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Oxidative Cyclization of Amino Alcohols: Comparing Gold Nanocluster Photocatalysis with Electrochemical Oxygen Activation Authors

Tribani Boruah, Elizaveta Borisova, Alice Strukelj, Rebecca L Melen, Sota Sekiya, Katsuhiro Isozaki, Masaharu Nakamura, Thomas Wirth.

Affiliations below.

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Abstract:

Oxazolidines are valuable five-membered heterocycles with broad applications in medicinal and synthetic chemistry. Herein, we investigate sustainable oxidative cyclization of amino alcohols using molecular oxygen, comparing gold nanocluster photocatalysis with electrochemical activation. Peptide dendron-functionalized gold nanoclusters promoted the cyclization of amino alcohols to oxazolidines in good yield, consistent with an oxygen-mediated pathway involving singlet oxygen and iminium formation. In contrast, electrochemical activation of oxygen under a range of electrode, solvent, electrolyte, current, and flow conditions failed to produce the desired cyclized products and instead resulted predominantly in oxidative degradation to benzaldehyde. Cyclic voltammetry indicated that overoxidation of the amino alcohol may account for the observed degradation. These results demonstrate that the mode of oxygen activation is critical for controlling selectivity in oxidative amino alcohol cyclization and highlight the potential of gold nanocluster photocatalysis as a sustainable approach to oxazolidine synthesis.

Corresponding Author:

Prof. Thomas Wirth, Cardiff University, School of Chemistry, Cardiff, United Kingdom of Great Britain and Northern Ireland, wirth@cf.ac.uk

Contributors' Statement: Tribani Boruah: Data curation, Formal analysis, Investigation, Writing - review & editing. Elizaveta Borisova: Investigation. Alice Strukelj: Investigation. Rebecca L. Melen: Funding acquisition. Sota Sekiya: Investigation. Katsuhiro Isozaki: Conceptualization, Data curation, Investigation, Project administration, Writing - original draft, Writing - review & editing. Masaharu Nakamura: Conceptualization, Data curation, Funding acquisition, Investigation, Project administration, Writing - original draft, Writing - review & editing. Thomas Wirth: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Project administration, Supervision, Writing - original draft, Writing - review & editing.

Affiliations:

Tribani Boruah, Cardiff University, School of Chemistry, Cardiff, United Kingdom of Great Britain and Northern Ireland

Tribani Boruah, Cardiff University, 2 School of Chemistry, Cardiff Catalysis Institute, Cardiff, United Kingdom of Great Britain and Northern Ireland

Elizaveta Borisova, Cardiff University, School of Chemistry, Cardiff, United Kingdom of Great Britain and Northern Ireland

[...]

Thomas Wirth, Cardiff University, School of Chemistry, Cardiff, United Kingdom of Great Britain and Northern Ireland



Oxidative Cyclization of Amino Alcohols: Comparing Gold Nanocluster Photocatalysis with Electrochemical Oxygen Activation



Authors

Tribani Boruah ^{1,2}, Elizaveta Borisova ¹, Alice Strukelj ¹, Rebecca L. Melen ², Sota Sekiya ³, Katsuhiro Isozaki ^{3,*}, Masaharu Nakamura ^{3,*}, Thomas Wirth ^{1,*}

Affiliations

- 1 School of Chemistry, Cardiff University, Park Place, Main Building, Cardiff CF10 3AT, Cymru/Wales, UK.
- 2 School of Chemistry, Cardiff Catalysis Institute, Cardiff University, Translational Research Hub, Maindy Road, Cardiff CF24 4HQ, Cymru/Wales, UK.
- 3 Institute for Chemical Research, Kyoto University, Kyoto 611-0011, Japan; Graduate School of Engineering, Kyoto University, Kyoto 615-8510, Japan.

SIGNIFICANCE

This work compares two sustainable approaches for the oxidative cyclization of amino alcohols to oxazolidines using molecular oxygen: gold nanocluster photocatalysis and electrochemical activation. Gold nanoclusters enabled selective oxazolidine formation, while electrochemical conditions predominantly caused oxidative degradation. The results highlight how the mode of oxygen activation governs reaction selectivity and provide insights for developing more sustainable routes to valuable heterocyclic compounds.

Keywords

Amino alcohols, cyclization, gold nanoclusters, singlet oxygen

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Correspondence Katsuhiro Isozaki, Masaharu Nakamura, Thomas Wirth

kisozaki@scl.kyoto-u.ac.uk;

masaharu@scl.kyoto-u.ac.jp;

wirth@cf.ac.uk



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ABSTRACT

Oxazolidines are valuable five-membered heterocycles with broad applications in medicinal and synthetic chemistry. Herein, we investigate sustainable oxidative cyclization of amino alcohols using molecular oxygen, comparing gold nanocluster photocatalysis with electrochemical activation. Peptide dendron-functionalized gold nanoclusters promoted the cyclization of amino alcohols to oxazolidines in good yield, consistent with an oxygen-mediated

pathway involving singlet oxygen and iminium formation. In contrast, electrochemical activation of oxygen under a range of electrode, solvent, electrolyte, current, and flow conditions failed to produce the desired cyclized products and instead resulted predominantly in oxidative degradation to benzaldehyde. Cyclic voltammetry indicated that overoxidation of the amino alcohol may account for the observed degradation. These results demonstrate that the mode of oxygen activation is critical for controlling selectivity in oxidative amino alcohol cyclization and highlight the potential of gold nanocluster photocatalysis as a sustainable approach to oxazolidine synthesis.



Introduction

Oxazolidines as five-membered *N,O*-heterocycles have attracted large interest in organic and medicinal chemistry because of their structural diversity and utility as synthetic intermediates, building blocks, and biologically relevant scaffolds.^{1,2} A variety of approaches have been developed for their preparation, with the condensation and cyclization of 1,2-amino alcohols with aldehydes or ketones representing one of the most established strategies. More recent methodologies have sought to improve the efficiency and sustainability of oxazolidine synthesis through catalytic, oxidative, and multicomponent processes. In this context, amino alcohols are particularly attractive precursors because they already contain the nitrogen and oxygen functionalities required for the ring formation. The development of catalytic methods that minimize stoichiometric reagents, hazardous solvents, and waste is therefore of continuing interest in the synthesis of these valuable heterocycles.

Photocatalysis and electrochemistry have emerged as complementary approaches for achieving more sustainable organic transformations. In particular, visible-light photocatalysis can provide mild reaction conditions and enable oxygen-mediated oxidation processes, while metal nanoclusters have attracted increasing attention because of their distinctive electronic and photophysical properties.³ Gold nanoclusters functionalized with peptide dendron ligands have been reported to catalyze the photocatalytic oxidation of amino alcohols to oxazolidines, with the ligand environment contributing to substrate recognition and reaction acceleration.⁴ Mechanistic studies have implicated singlet oxygen and iminium-type intermediates in this transformation, illustrating the potential of nanocluster photocatalysts for selective heterocycle synthesis. Electrochemistry provides a complementary means of controlling oxidation reactions through direct electron transfer and can eliminate the need for conventional stoichiometric oxidants. Recent studies have demonstrated electrochemical transformations of amino alcohols to related *N,O*-heterocycles, highlighting the potential of electricity as a clean and tunable redox reagent.⁵

In this work, we investigate sustainable approaches to the synthesis of oxazolidines through cyclization of amino alcohol precursors, focusing on two complementary activation strategies: photocatalysis using gold nanoclusters and electrochemical oxidation involving molecular oxygen. These approaches are compared with respect to reaction conditions, substrate scope,

efficiency, and the role of the oxidation process in promoting heterocycle formation. This study aims to contribute to the development of more sustainable methodologies for the preparation of oxazolidine scaffolds and to demonstrate the potential of light-driven nanocatalysis and electrochemical synthesis as potential alternatives to conventional reagent-intensive approaches.

Results and Discussion

Conventionally, singlet oxygen is generated photochemically from triplet oxygen in the presence of a photosensitizer. This principle has been investigated by the Nakamura group using different gold clusters and resulted in the discovery of an unprecedented oxidative cyclization of amino alcohols to oxazoline derivatives.³ Gold nanoclusters functionalized by peptide dendron thiolate ligands are providing photogenerated singlet oxygen (¹O₂) for the cyclization. Mechanistic investigations have shown that, upon addition of radical scavengers such as 1,4-hydroquinone, the formation of side products such as *N*-oxides and benzaldehyde is suppressed, and the yield of the product is increased. For detailed mechanistic investigations, see ref.⁶

We propose that a pathway consisting of single-electron transfer events can also lead to the formation of cyclized oxazolines. For the evaluation of an electrochemical pathway, the starting materials have been prepared as precursor molecules were no longer commercially available. The optimized reaction sequence starts with the bromination of propiophenone **1** using *N*-bromosuccinimide (NBS), followed by amination to aminoketones **2** and subsequent reduction with sodium tetraborohydride. Different amino alcohols **3a–3c** were prepared as shown in Scheme 1, amino alcohol **3d** is commercially available.

Scheme 1. Synthesis of amino alcohols **3a–3c**.

Different oxidants have already been reported for the

oxidative coupling of amino alcohols to bicyclic heterocycles. Sedelmeier *et al.* used potassium permanganate as oxidant in an aqueous buffer solution to effect such a cyclization in a flow system.⁷ The oxidation of the tertiary amine to the iminium ion is faster than the oxidation of the secondary alcohol under the reaction conditions.

Superoxide radical anions ($O_2^{\cdot-}$) are long-known in chemical synthesis,⁸ we have investigated their use in flow electrochemical processes. Its generation from oxygen is easily achieved and can be used for a reaction with alkenes providing the corresponding ketones.⁹ We also could show that nitrosamines can be oxidized to the nitramines using electrochemically activated oxygen,¹⁰ also the oxidation of activated toluene derivatives with superoxide radical anions ($O_2^{\cdot-}$) has recently been reported by us.¹¹

Herein, we describe the attempted use of activated oxygen in the cyclization of amino alcohols **3** under electrochemical flow reaction conditions. Many different reaction conditions have been investigated, but decomposition products and side products such as benzaldehyde **5a** were obtained as degradation product. Cyclized compound **4a** could not be identified in the product mixtures, not even by comparing the crude NMR mixtures with literature spectra.

Table 1. Attempted development of reaction conditions for amino alcohol cyclization.

No.	Electrodes ^a	Solvent, electrolyte	Yield (%) ^b	
			4a	5a
1	Pt(–), Ni(+)	THF, nBu ₄ NClO ₄	–	42%
2	Pt(–), GC(+)	THF, nBu ₄ NClO ₄	–	25%
3	Pt(–), SS(+)	THF, nBu ₄ NClO ₄	–	46%
4	Pt(–), Pt(+)	THF, nBu ₄ NClO ₄	–	10%
5	Pt(–), SS(+)	MeCN, nBu ₄ NPF ₆	–	48%
6	Pt(–), SS(+)	THF, nBu ₄ NPF ₆	–	35%
7	Pt(–), SS(+)	THF, nBu ₄ NClO ₄ (without O ₂)	–	28%
8	Pt(–), GC(+)	THF, nBu ₄ NClO ₄ , Q ₁ : 0.08 mL/min, 22 mA	–	12%
9	Pt(–), GC(+)	THF, nBu ₄ NClO ₄ , Q ₁ : 0.025 mL/min, 15 mA	–	28%
10	Pt(–), GC(+)	THF, nBu ₄ NClO ₄ , Q ₁ : 0.1 mL/min, 24 mA	–	8%

^a GC: glassy carbon, SS: stainless steel; standard reaction conditions: current: 18 mA, charge: 2.5 F/mol; conc.: 0.03 M; flow rate: Q₁: 0.05 mL/min, Q₂

(O₂): 0.1 mL/min; IED: 0.5 mm; residence time: 4 min.

^b NMR yield using dibromomethane as internal standard.

The electrochemical reaction was initially investigated by varying the electrode materials, solvent, supporting electrolyte, and flow parameters (Table 1). Under all conditions examined, the desired product **4a** was not detected. Instead, benzaldehyde (**5a**) was consistently observed as the major product, indicating that the reaction predominantly proceeded through decomposition or oxidative cleavage of the starting material rather than the targeted transformation.

The nature of the anode had a significant influence on the extent of substrate degradation. Using a Pt cathode and stainless steel (SS) anode afforded benzaldehyde in up to 46% yield (entry 3), whereas graphite carbon, nickel, and platinum anodes gave lower yields of **5a** in 42%, 25%, and 10%, respectively (entries 1, 2, and 4). Solvent and electrolyte screening revealed a similar trend, with MeCN/nBu₄NPF₆ providing the highest benzaldehyde yield of 48% (entry 5), while THF/nBu₄NPF₆ afforded 35% (entry 6). Notably, exclusion of oxygen resulted in a decrease in benzaldehyde formation from 46% to 28% (entries 3 and 7), suggesting that molecular oxygen promotes the oxidative decomposition pathway leading to benzaldehyde.

Further studies under flow conditions using a Pt cathode and graphite carbon anode showed that both flow rate and applied current affected the extent of substrate cleavage. Decreasing the flow rate to 0.025 mL/min and the current to 15 mA increased the benzaldehyde yield to 28%, whereas higher flow rates and currents resulted in substantially lower yields (8–12%). Collectively, these results demonstrate that the investigated electrochemical conditions favour fragmentation of the starting material to benzaldehyde rather than formation of the desired product **4a**, highlighting the susceptibility of the substrate to oxidative degradation under the applied reaction conditions.

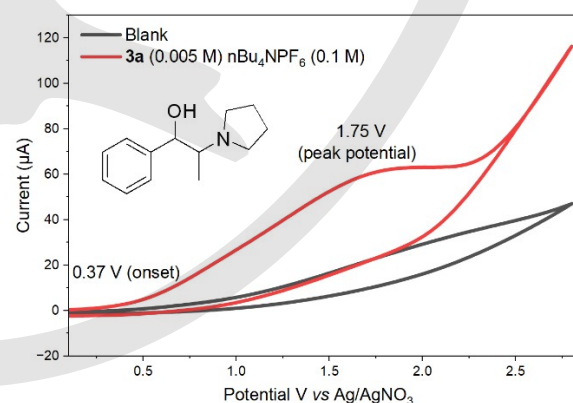


Figure 1. Cyclovoltammogram of amino alcohol **3a**. Recorded using PS trace 5.8 potentiostat in THF

(tetrahydrofuran), with an electrode set-up of GC carbon disk (immersed surface area: 0.03 cm²), Pt wire as counter electrode, 0.01 M Ag/AgNO₃ as reference at a scan rate of $n = 100 \text{ mV s}^{-1}$, electrolyte nBu₄NPF₆ (0.1 M), solvent THF, **3a** (0.005 M).

Cyclic voltammetry of **3a** reveals a low-potential anodic onset at ca. 0.37 V (Figure 1). This is consistent with an initial one-electron oxidation of the tertiary amine to an aminium radical cation, followed by rapid conversion to iminium type intermediates.^{12,13} However, a second oxidation process at significantly higher potential ($E_p \approx 1.75 \text{ V}$) indicates a pronounced susceptibility to overoxidation. Under galvanostatic flow electrolysis in the presence of molecular oxygen, the anode potential is likely driven into this high-potential regime, promoting formation of carbon-centred radical or cationic species that are efficiently intercepted by O₂ to generate peroxy intermediates. These species undergo β -scission and oxidative C–C bond cleavage, favouring benzylic fragmentation to benzaldehyde.^{14,15} Consequently, oxygen-mediated oxidative degradation pathways dominate over iminium formation and intramolecular cyclization, accounting for the failure to obtain the desired 3-methyl-2-phenylhexahydropyrrolo[2,1-*b*]oxazole (**4a**).

In addition, the application of similar reaction conditions to the synthesis of other heterocyclic derivatives failed and compounds **3b–3d** could not be converted into their cyclized counterparts. Only decomposition products were obtained.

The same reaction has been performed using gold nanoclusters coordinating to peptide dendron thiolate ligands such as DOP1-AuNC in the presence of oxygen as shown in Table 2. Mechanistic investigations indicate an ionic pathway through singlet oxygen formation and oxidation of the starting amino alcohol **3a** to the corresponding iminium ion and subsequent cyclization to the oxazolidine derivatives **4a**. It was shown that the peptide dendron thiolate ligands have an accelerating effect on the reaction.⁴ Also theoretical investigations have shown the important role of gold nanoclusters in these reactions.¹⁶ From the other investigated starting materials **3**, only compound **3c** showed some reaction products after prolonged reaction time. This compound produced a mixture of two products, **4c-Me** and **4c-Bn**. The sterically slightly less hindered *N*-Me position is a little favorable for this reaction, suggesting a possibility of single electron transfer followed by hydrogen atom transfer mechanism, which has been documented in photoredox systems.¹⁷

Table 2. Gold nanoparticle-catalyzed amino alcohol cyclization.

No.	Starting material	Solvent, Reaction time	4 Yield (%)	6 Yield (%)
1 ¹	3a	CDCl ₃ , 24 h	4a : 84	trace
2	3b	CDCl ₃ , 24 h	4b : N.D.	N.D.
3	3c	CDCl ₃ , 140 h	4c : 29 ^a	trace
4	3d	CDCl ₃ , 24 h	4d : N.D.	N.D.

^a Mixture of *N*-Me-(**4c-Me**) and *N*-Bn-(**4c-Bn**) cyclized products in 16% and 13%. N.D.: not determined.

The electrochemical reaction in the presence of oxygen did not produce the cyclized reaction product under all investigated reaction conditions, while the gold nanocluster catalysis generated a good yield of **4a** and some products **4c**, while the starting materials **3b** and **3d** were also found unreactive under the gold nanocluster-catalyzed reaction conditions.

Conclusions

In conclusion, gold nanocluster photocatalysis enabled the oxidative cyclization of amino alcohol **3a** to oxazolidine **4a** in 84% yield, whereas the electrochemical activation of oxygen did not produce the desired cyclized products. The electrochemical conditions instead favored oxidative degradation, predominantly forming benzaldehyde, which is consistent with overoxidation of the amino alcohol and subsequent oxygen-mediated C–C bond cleavage. The contrasting outcomes demonstrate that the mode of oxygen activation strongly influences the selectivity of the reaction. Overall, the gold nanocluster approach shows greater potential for selective and sustainable oxazolidine synthesis, while further optimization is required to achieve productive electrochemical cyclization.

Experimental Section

General protocol for the synthesis of amino ketones **2** (GP1):

15 mL of anhydrous acetonitrile was added to the product (2.6 g, 12.2 mmol) from the last step. Then K₂CO₃ (2.5 eq.), amine (3 eq., 36.6 mmol) and 25 mL of anhydrous acetonitrile were added. The reaction was stirred overnight at room temperature. Acetonitrile and excessive amine were removed under

reduced pressure. The reaction mixture was treated with water, and the aqueous phase was extracted with ethyl acetate, which was then washed with brine and dried over anhydrous MgSO_4 . The solvent was evaporated under reduced pressure. The crude reaction mixture was purified using flash chromatography (petroleum ether/ethyl acetate = 7:3).

General protocol for the synthesis of amino alcohols 3 (GP2)

Amino ketone **2** (5.42 mmol) was dissolved in 20 mL of anhydrous ethanol. The reaction was cooled to 0 °C and NaBH_4 (1.5 eq.) was added. Then reaction mixture was left to react for 4 hours. Ethanol was evaporated at reduced pressure, and the crude product was directly purified with column chromatography (cyclohexane/ethyl acetate/ Et_3N = 4:1:0.1).

General Procedure for Photooxidation of Amino Alcohols Catalyzed by Gold Nanoclusters (GP3)

A Schlenk-head NMR tube was charged with amino alcohol (6 μmol) and gold nanocluster (60 nmol). The NMR tube was purged with O_2 (1 atm). To the NMR tube were added solvent (600 μL) and 1,1,2,2-tetrachloroethane as an internal standard. The NMR tube was irradiated by an Asahi Spectra MAX-303 xenon light sources from bottom. The photo-irradiation power was measured by HIOKI optical power meter 3664. The reaction process was monitored by ^1H NMR measurement on a JEOL ECZL-400R.

1-Phenyl-2-(pyrrolidin-1-yl)propan-1-one (2a)

Compound **2a** was prepared according to the general procedure GP1. The crude product was purified by flash column chromatography (ethyl acetate/petroleum ether = 5:95), affording a red oil (1.73 g, 70%, 8.54 mmol). ^1H NMR (400 MHz, CDCl_3) δ 8.07 – 8.03 (m, 2H), 7.51 – 7.46 (m, 1H), 7.41 – 7.35 (m, 2H), 3.92 (q, J = 6.9 Hz, 1H), 2.61 – 2.52 (m, 4H), 1.77 – 1.70 (m, 4H), 1.33 (d, J = 6.9 Hz, 3H) ppm; ^{13}C NMR (101 MHz, CDCl_3) δ 201.0, 135.9, 133.0, 128.7, 128.5, 128.4, 64.7, 51.3, 26.9, 16.6 ppm.

2-Morpholino-1-phenylpropan-1-one (2b)

Compound **2b** was prepared according to the general procedure GP1. The crude product was purified by flash column chromatography (ethyl acetate/petroleum ether = 5:95), affording a red oil (1.6 g, 7.3 mmol, 60% yield after two steps). ^1H NMR (500 MHz, CDCl_3) δ 8.08 – 8.03 (m, 2H), 7.55 – 7.49 (m, 1H), 7.45 – 7.39 (m, 2H), 4.03 (q, J = 6.8 Hz, 1H), 3.70 – 3.59 (m, 4H), 2.64 – 2.47 (m, 4H), 1.26 (d, J = 6.8 Hz, 3H) ppm; ^{13}C NMR (126 MHz, CDCl_3) δ 200.3, 136.3, 133.1, 128.9, 128.5, 67.2, 64.9, 50.1, 11.7 ppm.

2-(Benzyl(methyl)amino)-1-phenylpropan-1-one (2c)

Compound **2c** was prepared according to the general procedure GP1. The crude product was purified by flash column chromatography (ethyl acetate/petroleum ether = 5:95), affording a red oil (2.75 g, 11 mmol, 80%). ^1H NMR (400 MHz, CDCl_3) δ 8.08 – 7.98 (m, 2H), 7.62 – 7.54 (m, 1H), 7.49 – 7.44 (m, 2H), 7.32 – 7.23 (m, 5H), 4.34 (q, J = 6.7 Hz, 1H), 3.67 (s, 2H), 2.25 (s, 3H), 1.35 (d, J = 6.8 Hz, 3H) ppm; ^{13}C NMR (101 MHz, CDCl_3) δ 201.0, 139.2, 136.6, 132.9, 129.1, 129.1, 128.4, 128.3, 127.2, 62.3, 58.5, 37.7, 9.0 ppm.

1-Phenyl-2-(pyrrolidin-1-yl)propan-1-ol (3a)

Compound **3a** was prepared according to the general procedure GP2. The crude product was purified by flash column chromatography (ethyl acetate/petroleum ether = 5:95), affording a colourless oil (0.78 g, 75%, 4.0 mmol). ^1H NMR (300 MHz, CDCl_3) δ 7.39 – 7.26 (m, 5H), 5.24 (s, 1H), 4.20 (d, J = 9.6 Hz, 1H), 2.87 (m, 1H), 2.74 – 2.57 (m, 4H), 1.79 (m, 4H), 0.76 (d, J = 6.6 Hz, 3H) ppm; ^{13}C NMR (101 MHz, CDCl_3) δ 142.4, 128.3, 127.8, 127.4, 76.1, 61.5, 47.2, 23.7, 7.7 ppm.

2-Morpholino-1-phenylpropan-1-ol (3b)

Compound **3b** was prepared according to the general procedure GP2. The crude product was purified by flash column chromatography (ethyl acetate/petroleum ether = 5:95), affording a brown solid (0.90 g, 4.1 mmol, 60%). ^1H NMR (400 MHz, CDCl_3) δ 7.38 – 7.29 (m, 5H), 4.92 (d, J = 3.7 Hz, 1H), 3.74 (t, J = 4.7 Hz, 4H), 2.77 – 2.47 (m, 6H), 0.83 (d, J = 6.9 Hz, 3H) ppm; ^{13}C NMR (101 MHz, CDCl_3) δ 141.9, 128.2, 127.1, 126.0, 71.8, 67.6, 65.0, 51.1, 10.0 ppm.

2-(Benzyl(methyl)amino)-1-phenylpropan-1-ol (3c)

Compound **3c** was prepared according to the general procedure GP2. The crude product was purified by flash column chromatography (ethyl acetate/petroleum ether = 20:80), affording a colourless oil (0.65 g, 8.1 mmol, 81%). ^1H NMR (500 MHz, CDCl_3) δ 7.32 (m, 10H), 5.18 (s, 1H), 4.32 (d, J = 9.7 Hz, 1H), 3.76 (d, J = 13.0 Hz, 1H), 3.52 (d, J = 13.0 Hz, 1H), 2.76 (s, 1H), 2.24 (s, 3H), 0.82 (d, J = 6.7 Hz, 3H) ppm; ^{13}C NMR (126 MHz, CDCl_3) δ 129.1, 128.6, 128.4, 127.9, 127.5, 74.9, 65.0, 58.5, 35.8, 7.5 ppm.

3-Methyl-2-phenylhexahydropyrrolo[2,1-b]oxazole (4a)

The formation of this compound was confirmed by the correspondence with the reported spectral data.¹

3,4-Dimethyl-2,5-diphenyloxazolidine (4c-Bn) using GP3

^1H NMR (399 MHz, CDCl_3) δ 7.56 (dd, J = 8.0, 1.6 Hz, 2H, -Ar-H), 7.44–7.30 (m, 8H, -Ar-H), 4.95 (s, 1H,

-OCHN-), 4.77 (d, J = 8.4 Hz, 1H, -OCHCH-), 2.54 (qd, J = 6.0, 8.8 Hz, 1H, -NCHCH-), 2.21 (s, 3H, -NCH₃), 1.23 (d, J = 6.0 Hz, 3H, -CHCH₃) ppm; ¹³C NMR (100 MHz, CDCl₃) δ 140.5, 139.6, 129.1, 128.4, 128.1, 128.0, 126.8, 99.7, 86.6, 68.9, 35.3, 14.4 ppm.

3-Benzyl-4-methyl-5-phenyloxazolidine (4c-Me) using GP3

¹H NMR (399 MHz, CDCl₃) δ 7.39–7.24 (m, 10H, -Ar-H), 4.63 (d, J = 4.8 Hz, 1H, -OCH₂N-), 4.50 (d, J = 7.2 Hz, ArCH(O-)-CH-), 4.42 (d, J = 4.4 Hz, 1H, -OCH₂N-), 3.94 (d, J = 13.2 Hz, 1H, ArCH₂N-), 3.62 (d, J = 13.2 Hz, 1H, ArCH₂N-), 2.76 (qt, J = 6.4, 7.2 Hz, 1H, CH₃CH(CH-)-N-), 1.23 (d, J = 6.4 Hz, 3H, -CHCH₃) ppm; ¹³C NMR (100 MHz, CDCl₃) δ 140.9, 138.8, 128.7, 128.6, 127.8, 127.3, 126.2, 87.0, 86.3, 67.2, 56.7, 16.2 ppm.

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Primary Data

NO

Conflict of Interest

The authors declare no conflict of interest.

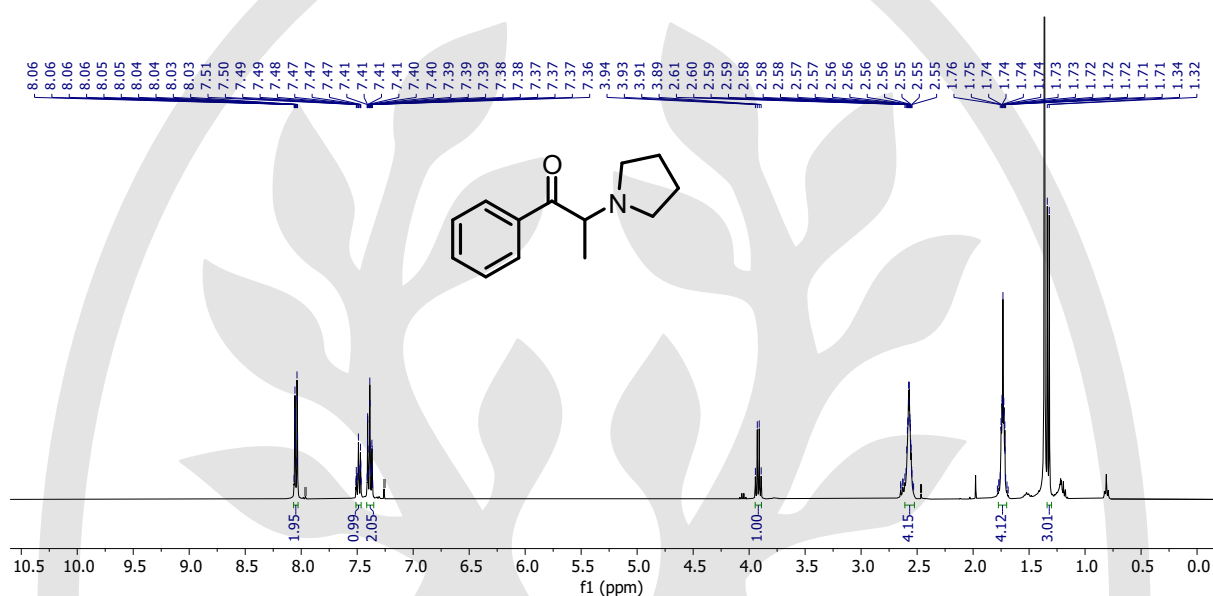
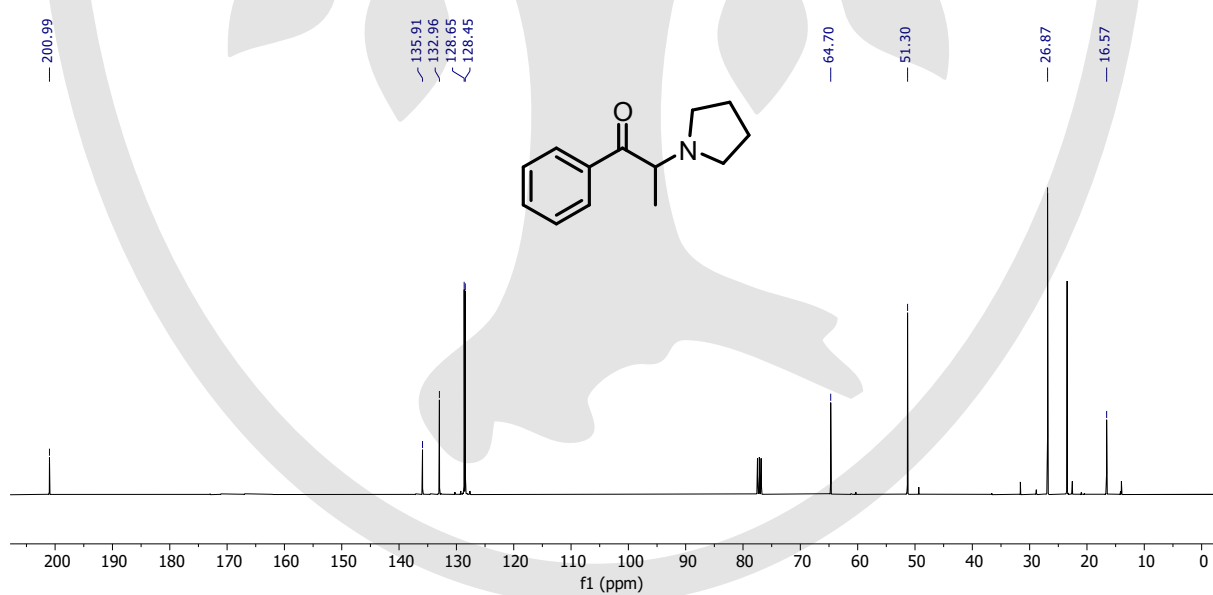
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No use of AI.

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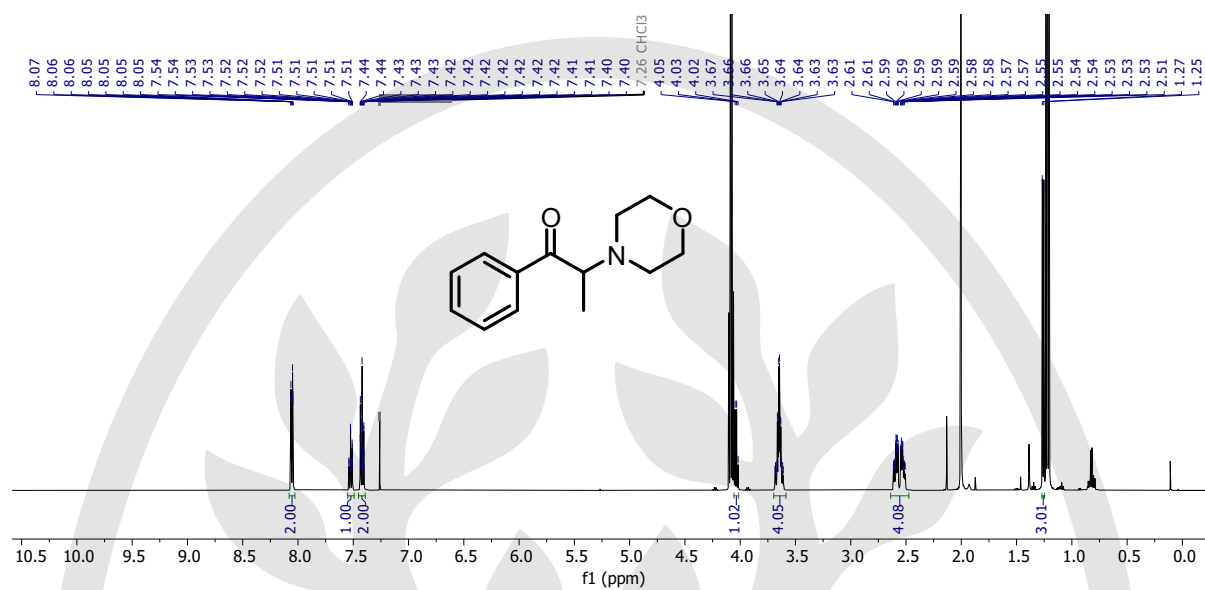
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NMR spectroscopic data

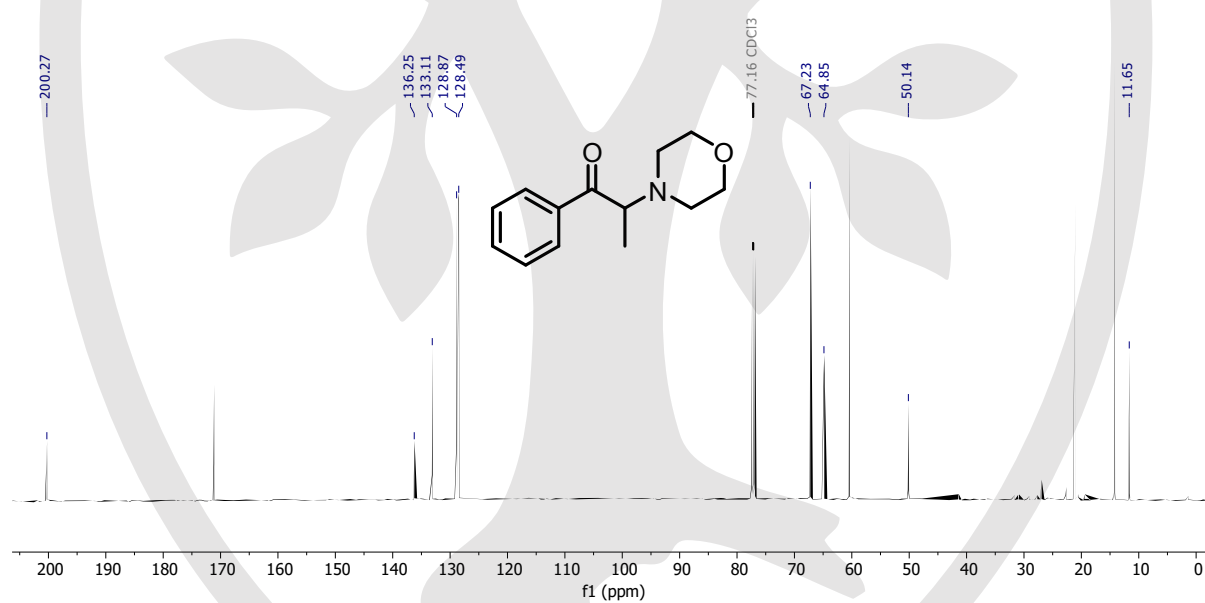
1-Phenyl-2-(pyrrolidin-1-yl)propan-1-one (**2a**) ^1H NMR (400 MHz, CDCl_3) ^{13}C NMR (101 MHz, CDCl_3)

2-Morpholino-1-phenylpropan-1-one (**2b**)

^1H NMR (400 MHz, CDCl_3)

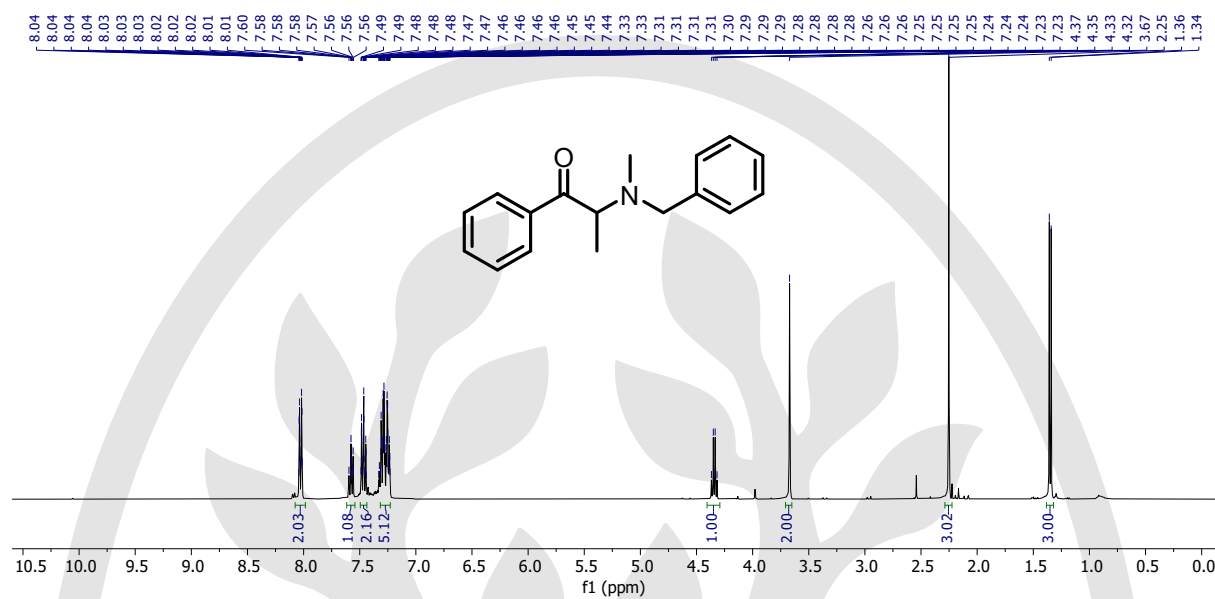


^{13}C NMR (101 MHz, CDCl_3)

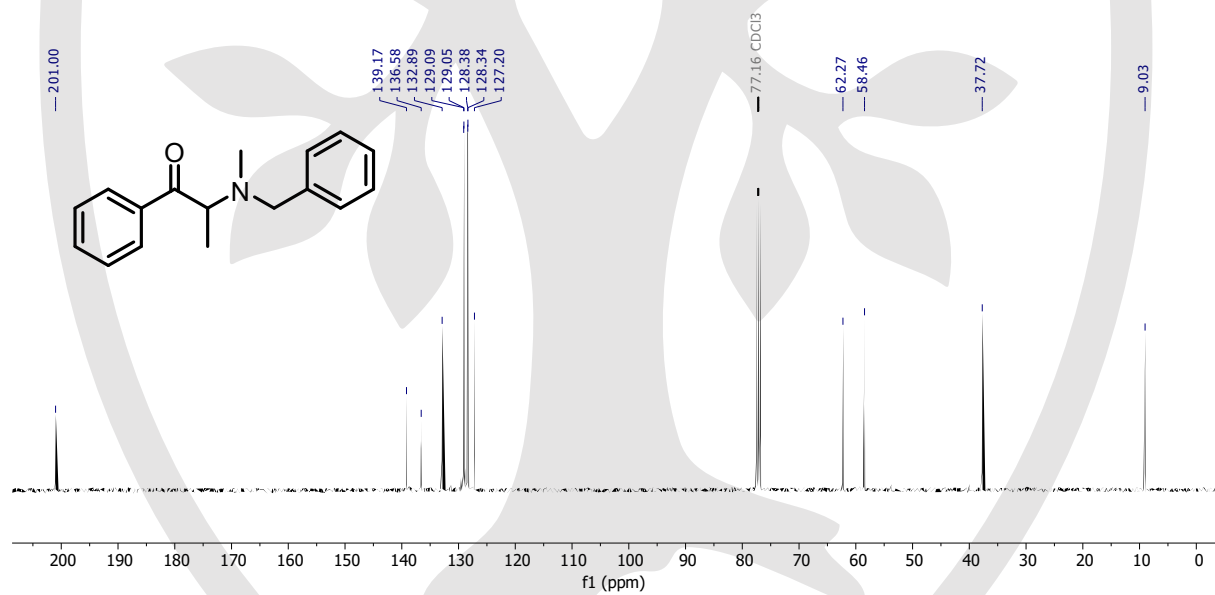


2-(Benzyl(methyl)amino)-1-phenylpropan-1-one (**2c**)

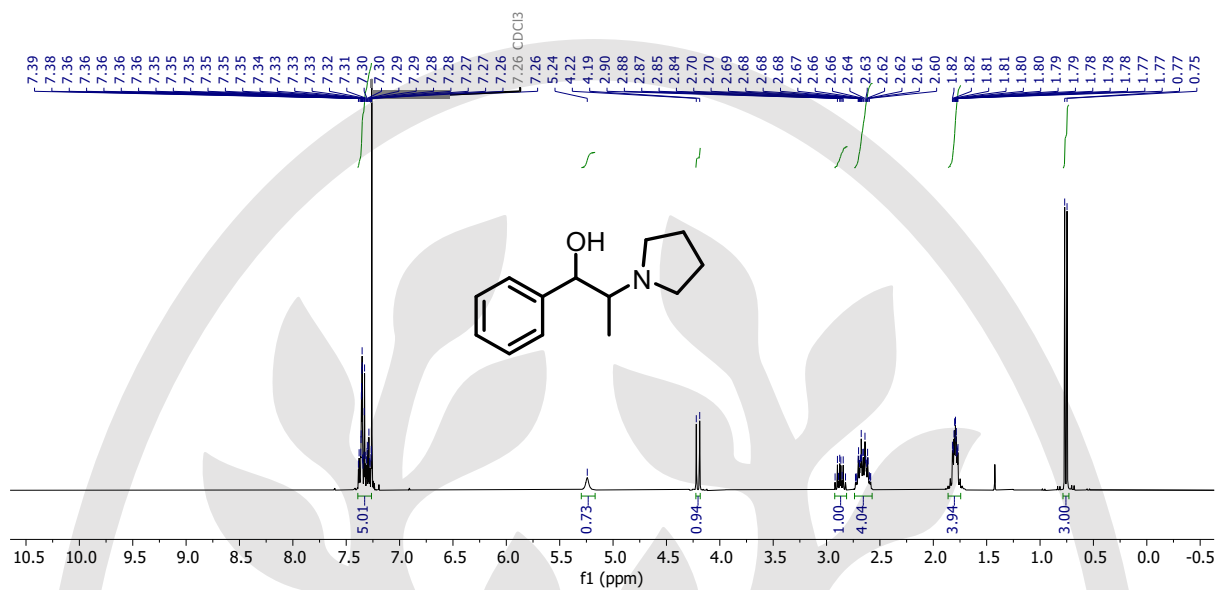
^1H NMR (400 MHz, CDCl_3)



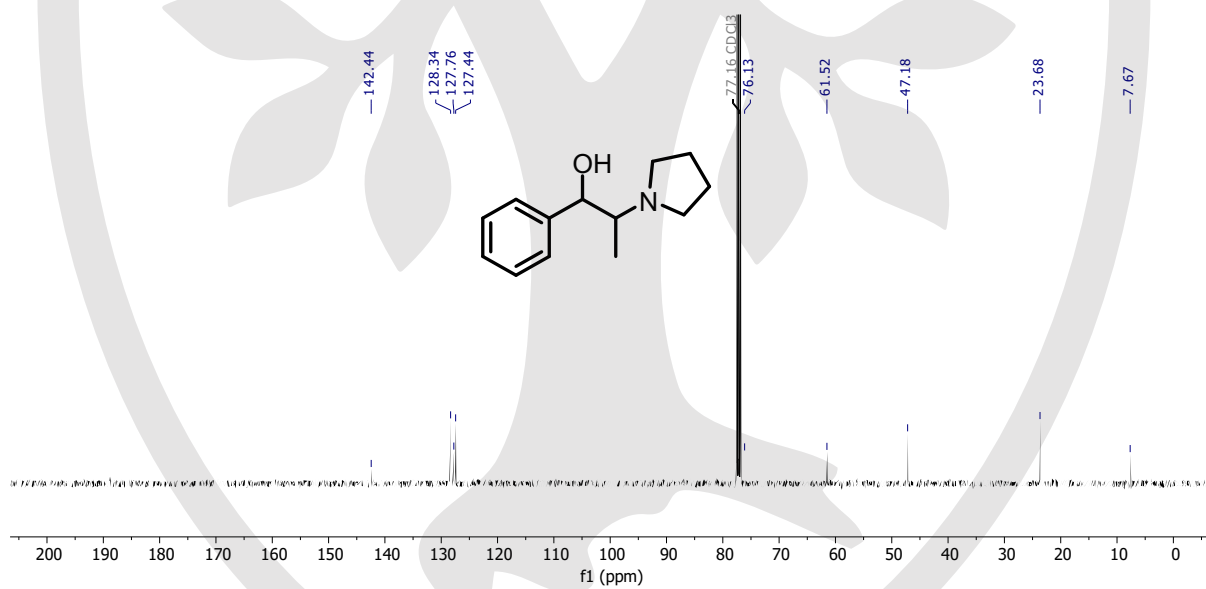
^{13}C NMR (101 MHz, CDCl_3)



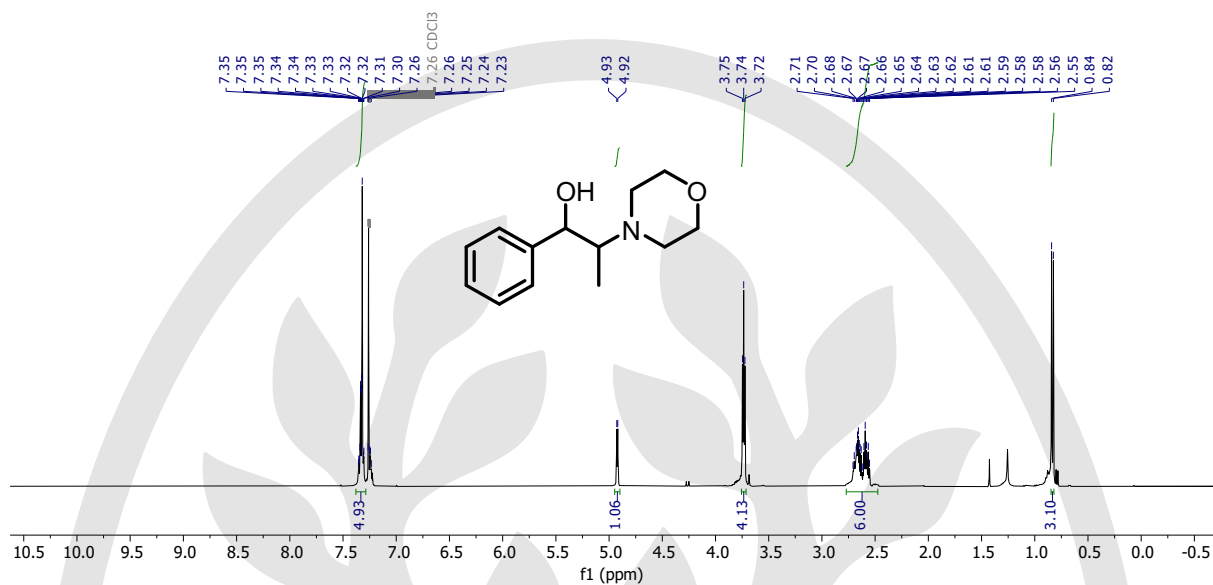
¹H NMR (400 MHz, CDCl₃) of 1-phenyl-2-(pyrrolidin-1-yl)propan-1-ol (**3a**)



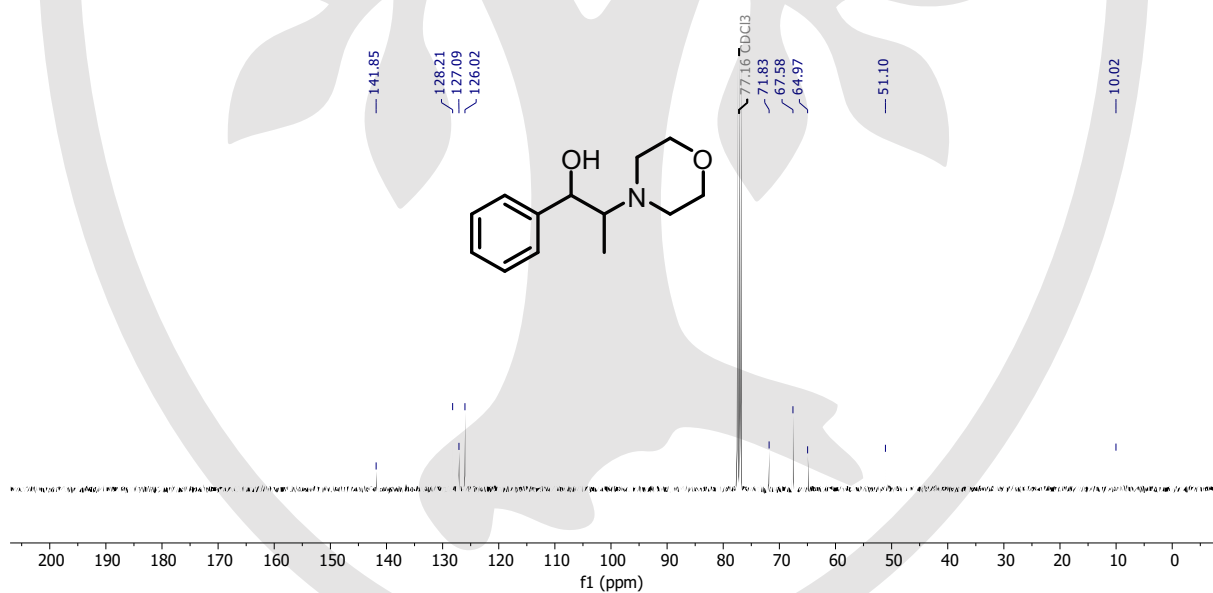
¹³C NMR (101 MHz, CDCl₃)



¹H NMR (400 MHz, CDCl₃) of 2-morpholino-1-phenylpropan-1-ol (**3b**)

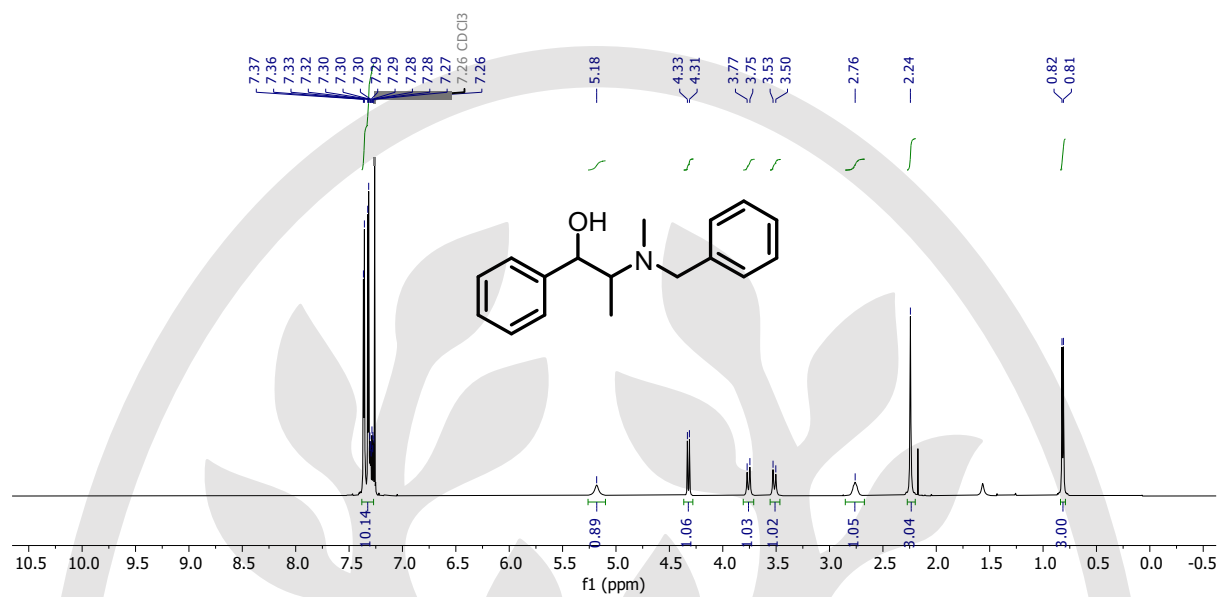


¹³C NMR (101 MHz, CDCl₃)

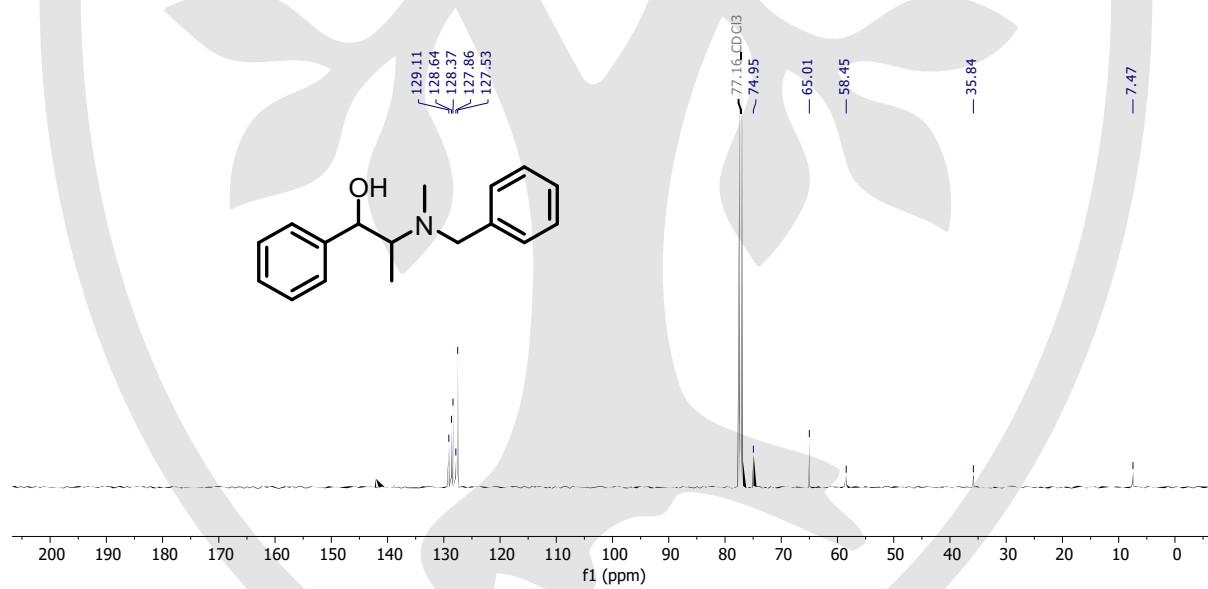


2-(Benzyl(methyl)amino)-1-phenylpropan-1-ol (**3c**)

^1H NMR (500 MHz, CDCl_3)

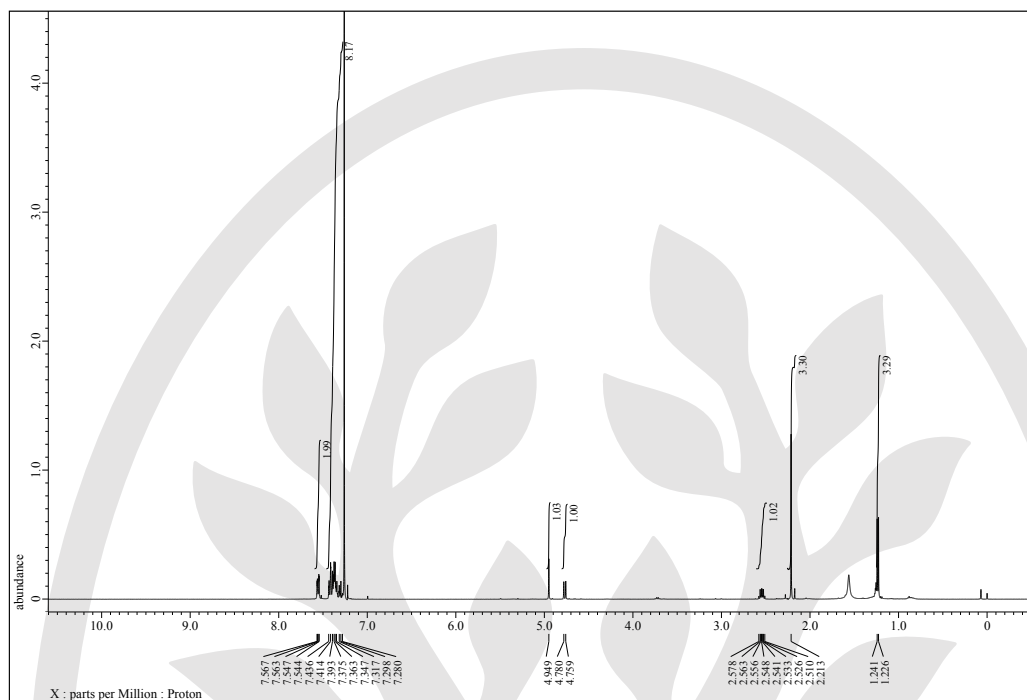


^{13}C NMR (126 MHz, CDCl_3)

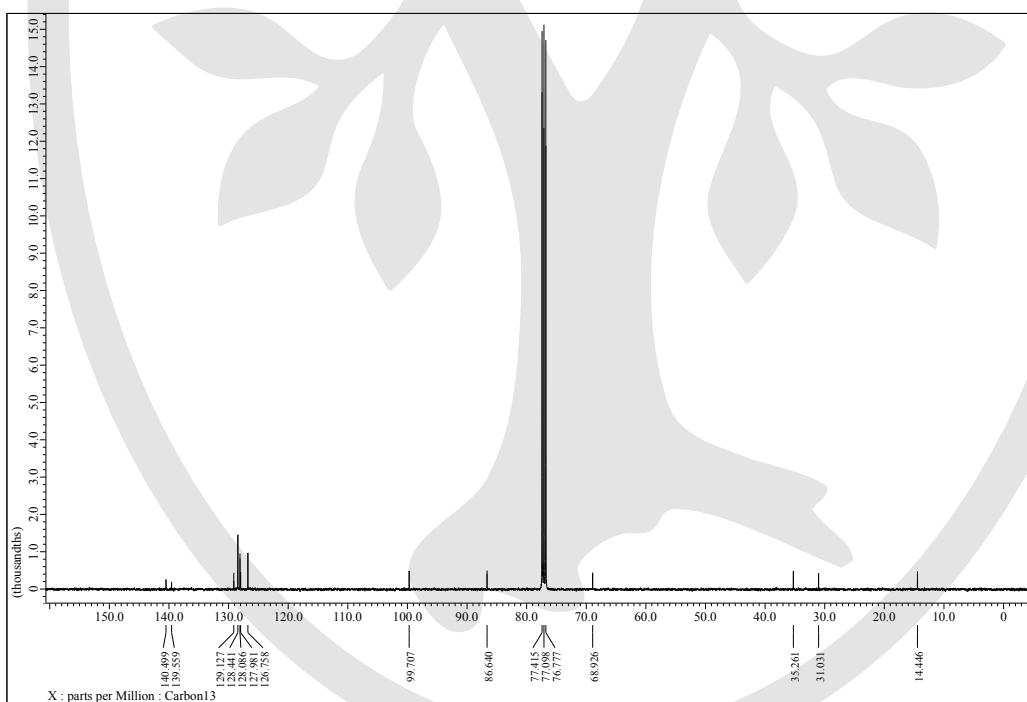


3,4-Dimethyl-2,5-diphenyloxazolidine (4c-Bn)

¹H NMR (399 MHz, CDCl₃)

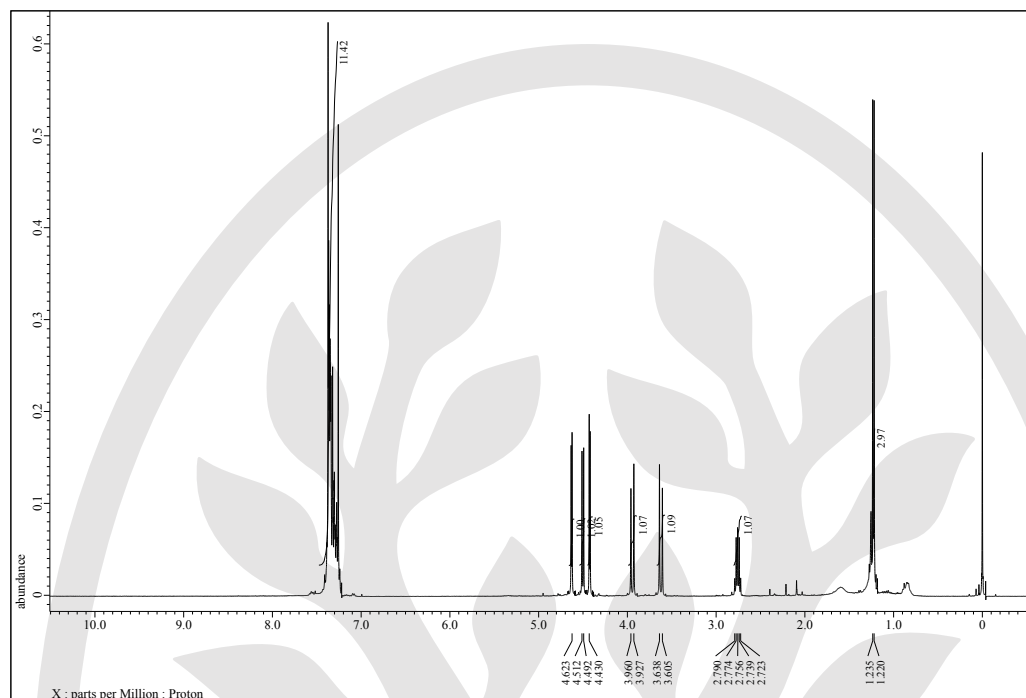


¹³C NMR (100 MHz, CDCl₃)



3-Benzyl-4-methyl-5-phenyloxazolidine (4c-Me)

^1H NMR (399 MHz, CDCl_3)



^{13}C NMR (100 MHz, CDCl_3)

