

Supplementary Information

Urea derivatives are highly active catalysts for the base-mediated generation of terminal epoxides from aldehydes and trimethylsulfonium iodide

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1.0 General

Proton Nuclear Magnetic Resonance spectra were recorded on either a 400 MHz or 600 MHz spectrometer in CDCl₃ referenced relative to residual CHCl₃ ($\delta = 7.26$ ppm). Chemical shifts are reported in ppm and coupling constants in Hertz. Carbon NMR spectra were recorded on the same instrument (100 MHz) with total proton decoupling. Flash chromatography was carried out using silica gel, particle size 0.04-0.063 mm. TLC analysis was performed on precoated 60F₂₅₄ slides, and visualised by either UV irradiation or KMnO₄ staining. Methylene chloride and triethylamine were distilled from calcium hydride. Unless otherwise stated, all chemicals were obtained from commercial sources and used as received. Unless otherwise specified, all reactions were carried out with magnetic stirrers under an atmosphere of argon. The reactions detailed in Table 1 were carried out under stringently consistent conditions – a Radley's discovery Technologies 12-station carousel reactor (No. RR98030) in conjunction with a heater-stirrer (No. RR98072, stirring setting 4) was used which provided uniform stirring in each reaction 24 x 150 mm vessels. Each reaction vessel was fitted with a cross-shaped stirring bar measuring 16.5 mm across. Catalyst **20** was prepared according to a literature procedure.¹ All epoxide products were purified by column chromatography on silica gel with the exception of **33** and **34**, which rapidly decompose under these conditions. These can be purified (also with significant decomposition) by Kugel-Rohr distillation.

2.0 Catalysis of the epoxidation of **10** (Table 1): General procedure



Note: These reactions must be carried out under rigorously identical conditions (flask- and stirring bar size, stirring rate and temperature) to achieve reproducible results.

The carousel flasks (*vide supra*) containing a magnetic stirring bar was placed on the carousel. Trimethylsulfonium iodide (165.7 mg, 0.81 mmol) was then added to each flask. 50% NaOH/H₂O solution (1.77 cm³, 44.3 mmol) was then added *via* syringe and the resulting suspension was allowed to stir for 10 min. (*E*)-Stilbene (66.5 mg, 0.37 mmol) and catalyst (0.037 mmol) were then added and the flask was fitted with a

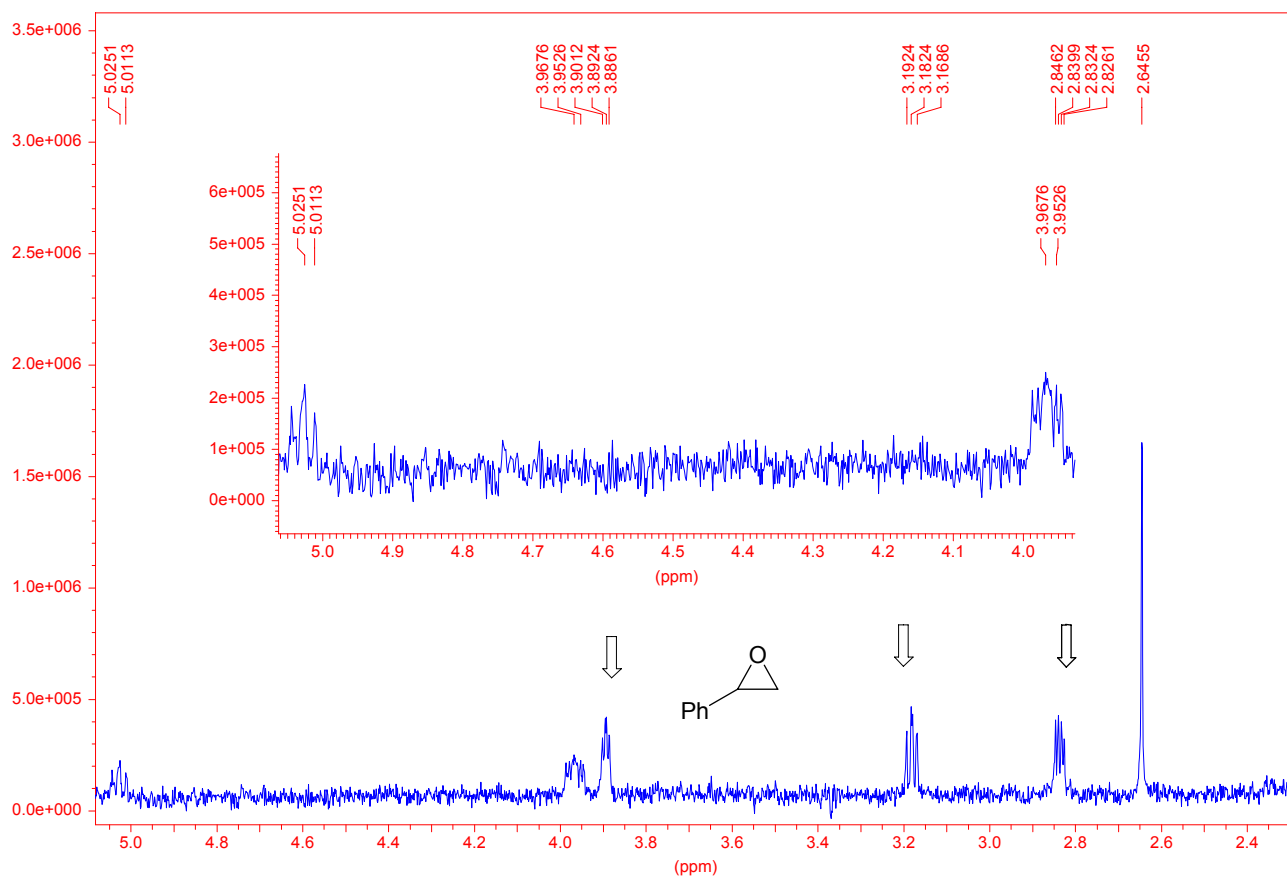
cap and placed under an atmosphere of argon (balloon). CH_2Cl_2 (2.175 cm^3) and freshly distilled aldehyde (0.74 mmol) were then added sequentially *via* syringe and the reaction stirred at ambient temperature for 24 h. The spectra characteristics of the pure epoxides **12** and **30-36** were consistent with those in the literature.²

Synthesis of **38**

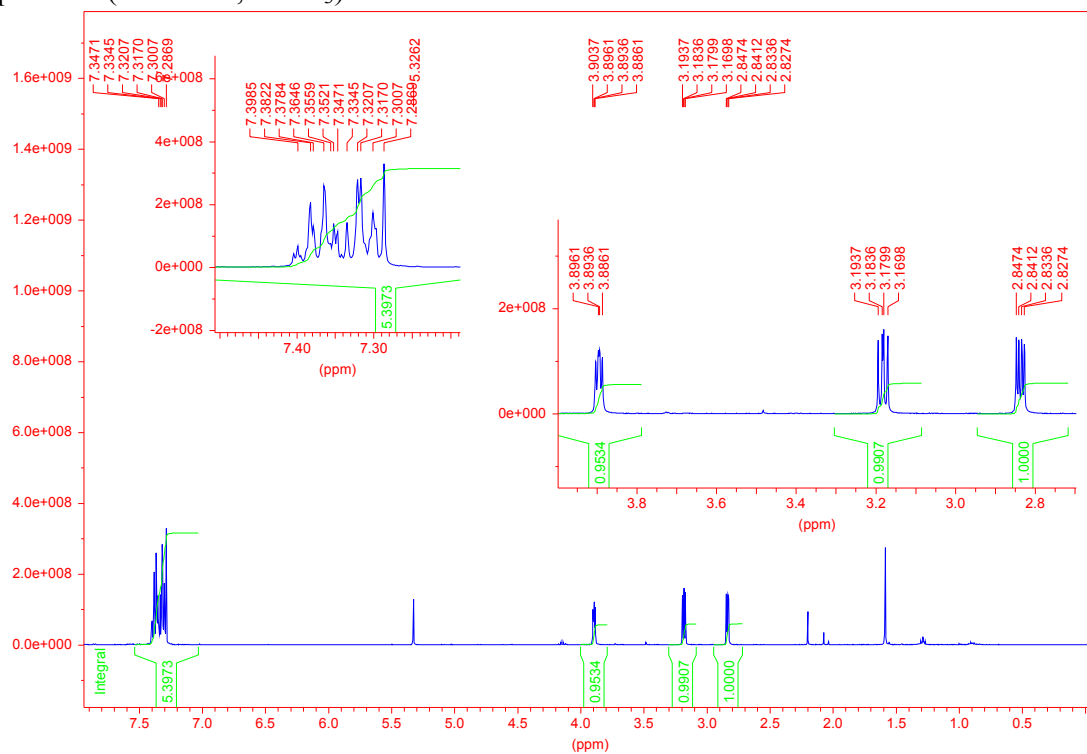
The synthesis of epoxide **32** was performed exactly detailed above on 3.70 mmol scale with 11 cm^3 of CH_2Cl_2 as solvent. When the reaction was complete (analysis by ^1H NMR spectroscopy) the mixture was diluted with water (20 cm^3) and transferred to a separating funnel. As the molarity of the organic phase of the subsequent reaction is 0.095 M the work up was done so that the final organic phase volume was 39 cm^3 . The aqueous phase was extracted with CH_2Cl_2 ($3 \times 8 \text{ cm}^3$), leaving 4 cm^3 for washings. The combined organic extracts were then washed with water ($2 \times 30 \text{ cm}^3$) and brine ($1 \times 30 \text{ cm}^3$). The organic phase was then dried (MgSO_4) and the solution filtered. An oven dried 50 ml round bottomed flask containing a stirring bar and molecular sieves (4 \AA) was fitted with a septum and placed under argon. Using an oven dried glass syringe, the filtrate was then transferred to the flask. The catalyst, copper tetrafluoroborate hydrate (218.8 mg , 0.923 mmol , 0.25 eq.) was then added to the reaction flask and the resulting mixture stirred for 21 h at ambient temperature. The reaction mixture was diluted with CH_2Cl_2 (50 cm^3) and filtered to remove the molecular sieves. The organic phase was then washed with water ($3 \times 50 \text{ cm}^3$) and brine ($3 \times 50 \text{ cm}^3$). The organic phase was then dried (MgSO_4), filtered and the solvent was removed *in vacuo*. The product was purified by column chromatography ($60:40$ hexane: CH_2Cl_2) to yield **38** as a colourless oil (307 mg , 69%) with spectral characteristics consistent with those in the literature.³

3.0 NMR spectra

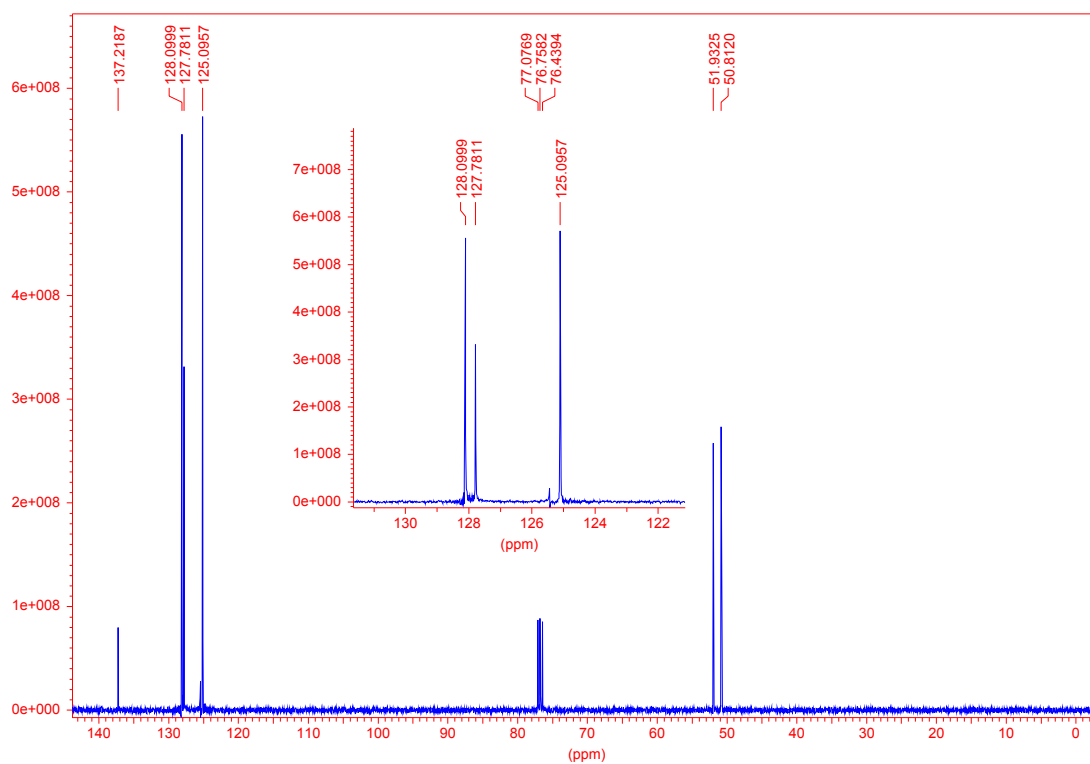
^1H NMR spectrum (400 MHz, CDCl_3) of the reaction mixture (identical conditions to those detailed in Section 2.0) showing the presence of an intermediate which is converted to **12** over time. The resonances associated with **12** are highlighted.



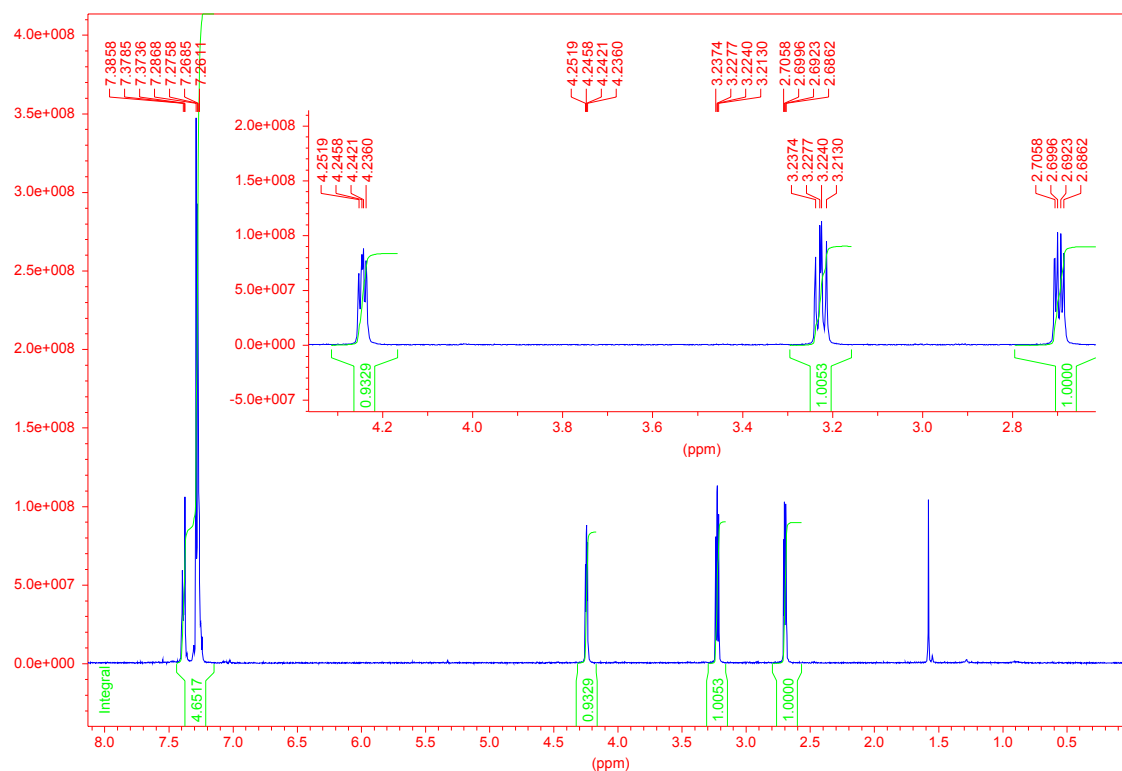
^1H NMR spectrum (400 MHz, CDCl_3) of **12**



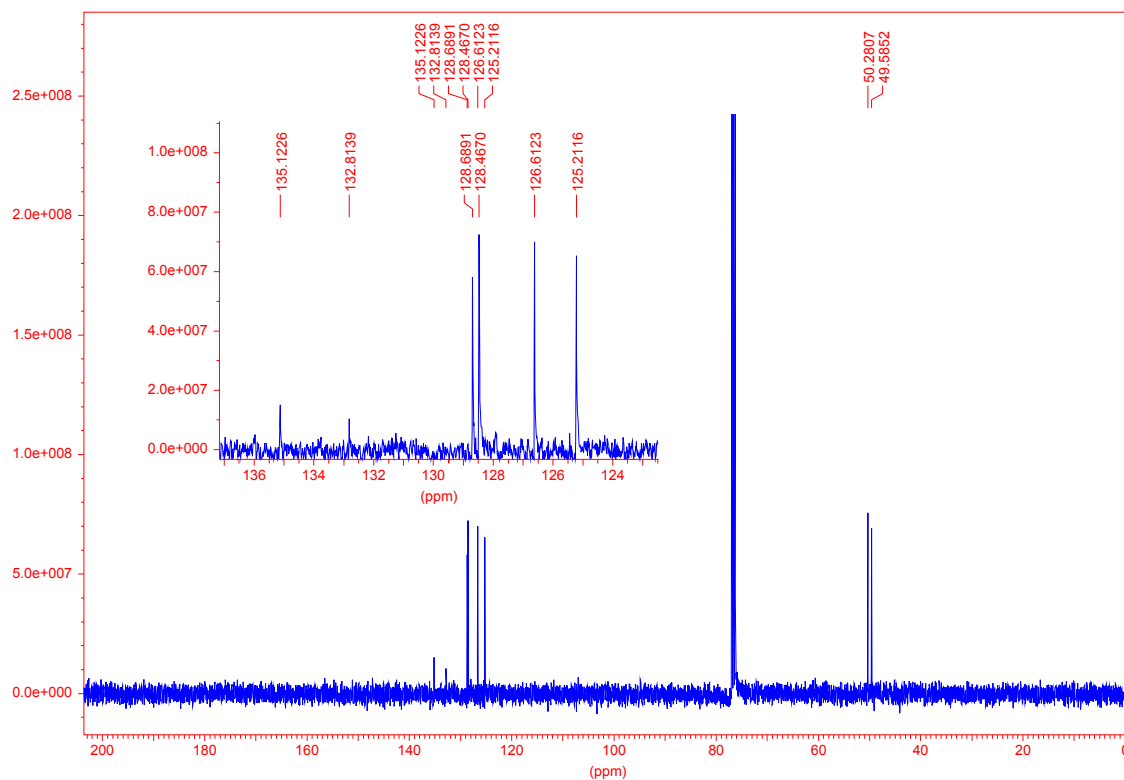
^{13}C NMR spectrum (100 MHz, CDCl_3) of **12**



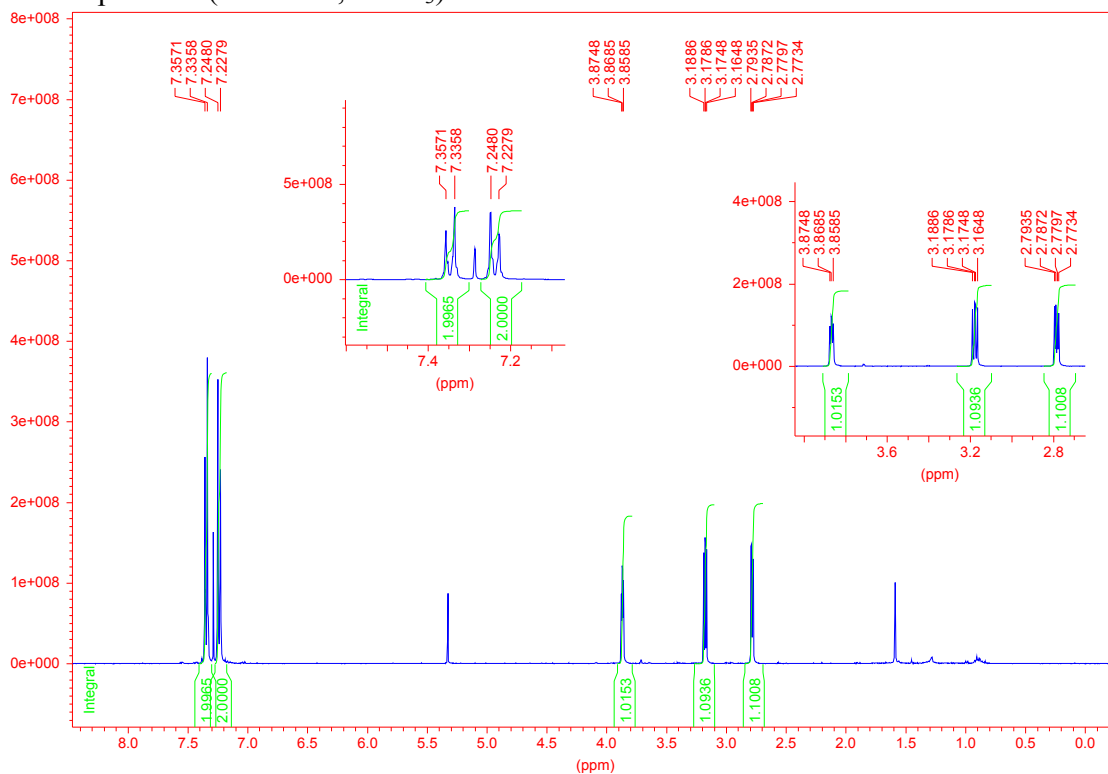
^1H NMR spectrum (400 MHz, CDCl_3) of **30**



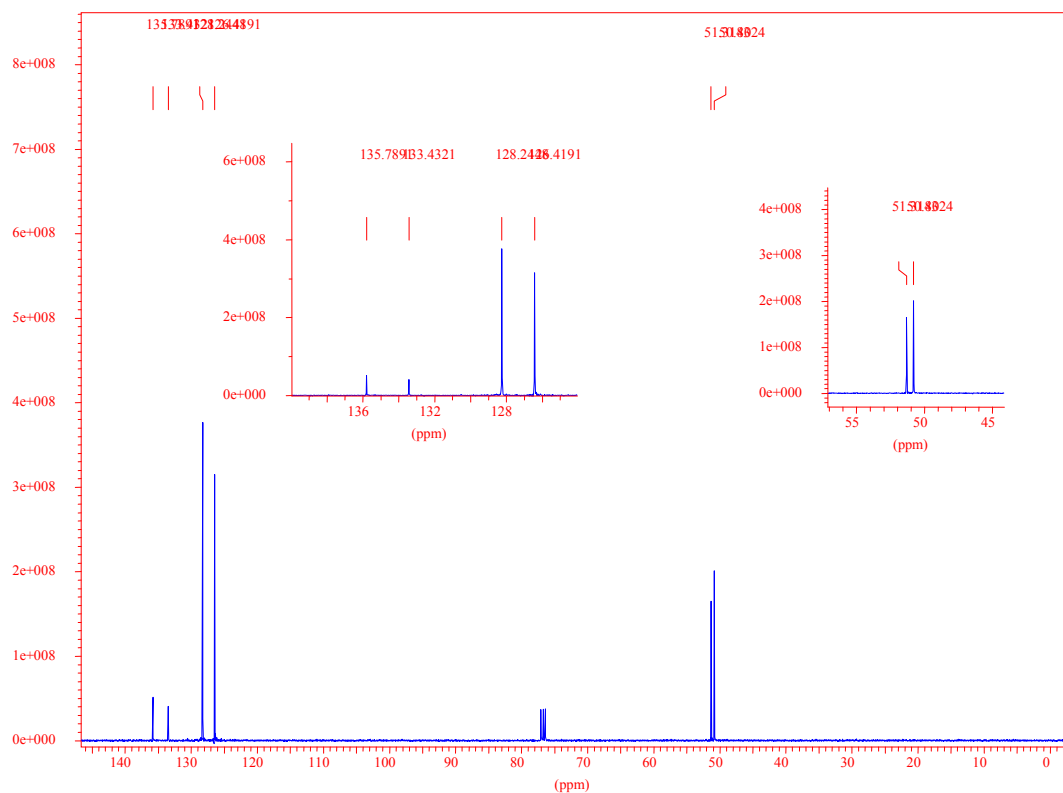
^{13}C NMR spectrum (100 MHz, CDCl_3) of **30**



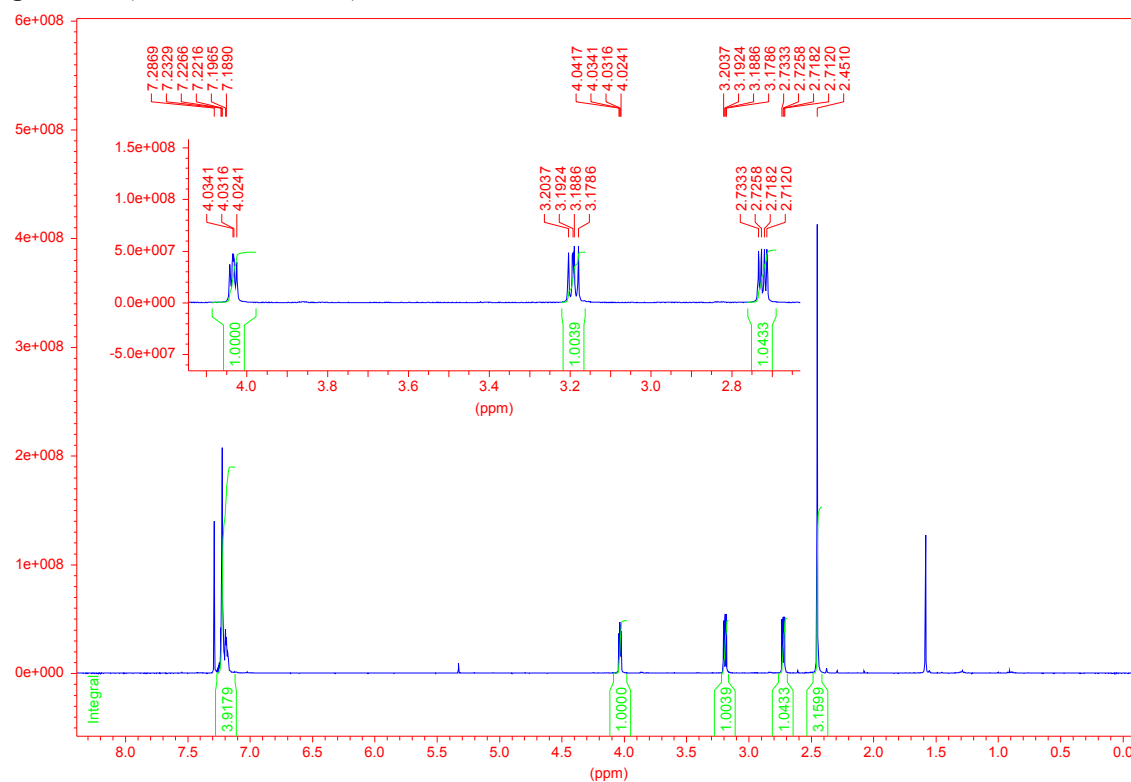
^1H NMR spectrum (400 MHz, CDCl_3) of **31**



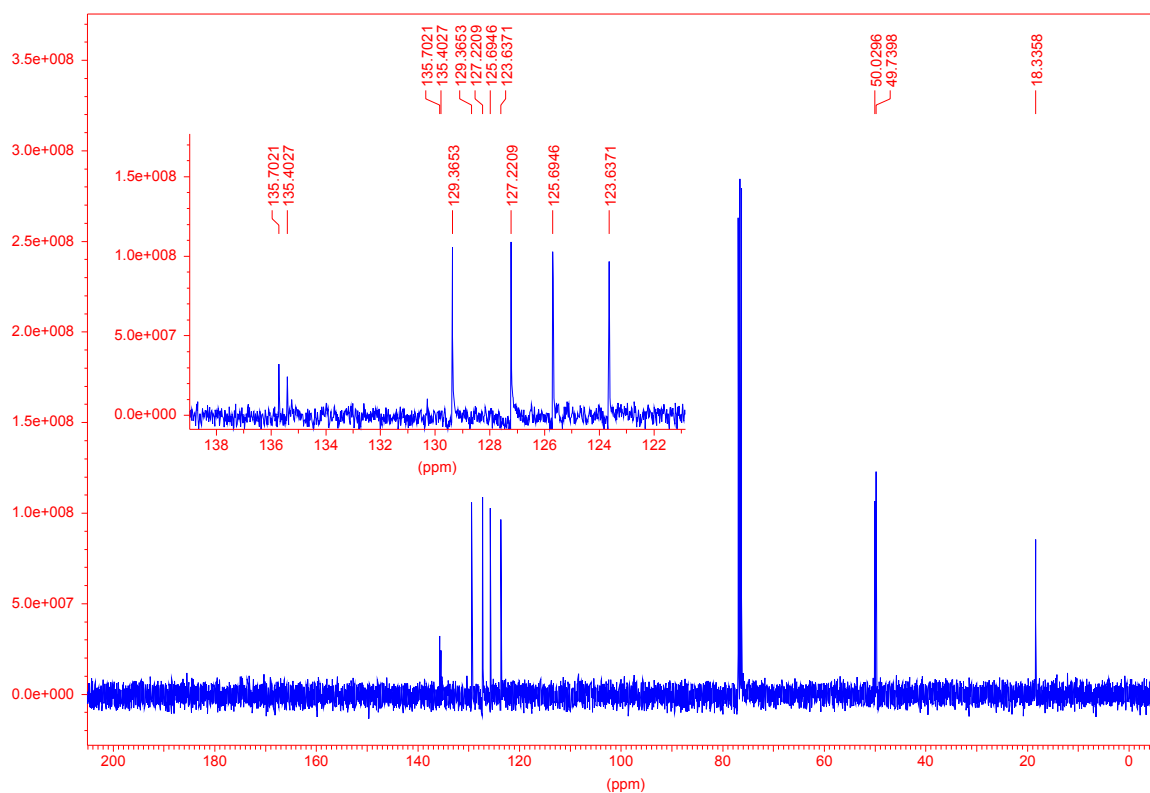
^{13}C NMR spectrum (100 MHz, CDCl_3) of **31**



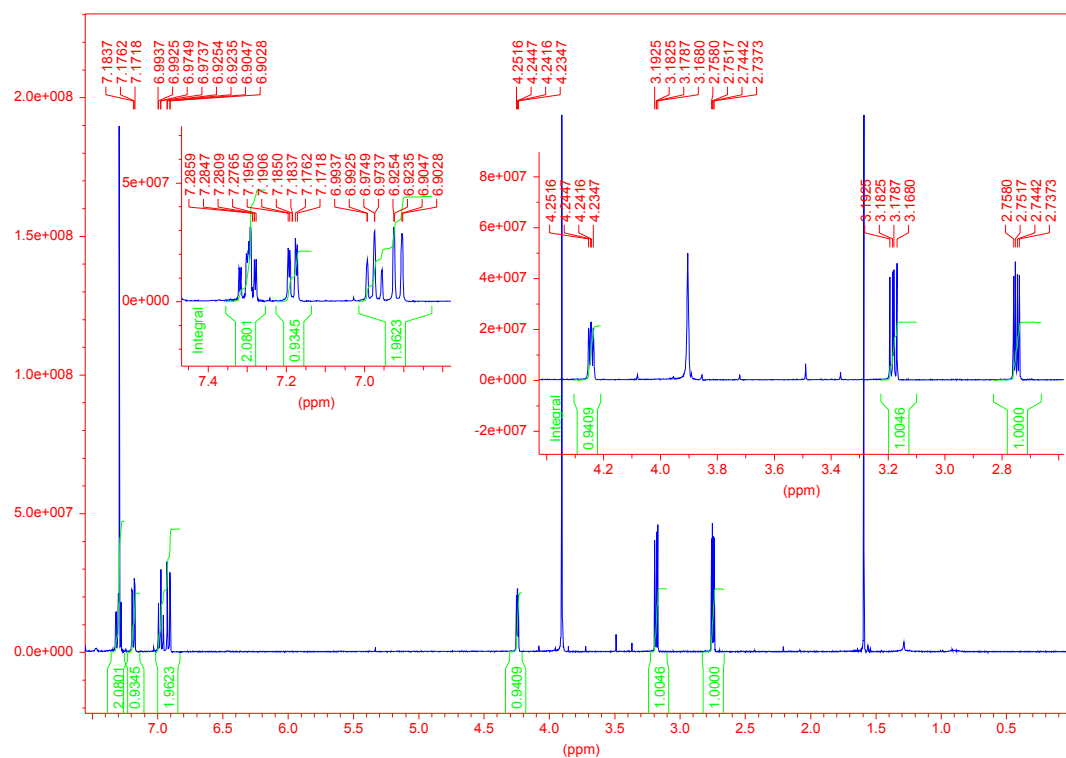
^1H NMR spectrum (400 MHz, CDCl_3) of **32**



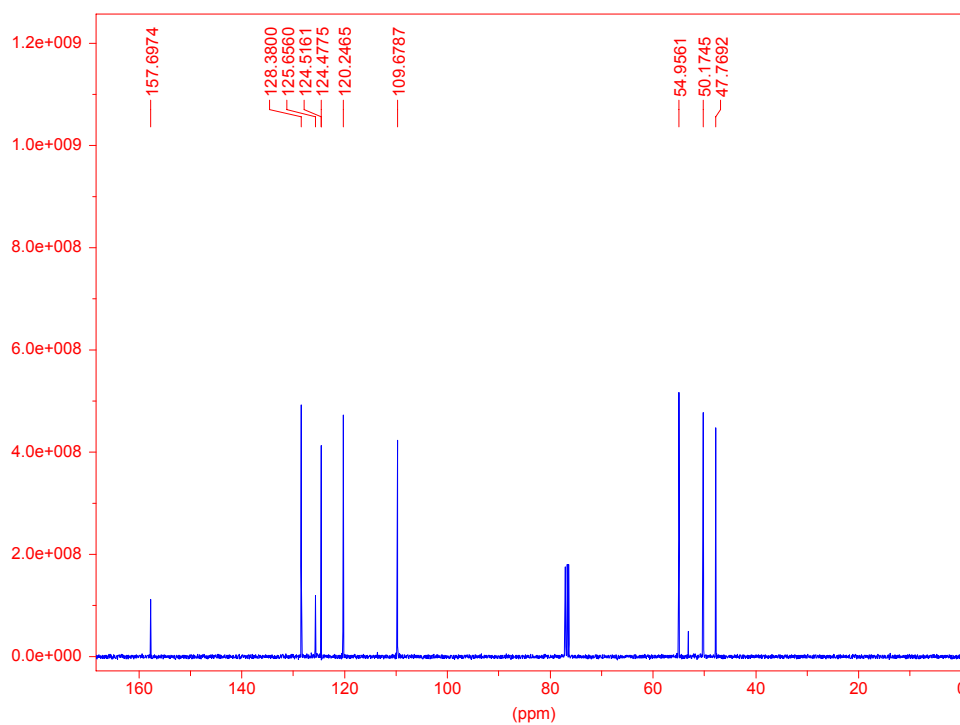
^{13}C NMR spectrum (100 MHz, CDCl_3) of **32**



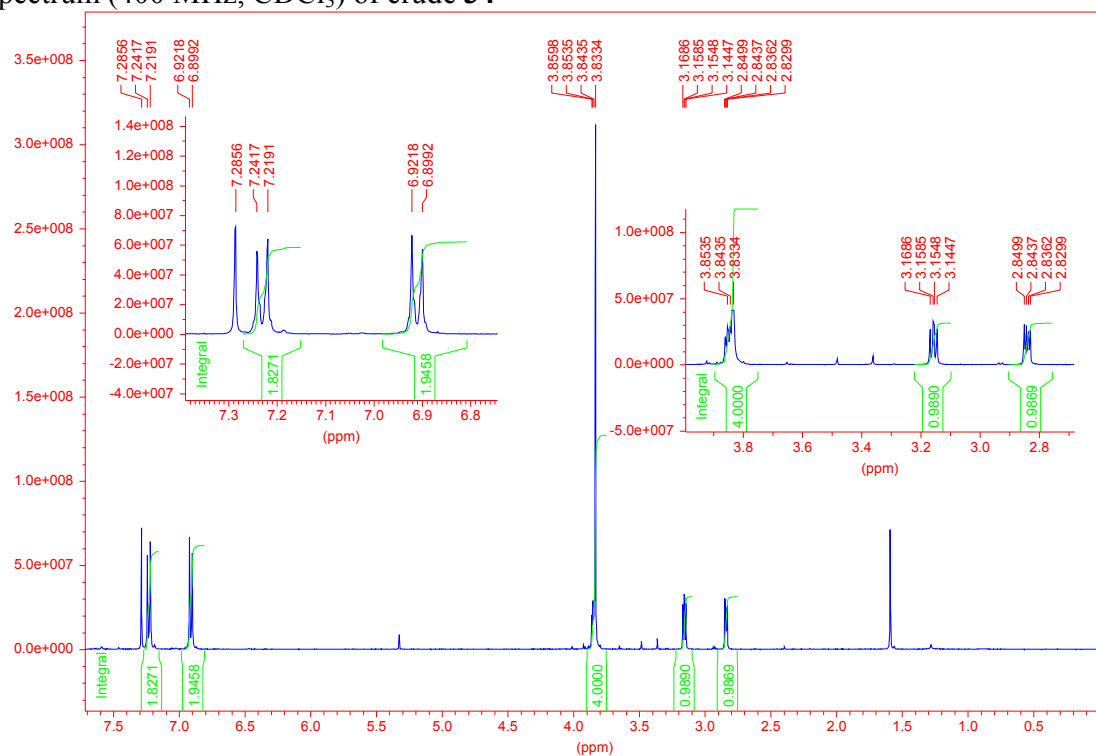
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¹H NMR spectrum (400 MHz, CDCl₃) of crude **33**



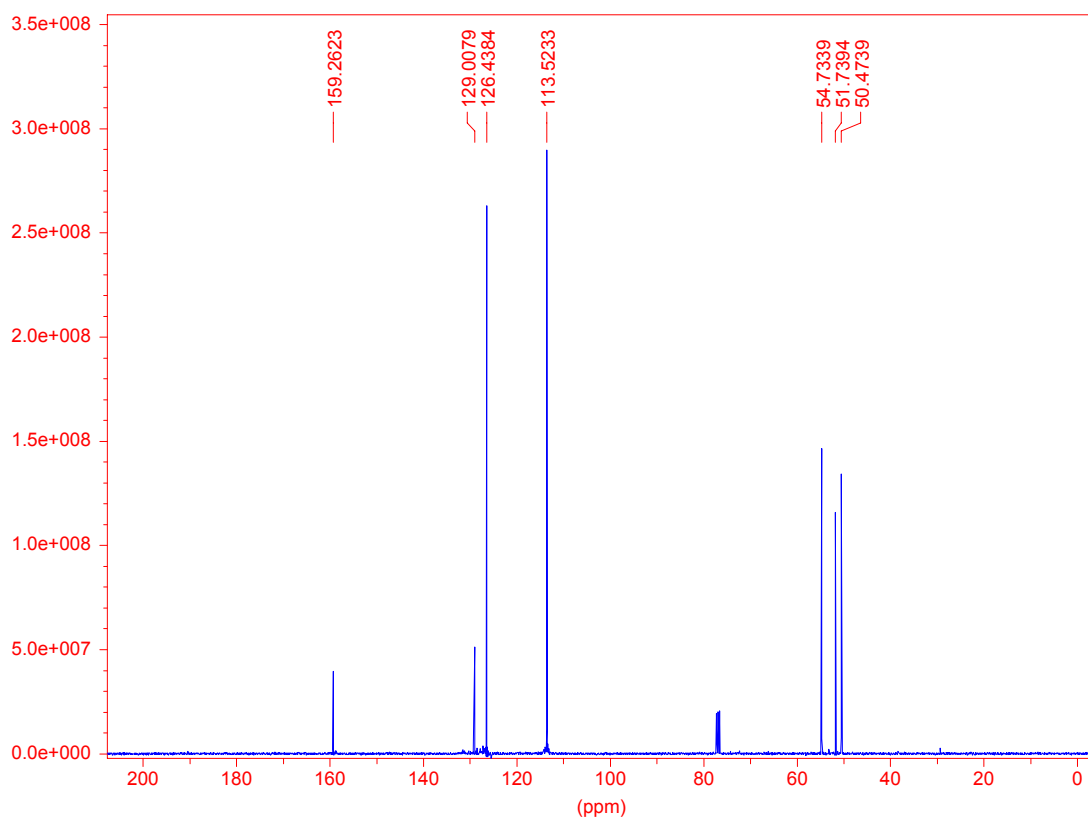
¹³C NMR spectrum (100 MHz, CDCl₃) of crude **33**



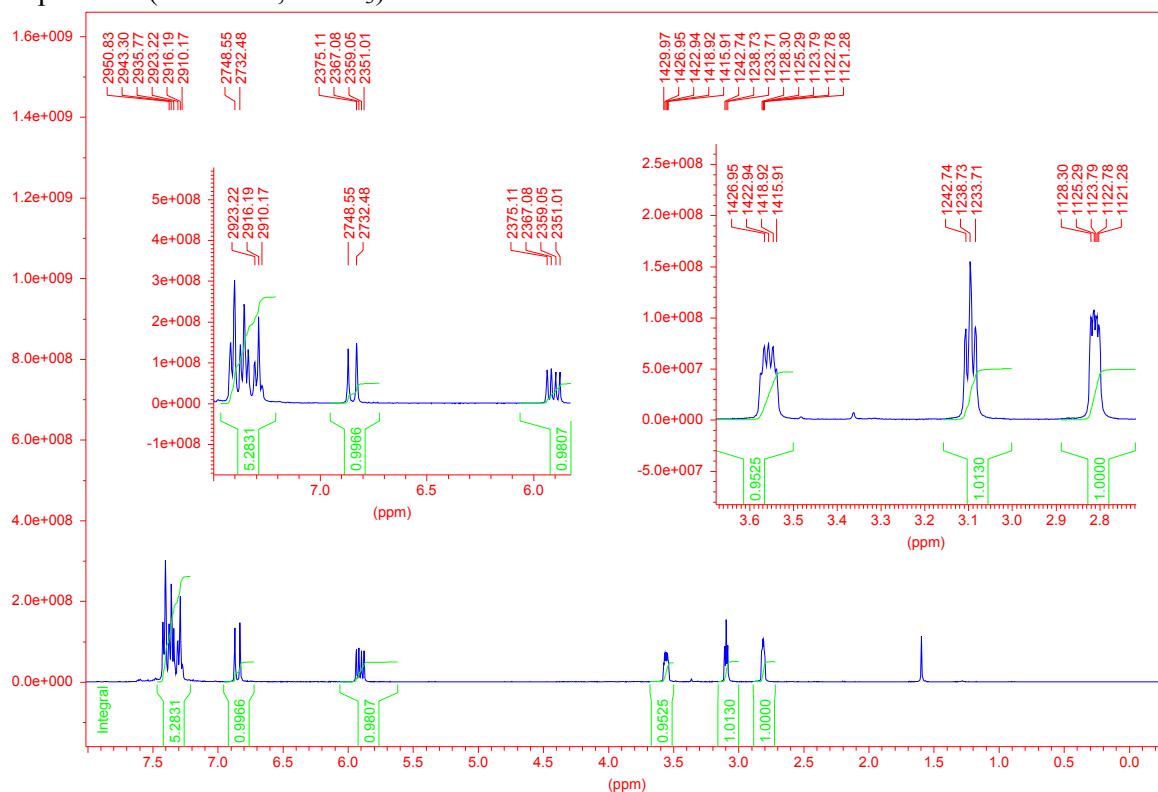
^1H NMR spectrum (400 MHz, CDCl_3) of crude **34**



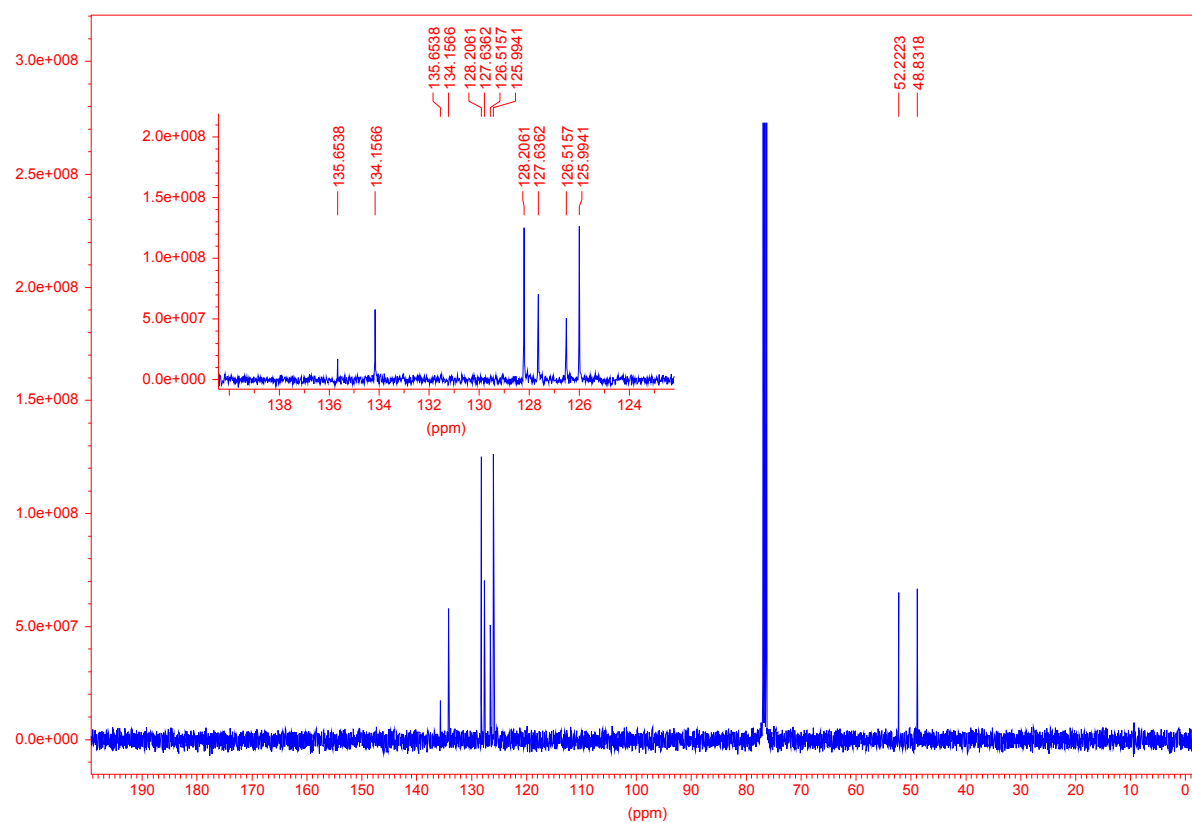
^{13}C NMR spectrum (100 MHz, CDCl_3) of crude **34**



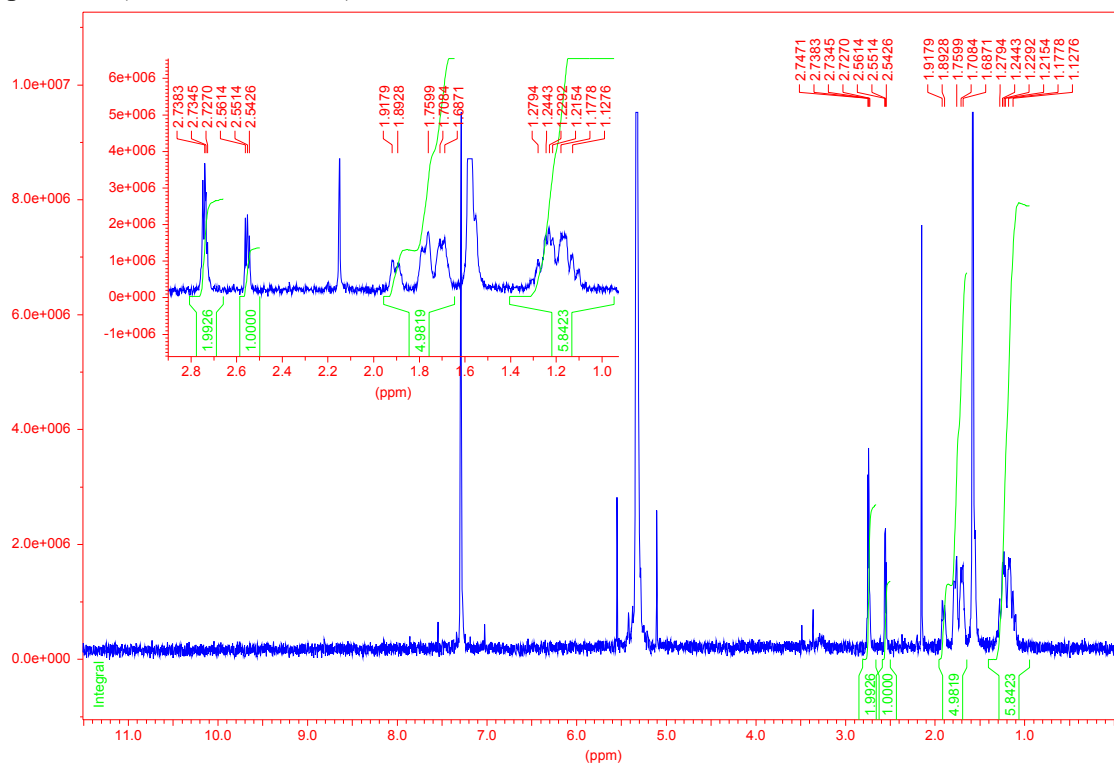
^1H NMR spectrum (400 MHz, CDCl_3) of **35**



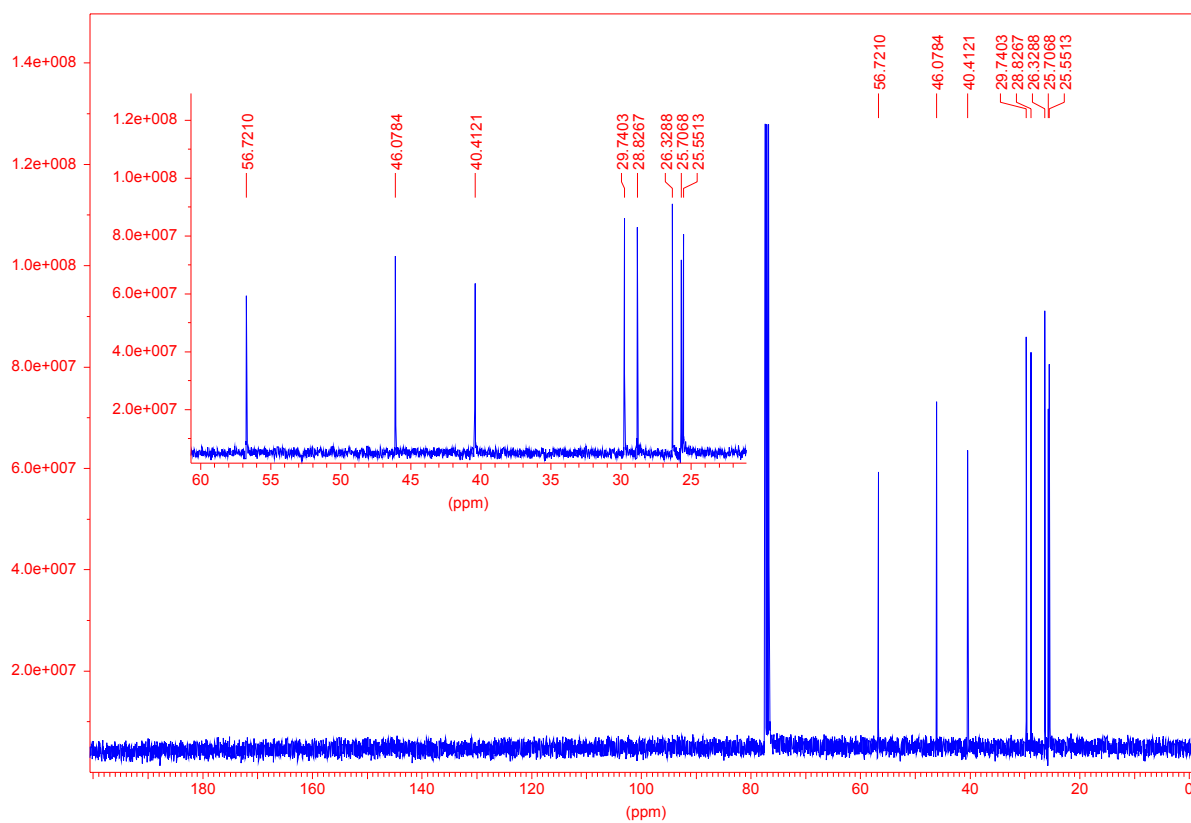
^{13}C NMR spectrum (100 MHz, CDCl_3) of **35**



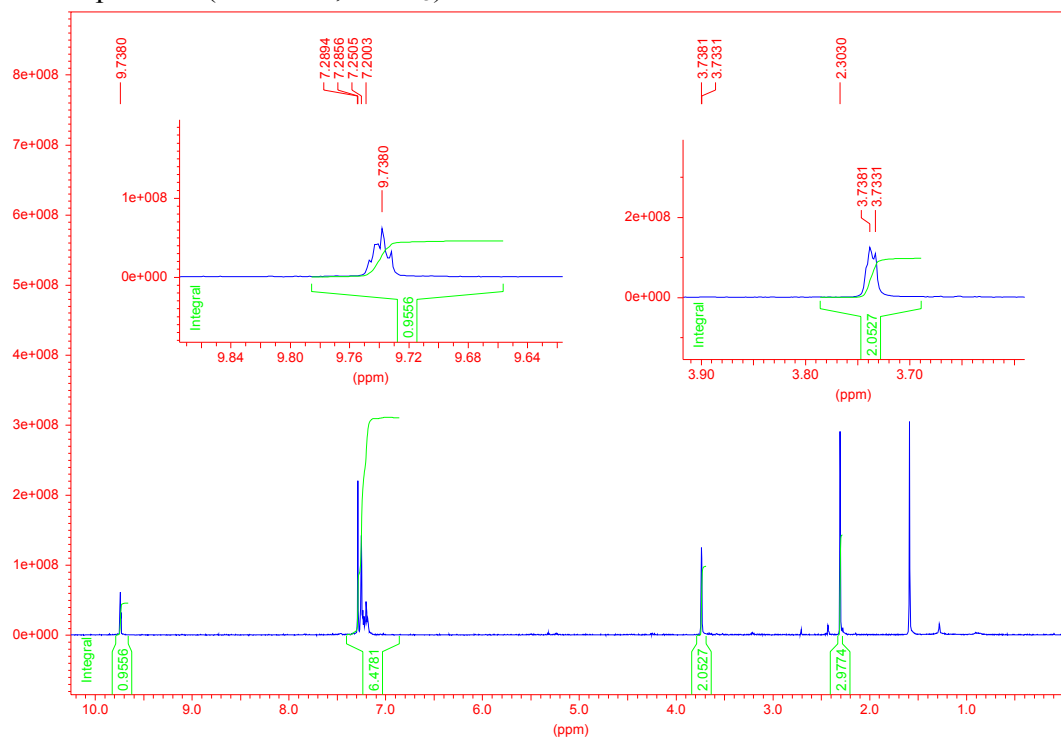
^1H NMR spectrum (400 MHz, CDCl_3) of crude **36**



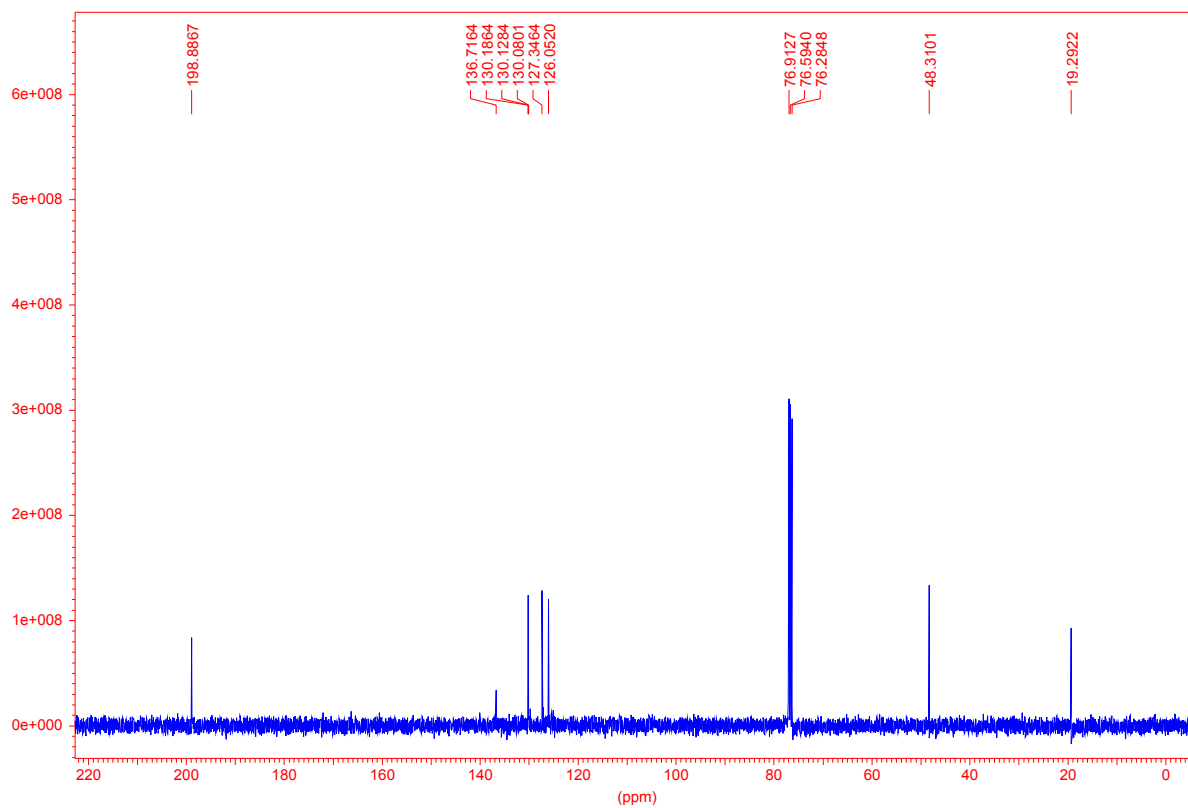
^{13}C NMR spectrum (100 MHz, CDCl_3) of **36**



^1H NMR spectrum (400 MHz, CDCl_3) of **38**



^{13}C NMR spectrum (100 MHz, CDCl_3) of **38**



5.0 References

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 2. (a) Compound **12**: Y. Kurosaki, T. Fukuda and M. Iwao, *Tetrahedron*, 2005, **61**, 3289; (b) Compound **30**: J. H. Lutje Spelberg, R. Rink, R. M. Kellogg and D. B. Jansen, *Tetrahedron: Asymmetry*, 1998, **9**, 459; (c) Compound **31**: W. Xu, J. -H. Xu, J. Pan, Q. Gu and X. -Y. Wu, *Org. Lett.*, 2006, **8**, 1737; (d) Compound **32**: W. Krimse and K. Kund, *J. Am. Chem. Soc.*, 1989, **111**, 1465; (e) Compounds **33** and **34**: Y. Tsuchiya, T. Kumamoto and T. Ishikawa, *J. Org. Chem.*, 2004; **69**, 8504; (f) Compound **35**: M. Lautens, M. L. Maddess, E. L. O. Sauer and S. G. Oullet, *Org. Lett.*, 2002, **4**, 83; (g) Compound **36**: M. C. White, A. G. Doyle and E. N. Jacobsen, *J. Am. Chem. Soc.*, 2001, **123**, 7194.
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