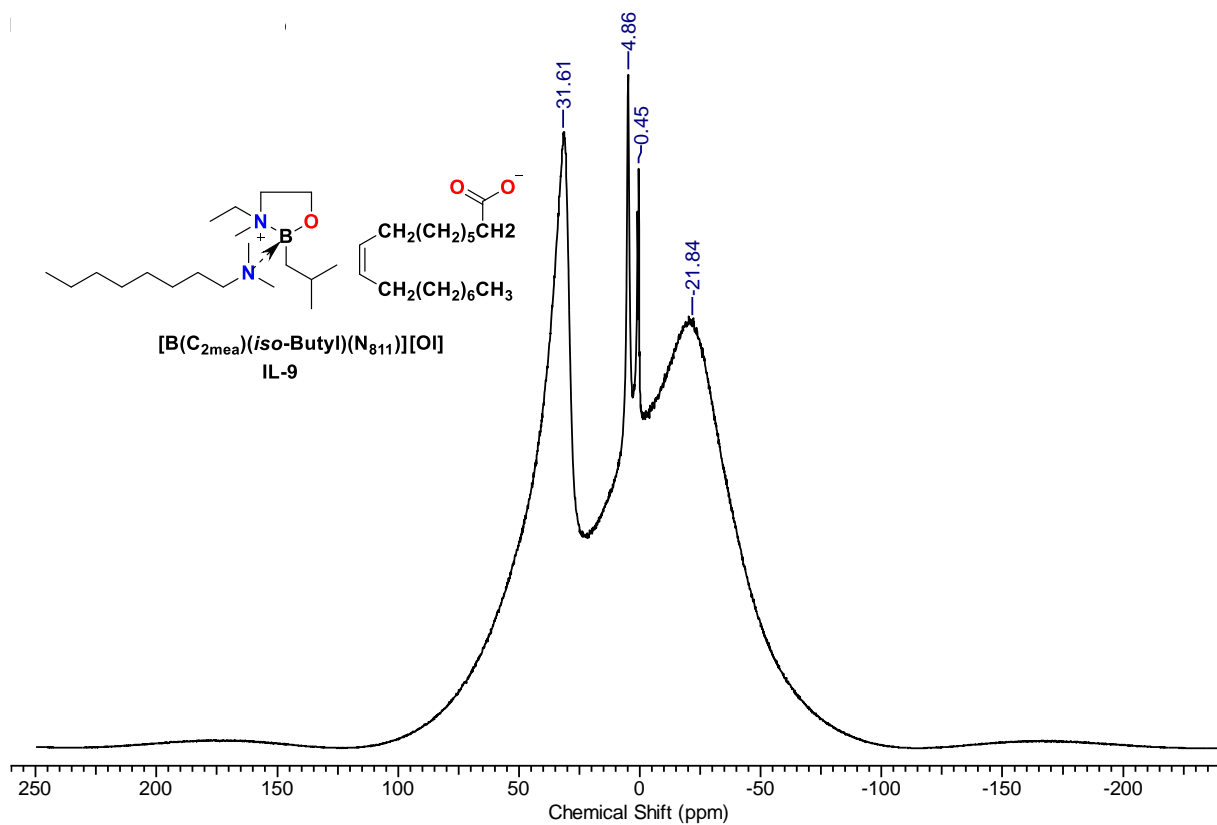


Figure S 51. ¹¹B NMR spectrum of IL-9 [B(C₂mea)(*iso*-butyl)(N₈₁₁)] [OI].

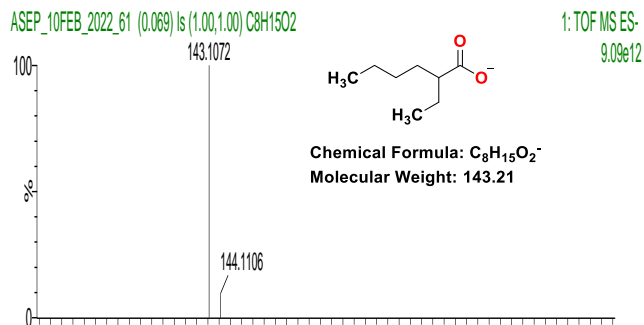
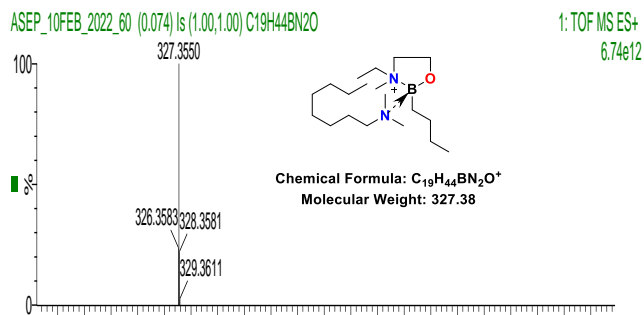


Figure S 52. Mass spectrum of IL-1 [B(C₂mea)(*n*-butyl)(N₈₁₁)] [EH].

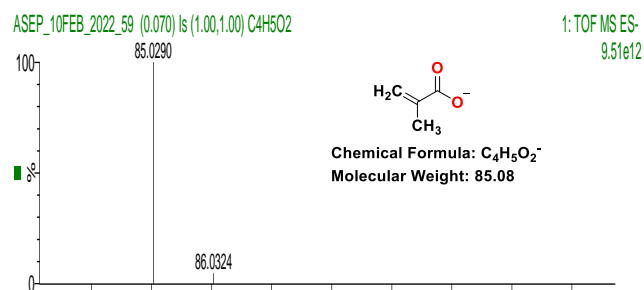
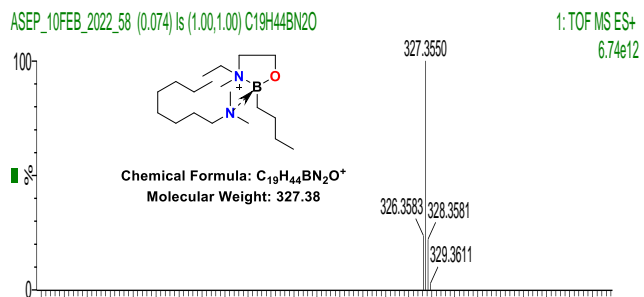


Figure S 53. Mass spectrum of IL-2 [B(C₂mea)(*n*-butyl)(N₈₁₁)] [MA].

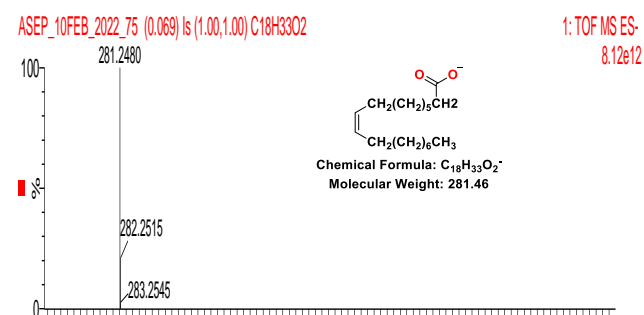
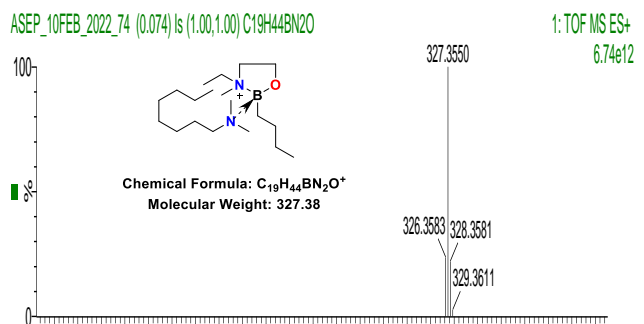


Figure S 54. Mass spectrum of IL-3 [B(C₂mea)(*n*-butyl)(N₈₁₁)] [OI].

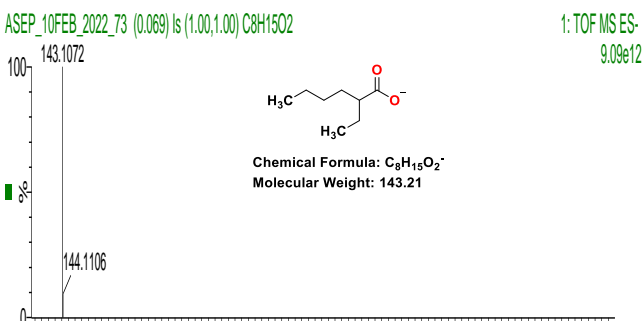
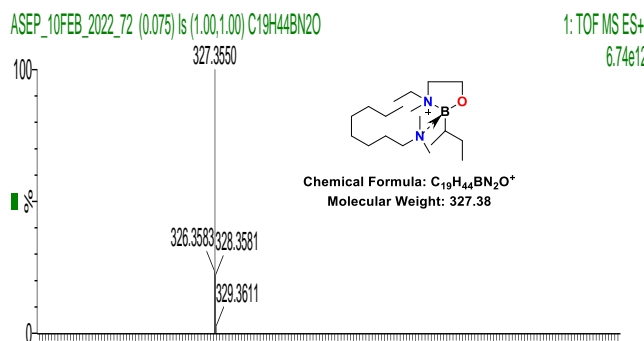


Figure S 55. Mass spectrum of IL-4 [B(C₂mea)(*sec*-butyl)(N₈₁₁)] [EH].

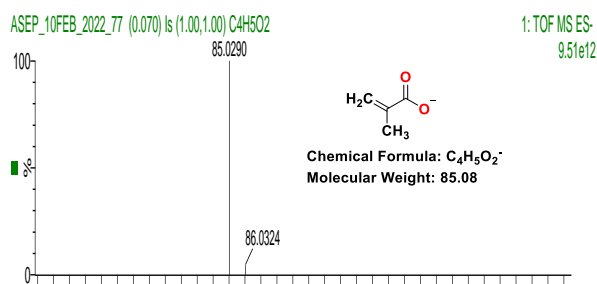
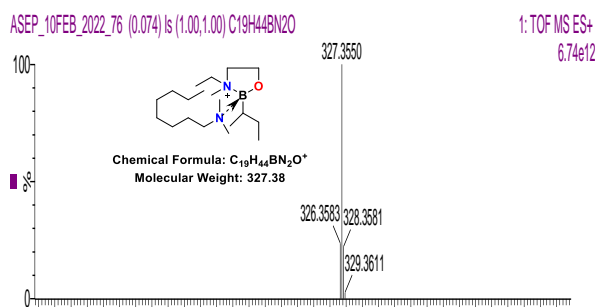


Figure S 56. Mass spectrum of IL-5 [B(C₂mea)(*sec*-butyl)(N₈₁₁)]+[MA].

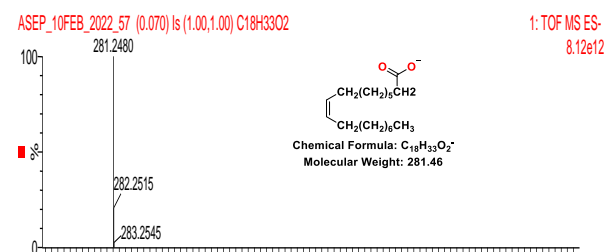
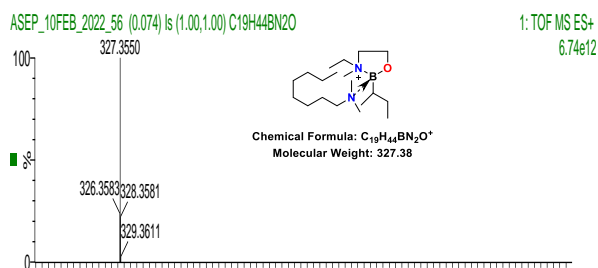


Figure S 57. Mass spectrum of IL-6 [B(C₂mea)(*sec*-butyl)(N₈₁₁)]+[OI].

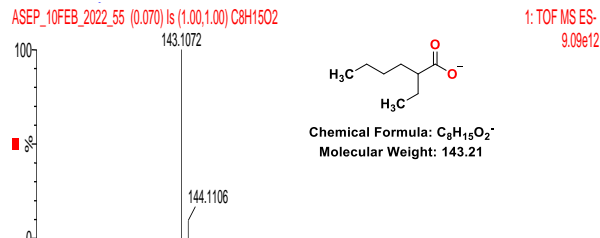
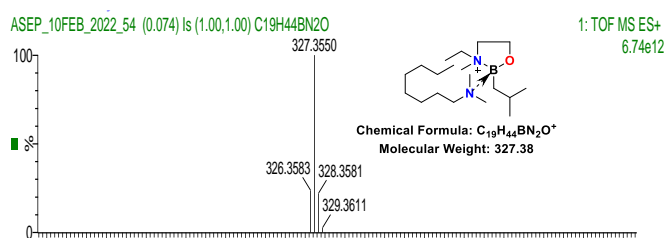


Figure S 58. Mass spectrum of IL-7 [B(C₂mea)(*iso*-butyl)(N₈₁₁)]+[EH].

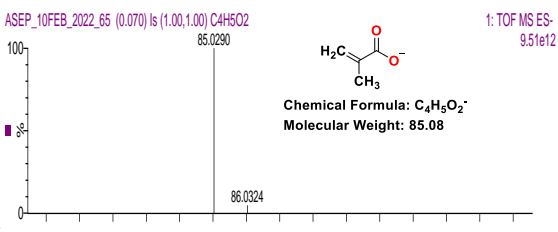
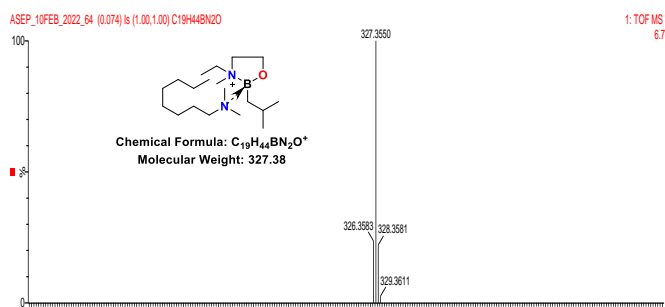


Figure S 59. Mass spectrum of IL-8 [B(C₂mea)(*iso*-butyl)(N₈₁₁)]+[MA].

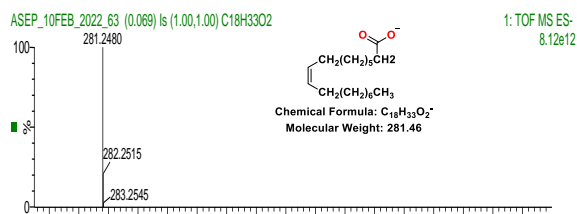
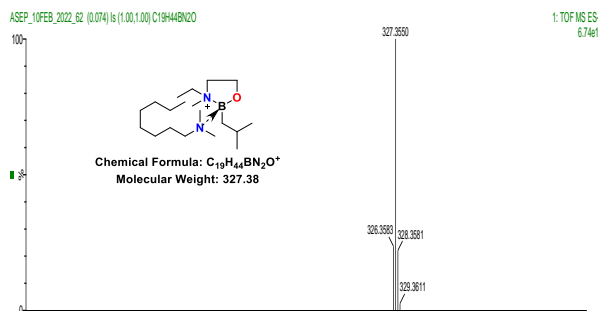


Figure S 60. Mass spectrum of IL-9 [B(C₂mea)(*iso*-butyl) (N₈₁₁)] [OI].

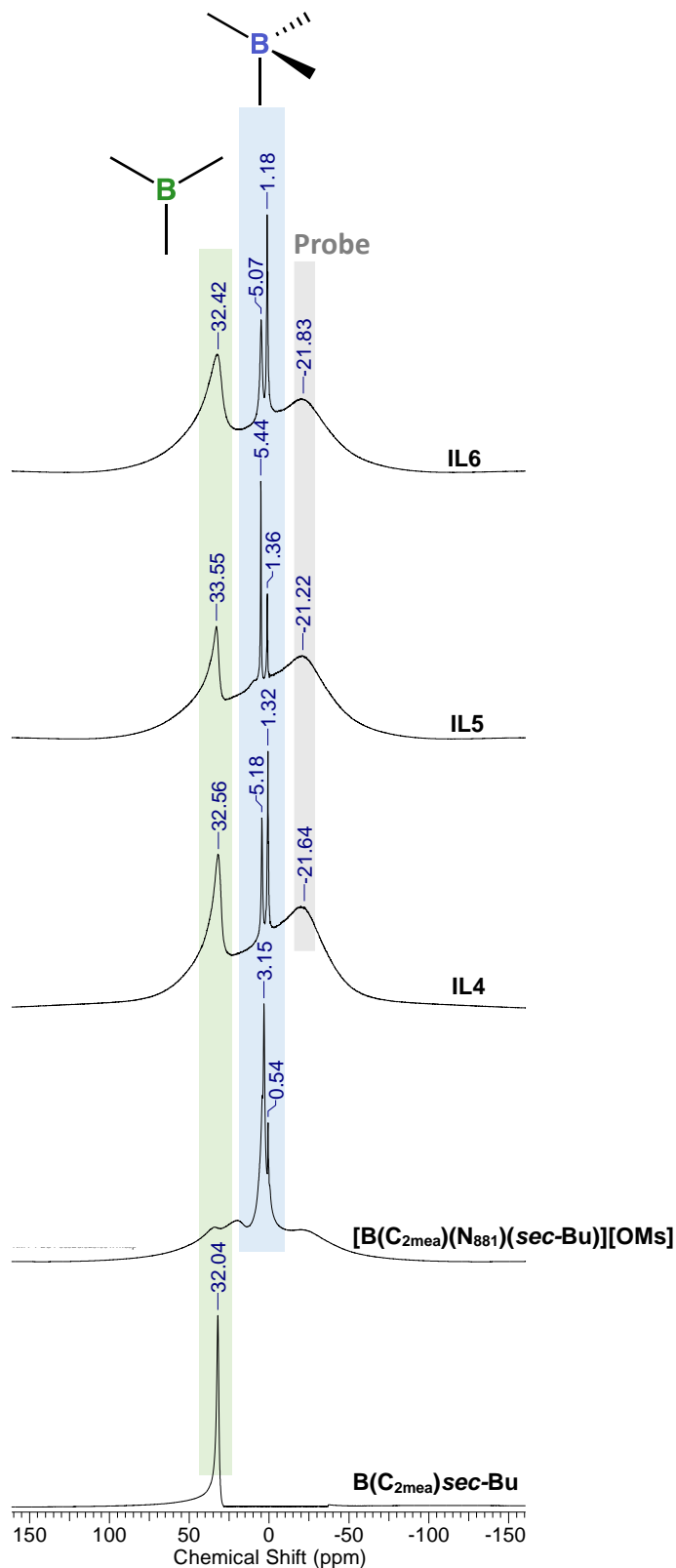


Figure S 61. ¹¹B NMR spectra of B(C₂mea)(*sec*-Bu) and derived ILs: [B(C₂mea)(*sec*-Bu)(N₈₁₁)] [OMs], IL-4, IL-5 and IL-6. Green-shaded area designates the chemical shift regions of tricoordinate boron compounds while blue area designates tetracoordinate species.

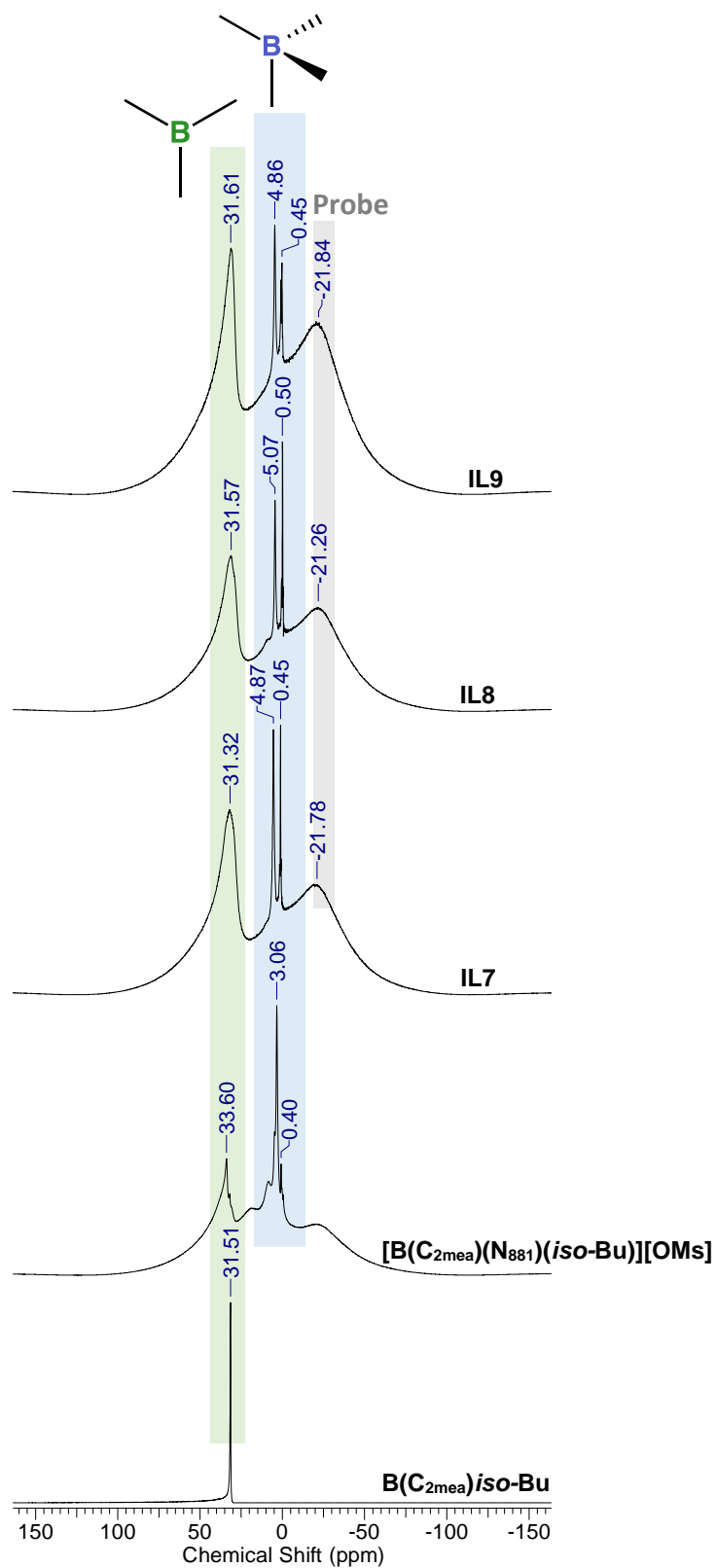


Figure S 62. ^{11}B NMR spectra of $B(C_{2mea})(iso-Bu)$ and derived ILs: $[B(C_{2mea})(iso-Bu)(N_{811})][OMs]$, IL-7, IL-8 and IL-9. Green-shaded area designates the chemical shift regions of tricoordinate boron compounds while blue area designates tetracoordinate species.

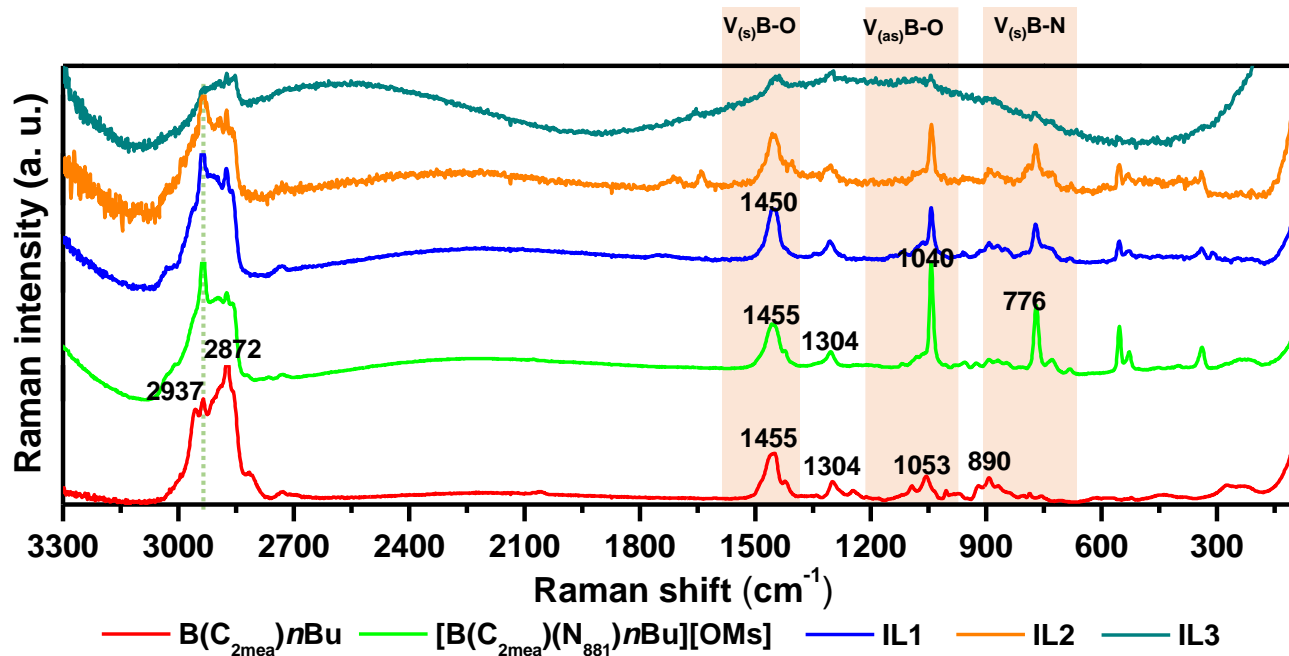


Figure S 63. Raman spectra of $B(C_{2mea})(n-Bu)$ and the derived ILs: $[B(C_{2mea})(n-Bu)(N_{811})][OMs]$, IL-1, IL-2 and IL-3.

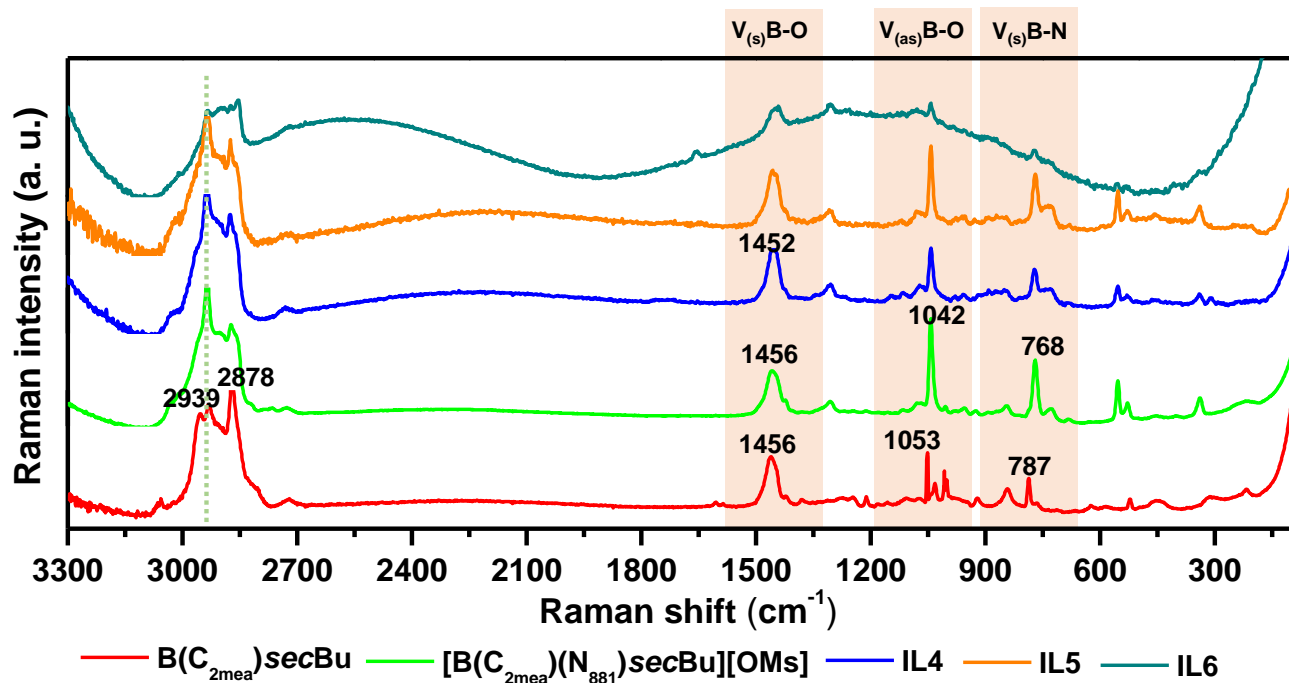


Figure S 64. Raman spectra of $B(C_{2mea})(sec-Bu)$ and the derived ILs: $[B(C_{2mea})(sec-Bu)(N_{811})][OMs]$, IL-4, IL-5 and IL-6.

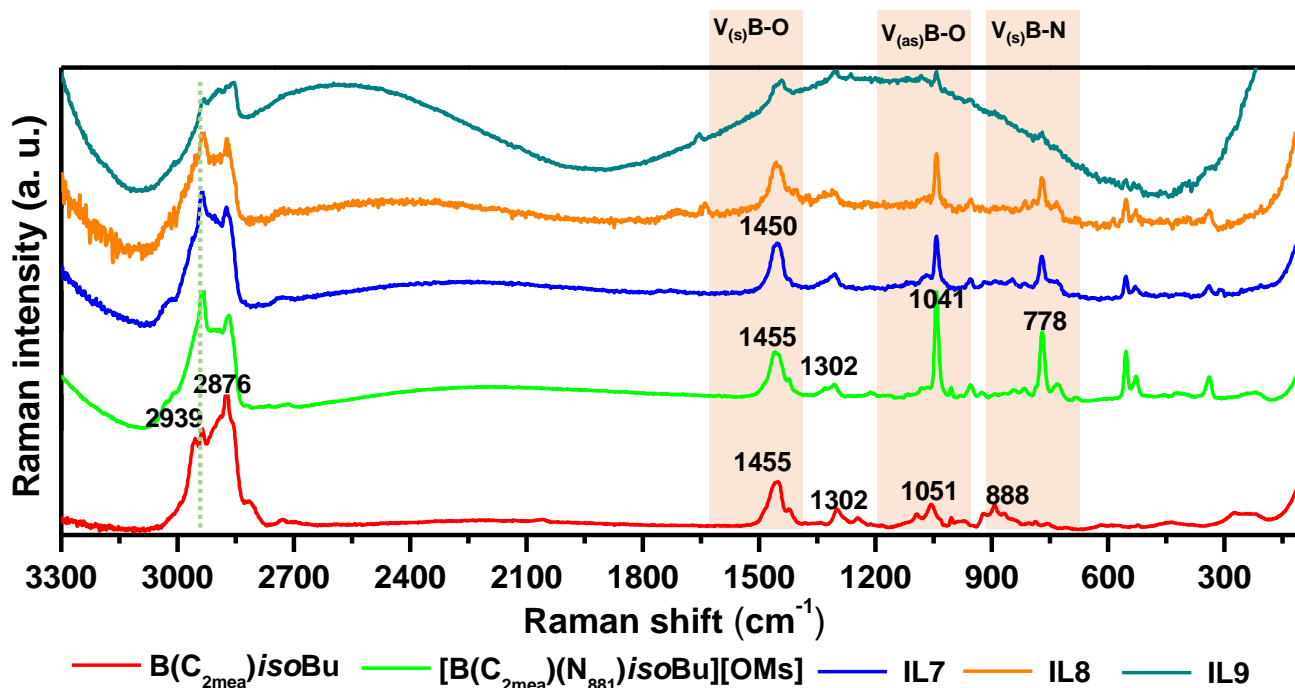


Figure S 65. Raman spectra of $B(C_{2mea})(iso-Bu)$ and the derived ILs: $[B(C_{2mea})(iso-Bu)(N_{811})][OMs]$, IL-7, IL-8 and IL-9.

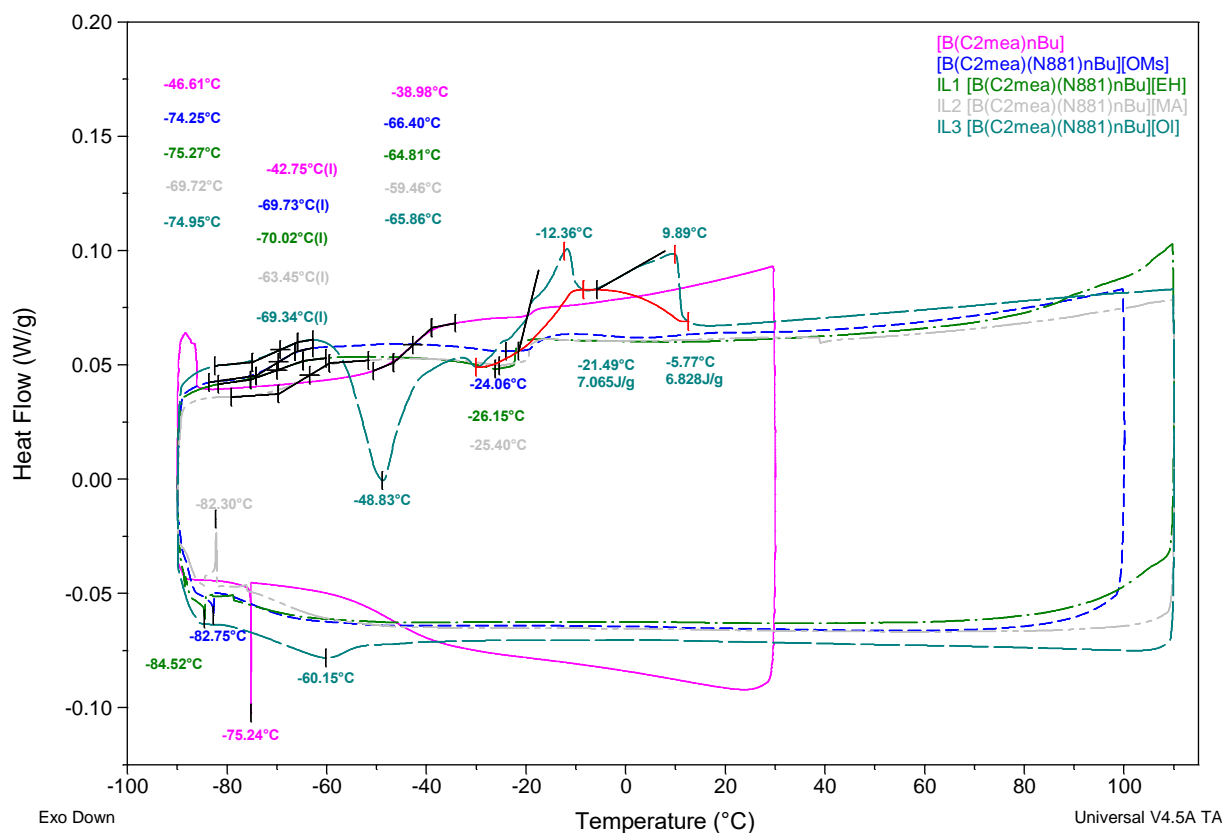


Figure S 66. DSC traces of neat of $B(C_{2mea})nBu$, and the derived ILs: $[B(C_{2mea})(N_{811})nBu][OMs]$, IL1, IL2 and IL3. Temperature scan rate: $2\text{ }^{\circ}\text{C min}^{-1}$. DSC trace from the second thermal cycle.

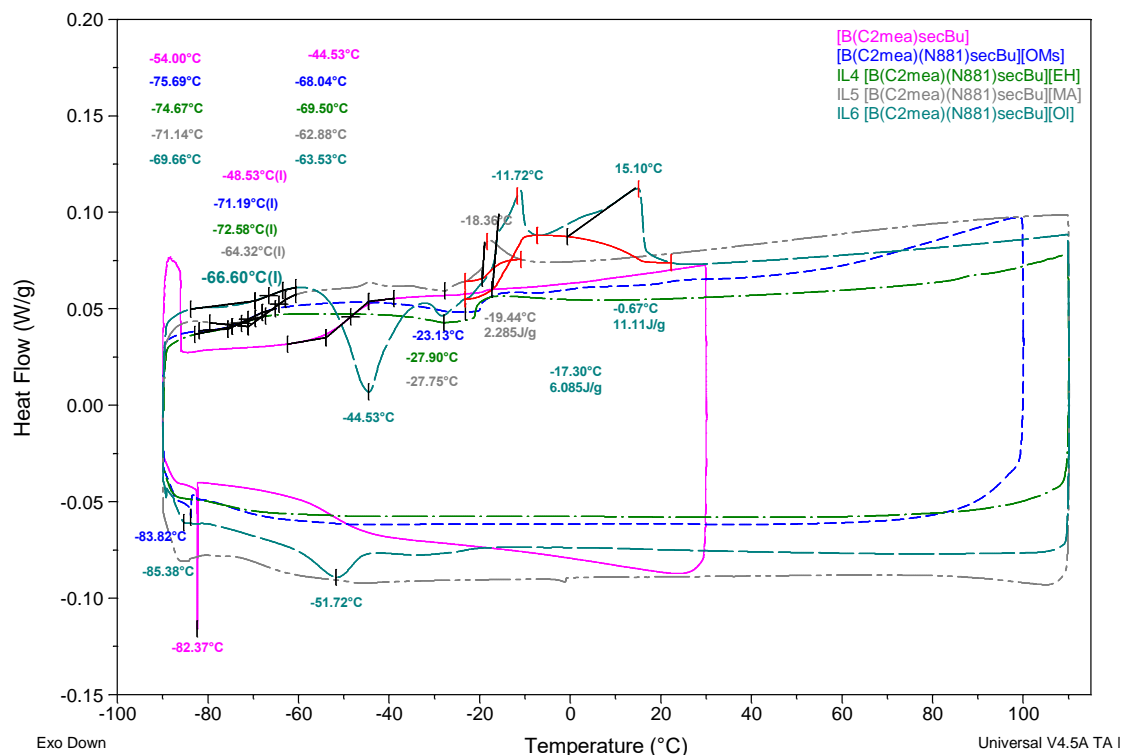


Figure S 67. DSC traces of neat of $B(C_{2mea})secBu$, and the derived ILs: $[B(C_{2mea})(N_{811})secBu][OMs]$, IL4, IL5 and IL6. Temperature scan rate: $2\text{ }^{\circ}C\text{ min}^{-1}$. DSC trace from the second thermal cycle.

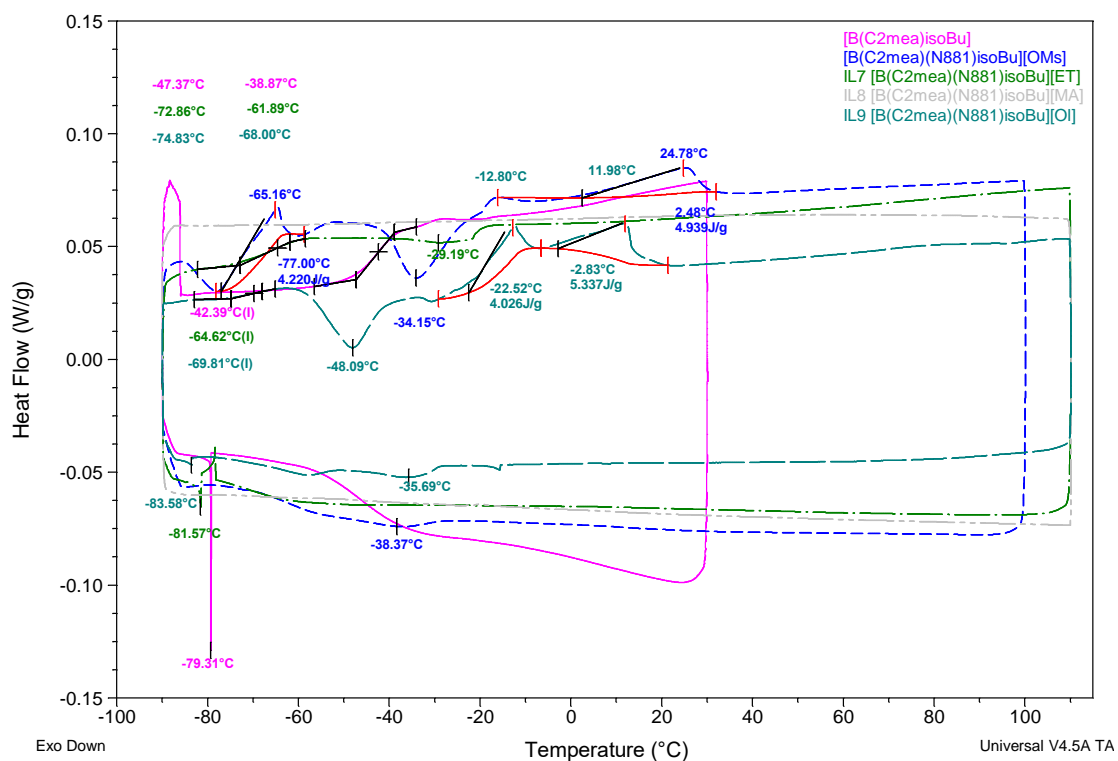


Figure S 68. DSC traces of neat of $B(C_{2mea})isoBu$, and the derived ILs: $[B(C_{2mea})(N_{811})isoBu][OMs]$, IL7, IL8 and IL9. Temperature scan rate: $2\text{ }^{\circ}C\text{ min}^{-1}$. DSC trace from the second thermal cycle.

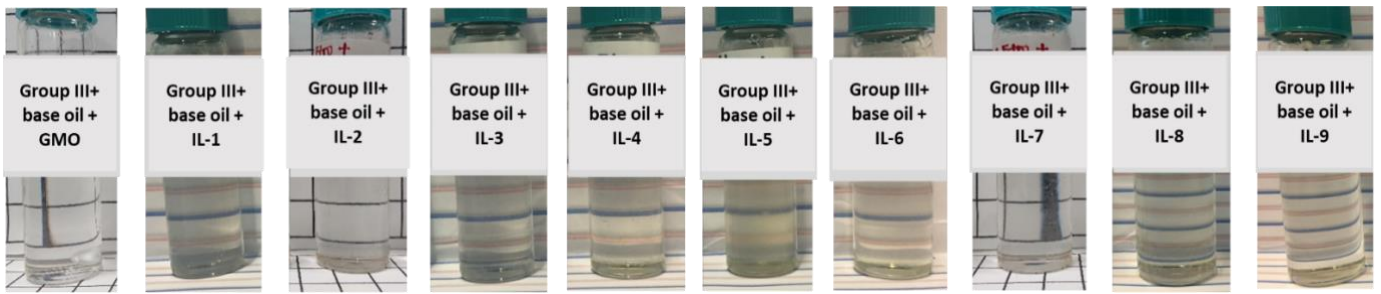
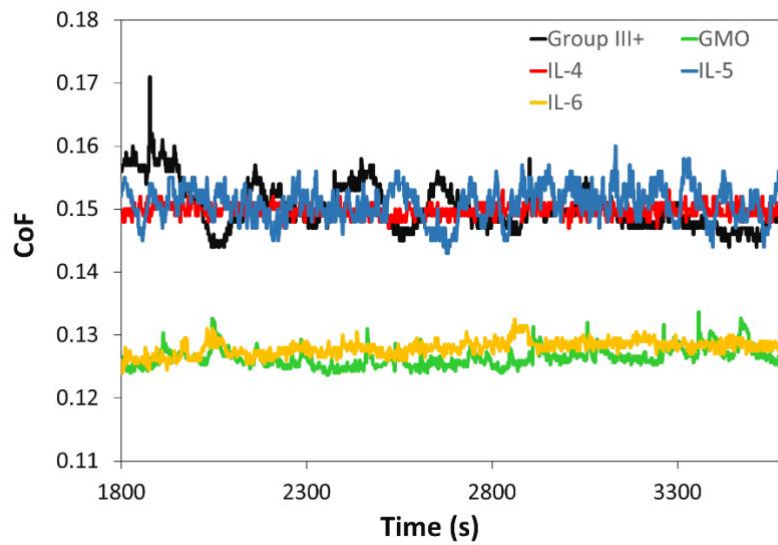
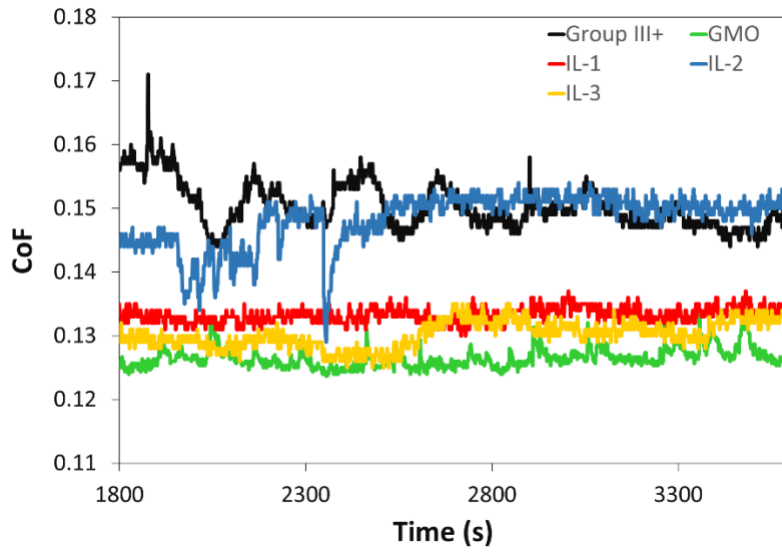


Figure S 69. Photograph of 9 boronium ILs in Group III+ base oil.



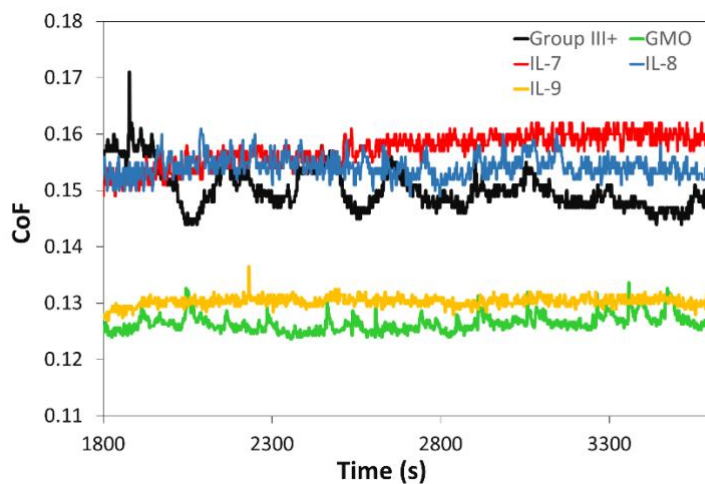


Figure S 70. Friction coefficient profile of Group III+ base oil and mixtures containing GMO and nine new boronium ILs at 1800 s test time and above

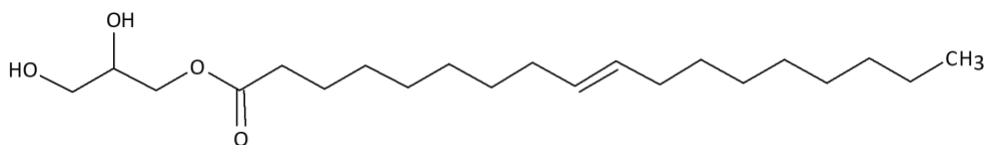


Figure S 71. Chemical structure of glycerol monooleate (GMO), a common type of friction modifier.

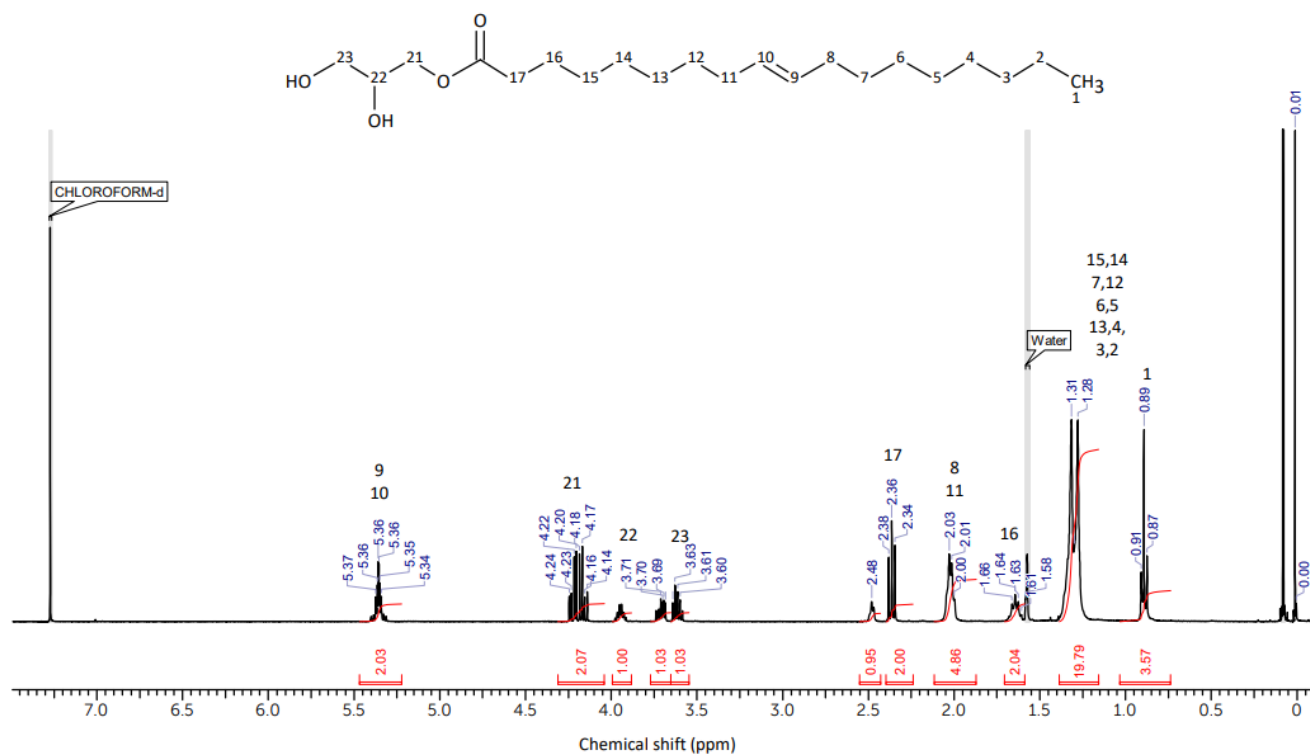


Figure S 72. ¹H NMR (400 MHz) spectrum of glycerol monooleate (GMO).

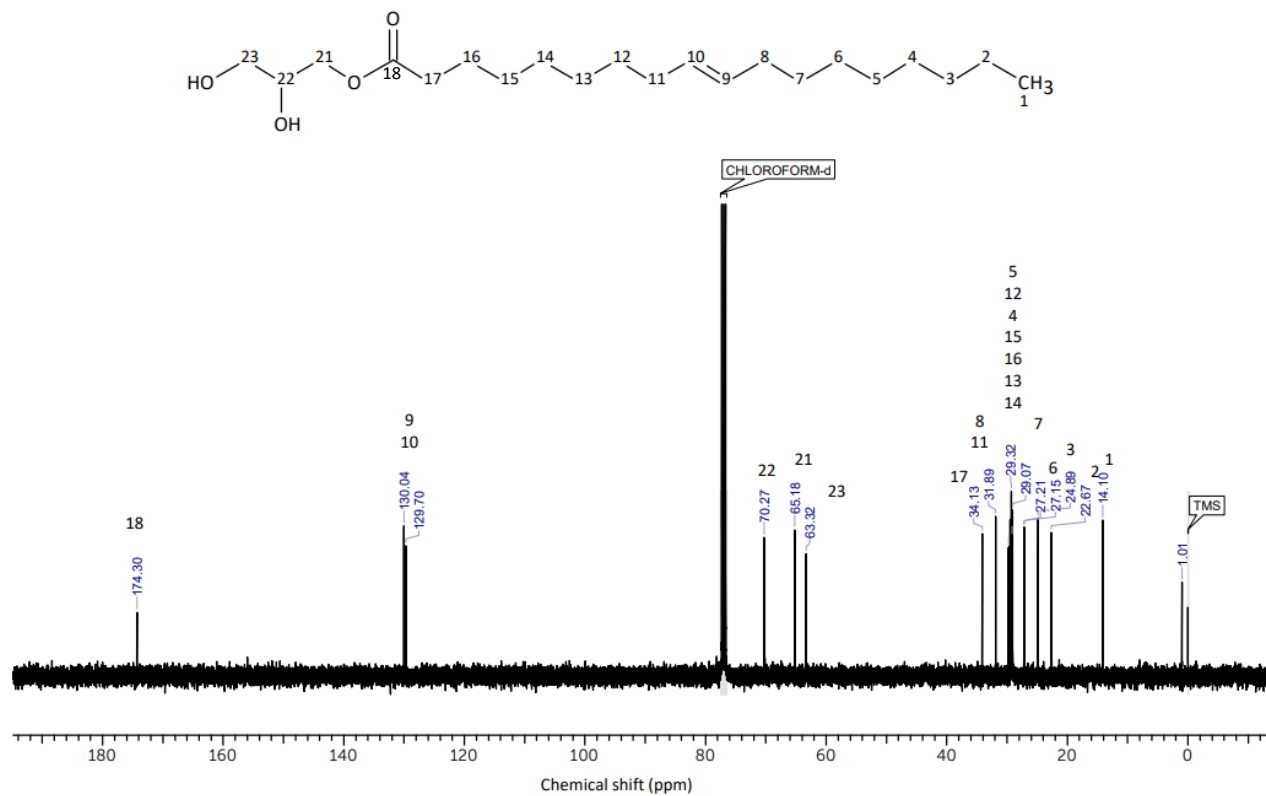


Figure S 73. ¹³C NMR spectrum of glycerol monooleate (GMO).