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A study about the synthesis of seven-membered-ring analogues of ketamine

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Abstract Synthesis of seven-membered ring analogues of ketamine was studied with two strategies. In the first approach a sequence of five reactions was used which previously applied for ketamine synthesis. This strategy led to formation of 1-[(2-chlorophenyl)(methylimino)methyl]cyclohexan-1-ol as a precursor for the target molecule. In the second approach, we have designed and attempted to synthesize a new analogue of ketamine applying challenging reactions such as ring expansion and selective bromination. The result of this route is synthesis of some interesting compounds such as 6-phenyl-1-oxa-4-thiaspiro[4.6]undecane, 3-bromo-6-phenyl-1-oxa-4-thiaspiro[4.6]undecane and 2,7-dibromo-2-phenylcycloheptanone.

Keywords Ketamine · Phenylcycloheptanone · Ring expansion · Analgesia

Introduction

Ketamine is an arylcycloalkylamine prepared by Stevens by thermal isomerization of 1-[(2-chlorophenyl)(methylimino)methyl]cyclopentanol [1]. This compound has a wide range of effects on humans, including analgesia, anesthesia, hallucinations, and elevated blood pressure. Although many drugs interact with the inflammatory response in a positive, negative, or "dual" manner, among these drugs ketamine seems to have a significant positive effect on regulation of inflammation [2–4]. Ketamine has applications as a sedative in intensive care, analgesia, and treatment

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of bronchospasm [5–13]. Because some biologically active compounds, for example eticyclidine [14], phencyclidine [15], rolicyclidine [16], and tiletamine [17], are structurally related to ketamine (Fig. 1), synthesis of ketamine analogues is of interest [18–21].

Synthesis of ketamine involves four steps, as depicted in Scheme 1 [1]. In this strategy, 1-(2-chlorobenzoyl)cyclopentane, **3**, prepared by reaction of 2-chlorobenzonitrile, **1**, and cyclopentylmagnesium bromide, **2**, was brominated to give (1-bromocyclopentyl)(2-chlorophenyl)methanone (**4**). Bromoketone **4**, on reaction with an aqueous solution of methylamine, yielded 1-((2-chlorophenyl)(methylimino)methyl)cyclopentan-1-ol (**5**). On heating compound **5** in decalin, a ring-expansion rearrangement occurs to produce ketamine, **A**.

Because of the wide range of applications of ketamine and its analogues, we wished to extend the strategy of ketamine synthesis to preparation of 2-(2-chlorophenyl)-2-(methylamino)cycloheptanone (**10**) as a new analogue of ketamine. The preparation procedure is summarized in Scheme 2. This strategy has previously been evaluated by our group [22], and led to synthesis of **9**. Herein, we attempt to optimize the reaction conditions of this approach and examine synthesis of **10** from **9**. This is a new strategy for synthesis of **10**.

Results and discussion

Synthesis of **10** was started by reaction of 2-chlorobenzonitrile, **1**, and the appropriate Grignard reagent, **6**, [23] in tetrahydrofuran (THF) to give (2-chlorophenyl)(cyclohexyl)methanone (**7**) in 78 % yield (Scheme 2). To improve the reaction yield, different halogenated copper(I) compounds were used as catalysts, and a high yield was obtained by use of 1 mol% CuI and 2 mol% DABCO. It is important to note that reaction yield decreased in the presence of larger and smaller amounts of CuI and in the absence of DABCO. The results of this study are summarized in Table 1.

Bromination of **7** with HBr/H_2O_2 at 70 °C for 24 h furnished (1-bromocyclohexyl)(2-chlorophenyl)methanone, **8**, in 79 % yield. Compound **8** was reacted with pure methylamine at low temperature in liquid nitrogen for 5 h and then room temperature for 12 h. The 1-[(2-chlorophenyl)(methylimino)methyl]cyclohexan-1-ol (**9**) obtained was crystallized from the reaction mixture, in 88 % yield, by use of *n*-hexane. This product is the result of two sequential reactions, imination of the ketone group and nucleophilic substitution of bromide by hydroxyl. The challenging step of this approach is the rearrangement reaction of **9** with ring expansion. Ring expansion in the classic synthesis of ketamine (**A**) encouraged us in the planning of this reaction. However, rearrangement product **10** was not obtained even under harsh reaction conditions, for example reflux in decalin, *o*-xylene, or toluene in the presence of a variety of catalysts, for example CuI, SnO_2, and Al_2O_3. This result proved 2,2-disubstituted cyclohexanone was more stable than 2,2-disubstituted cycloheptanone, because ketamine as a 2,2-disubstituted cyclohexanone was synthesized via this route.

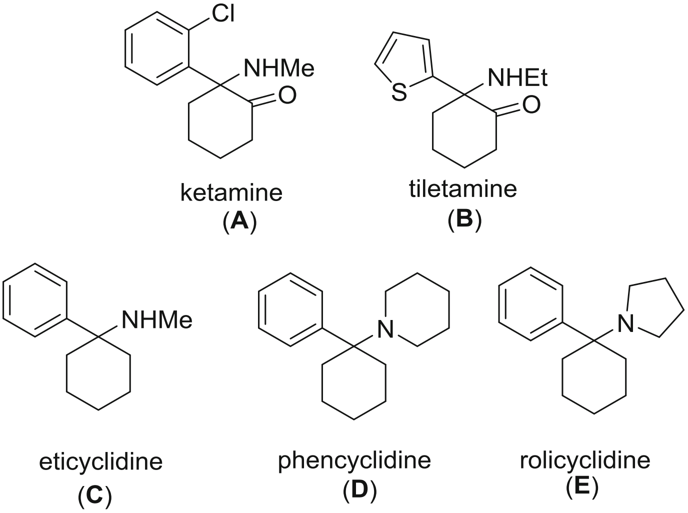
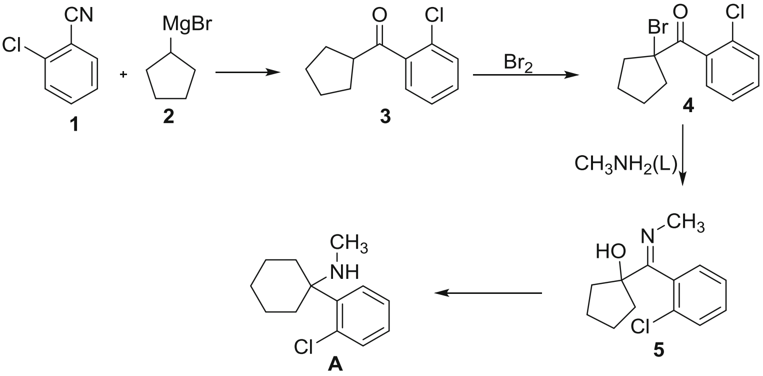


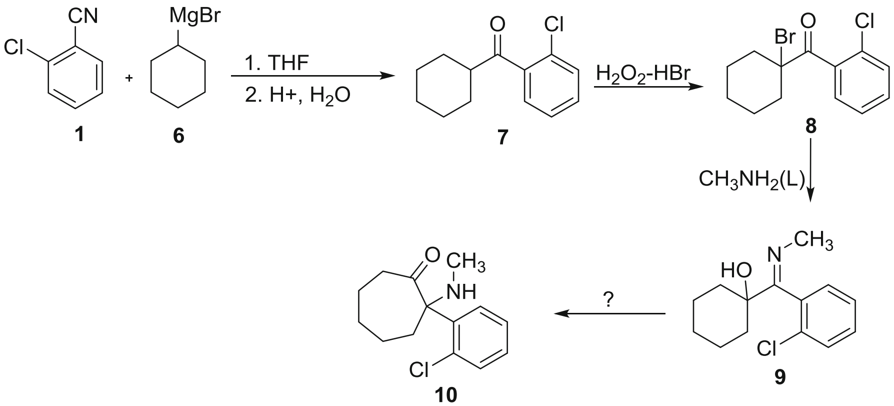
Fig. 1 Structures of some ketamine analogues



Scheme 1 Synthesis of ketamine

We therefore designed another approach to obtain the seven-membered ring analogue of ketamine, as depicted in Scheme 3.

In this approach cyclohexanone **11** was reacted with the Grignard reagent **12** in THF to give 1-benzylcyclohexanol (**13**) in 85 % yield [24]. Compound **13** was brominated with NBS in CCl_4 to produce 1-(bromo(phenyl)methyl)cyclohexanol (**14**) which, on treatment with butylmagnesium bromide in benzene under reflux, underwent rearrangement to 2-phenylcycloheptanone (**15**) [25, 26]. Because compound **15** has two active sites for bromination, for regioselective bromination the carbonyl group was protected by reaction with 2-mercaptoethanol in the presence of $BF_3.OEt_2$. This reaction produced two diastereomeric compounds in 74:26 ratio (Scheme 4), as determined from the ^1H NMR spectrum. Interestingly,

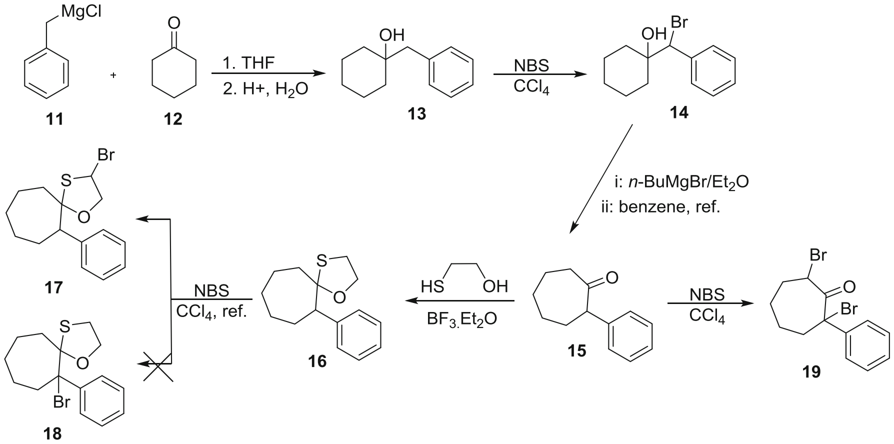


Scheme 2 Synthesis of 2-(2-chlorophenyl)-2-(methylamino)cycloheptanone (**10**)

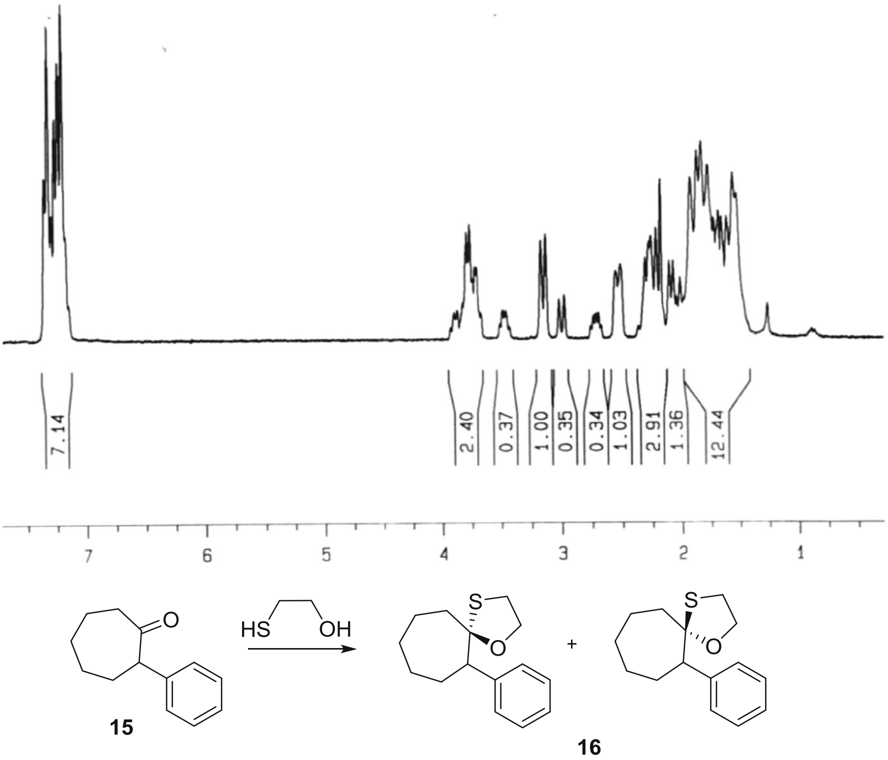
Table 1 Optimization of catalyst in the reaction of 2-chlorobenzonitrile **1** and Grignard reagent **6**

Entry	Cux (mol %)	DABCO (mol %)	Yield (%)^b
1	CuCl (1)	2	78
2	CuBr (1)	2	83
3	CuI (1)	2	93
4	CuI (1)	0	75
5	CuI (0.5)	1	80
6	CuI (2)	4	86

Reaction conditions: 2-Chlorobenzonitrile (**1**) (1.0 mmol), **6** (1.0 mmol), THF (10 mL), reflux, 4 h



Scheme 3 Attempts to synthesize the seven-membered ring analogue of ketamine



Scheme 4 Protection of 2-phenylcycloheptanone leading to two diastereoisomers, as confirmed by NMR

bromination of 6-phenyl-1-oxa-4-thiaspiro[4.6]undecane (**16**) proceeded with bromination of the methylene group of SCH_2 and led to the formation of 3-bromo-6-phenyl-1-oxa-4-thiaspiro[4.6]undecane (**17**) (Scheme 3), rather than the desired product **18**. The bromination reaction was therefore examined with other reagents, HBr/H_2O_2 [22] and Br_2 in CCl_4, but the same product was obtained. To prevent this unfavorable reaction we tried protecting the carbonyl group with 1,2-ethanediol but this reaction did not proceed. This might be attributed to the low activity of 1,2-ethanediol and hindrance by compound **15**.

It is important to note that bromination of **15** by use of the above mentioned approaches gave dibrominated product **19**. This reaction was investigated with control of the amount of bromine, with 0.5, 1, and 2 equivalents of bromine relative to 2-phenylcycloheptanone (**15**) (Table 2). In all cases product **19**, only, was obtained.

In conclusion, attempts to synthesize the seven-membered ring analogue of ketamine led to the formation of the new interesting compounds 1-[(2-chlorophenyl)(methylimino)methyl]cyclohexan-1-ol, 6-phenyl-1-*oxa*-4-thiaspiro[4.6]undecane, and 3-bromo-6-phenyl-1-oxa-4-thiaspiro[4.6]undecane and 2,7-dibromo-2-

Table 2 Effect of amount of bromine on bromination of **15**

Entry	Br_2 (mol %)	Yield (%)
1	0.5	24
2	1	41
3	2	85
4	3	86

Reaction conditions: **15** (1.0 mmol), NBS, benzoyl peroxide (0.1 g), CCl_4 (20 mL), under N_2 atmosphere, reflux, 4 h

phenylcycloheptanone. We hope these compounds may be of value to others seeking novel synthetic fragments with ketamine properties.

Experimental

General remarks

All the reagents were purchased from Merck. IR spectra were recorded on Bruker Tensor 27 and Perkin Elmer spectrophotometers. ^1H NMR spectra were recorded on Bruker 250 MHz instrument. ^{13}C NMR spectra were recorded on Bruker 62.90 MHz instrument.

Typical procedure for synthesis of cyclohexylmagnesium bromide

Cyclohexylmagnesium bromide was synthesized in THF in accordance with a literature method [22] and used immediately after preparation.

Typical procedure for synthesis of cyclohexyl (2-chlorophenyl) ketone (**7**)

Toluene (40 mL) and CuI (0.32 mmol) were added to a stirred solution of 2-chlorobenzonitrile (32 mmol) and cyclohexylmagnesium bromide (37 mmol; 2 M in THF). The mixture was heated to remove the THF by distillation then heated under reflux (under nitrogen) for 4 h. After cooling to 25 °C, H_2O (5 mL) was cautiously added, followed by 30 mL 15 % H_2SO_4. After stirring of the mixture for 5 h, 20 mL hexane was added. The organic layer was separated, and the aqueous layer was extracted with diethyl ether (2 × 10 mL). The combined organic phase was dried over $MgSO_4$ and concentrated by rotary evaporation to afford a brown oil. After chromatography (silica gel, hexane, 10:1 hexane: ethyl acetate) 6.6 g (93 % yield) cyclohexyl (2-chlorophenyl) ketone was obtained as a white crystalline compound. mp: 52 °C, IR (KBr), $\nu(cm^{-1})$: 2,922, 2,852, 1,665, 1,578, 1,444. ^1H NMR (250 MHz, $CDCl_3$) δ: 1.21–1.53 (5H, m), 1.61–1.92 (5H, m), 3.06–3.14 (1H, m), 7.23–7.42 (4H, m).; ^{13}C NMR (62.90 MHz, $CDCl_3$) δ: 25.6 (CH_2), 25.8 (CH_2), 28.4 (CH_2), 50.1 (CH), 126.7 (CH), 128.3 (CH), 130.2 (CH), 130.5 (quat-C), 131.8 (CH), 140.1 (quat-C), 207.4 (quat-C, C=O).

Typical procedure for synthesis of (1-bromocyclohexyl)(2-chlorophenyl)methanone (**8**)

Cyclohexyl (2-chlorophenyl) ketone **7** (10 mmol) was placed in a flask covered with aluminium foil. An aqueous solution (47 %) of HBr (1.2 mL, 1.1 mol equiv.) was added to ketone. After stirring of the reaction mixture for 5 min at room temperature, 10 mmol LiCl was added to the mixture and stirring was continued for 10 min. H_2O_2 (30 % aqueous solution, 2 mL, 2 mol equiv.) was then added slowly. The reaction mixture was heated at 70 °C for 1 h then 5 mL H_2O was cautiously added, followed by 5 mL hexane. This mixture was stirred for 5 min. The organic layer was separated and dried on $MgSO_4$. The insoluble material was isolated by filtration then the solvent was evaporated under reduced pressure to produce 2.4 g (79 %) compound **8** as a yellow oil. ^1H NMR (250 MHz, $CDCl_3$) δ: 1.23–1.27 (2H, m), 1.64–1.84 (6H, m), 1.96–2.21 (4H, m), 7.25–7.82 (4H, m).; ^{13}C NMR (62.90 MHz, $CDCl_3$) δ: 22.5 ($2CH_2$), 24.8 (CH_2), 36.1 ($2CH_2$), 70.6 (quat-C), 126.3 (CH), 129 (CH), 130 (CH), 130.3 (quat-C), 130.6 (CH), 137.8 (quat-C), 199.6 (quat-C, C=O).

Typical procedure for synthesis of (1-[(2-chlorophenyl)(methylimino)methyl]cyclohexanol (**9**)

(1-Bromocyclohexyl)(2-chlorophenyl)methanone (3.7 mmol) was slowly added to 4 mL methylamine in a sealed vitreous glass reactor cooled at −40 °C by liquid N_2. After stirring for 6 h, the temperature was increased to 25 °C and stirring was continued for 12 h. Finally, 10 mL hexane was added, and the organic layer was separated and concentrated by solvent removal under reduced pressure to afford brown crystals. The crystals were washed with methanol (2 × 10 mL) to afford shiny crystal in 88 % yield (0.8 g). Mp 79–81 °C.; IR (KBr) v: 3,209, 2,934, 2,855, 1,651, 1,410, 766 cm^{-1}.; ^1H NMR (250 MHz, $CDCl_3$) δ: 0.99–1.09 (1H, m), 1.31–1.35 (1H, m), 1.44–1.72 (8H, m), 3.02 (3H, S), 4.53 (1H, br s), 7.03–7.56 (4H, m).; ^{13}C NMR (62.90 MHz, $CDCl_3$) δ: 21.5 (CH_2), 21.7 (CH_2), 25.2 (CH_2), 34.7 (CH_2), 35.5 (CH_2), 39.0 (CH_3), 75.3 (quat-C), 126.5 (CH), 128.8 (CH), 129.8 (CH), 131.9 (quat-C), 134.1 (quat-C), 174.6 (quat-C).

Typical procedure for synthesis of 1-benzylcyclohexanol (**13**)

To a stirred solution of benzyl magnesium chloride (12 mmol) in THF (20 mL), 10 mmol cyclohexanone dissolved in 10 mL THF was added dropwise. The mixture was heated to remove the THF by distillation, then heated under reflux (under nitrogen) for 4 h. After cooling to room temperature, H_2O (5 mL) was cautiously added, followed by 30 mL 15 % H_2SO_4. The mixture was stirred for 1 then 20 mL hexane was added. The organic layer was separated and the aqueous layer was extracted with diethyl ether (2 × 10 mL). The combined organic phase was dried over $MgSO_4$ and concentrated by rotary evaporation to afford 1.9 g (85 % yield) white crystals of 1-benzylcyclohexan-1-ol (**13**). Mp 41–43 °C.:^1H NMR (250 MHz,

$CDCl_3$) δ: 1.28–1.64 (10H, m), 2.70 (2H, s), 7.23–7.39 (5H, m).; ^{13}C NMR (62.90 MHz, $CDCl_3$) δ: 22.1, 25.7, 37.2, 48.65, 71.0, 126.3, 128.0, 130.6, 137.15.

Typical procedure for synthesis of 1-(bromo(phenyl)methyl)cyclohexanol (**14**)

1-Benzylcyclohexan-1-ol (**13**) (15 mmol) was added to a vessel containing 20 mL anhydrous carbon tetrachloride, 1 equiv. *N*-bromosuccinimide, and benzoyl peroxide (0.1 g). The mixture was brought to reflux for 2 h then cooled in an ice bath. The succinimide was isolated by suction filtration. The carbon tetrachloride was removed under vacuum by rotary evaporation to furnish 3.9 g light yellow oil (96 % yield). ^1H NMR (250 MHz, $CDCl_3$) δ: 1.28–1.63 (10H, m), 4.77 (1H, s), 7.22–7.36 (5H, m); ^{13}C NMR (62.90 MHz, $CDCl_3$) δ: 22.0 ($2CH_2$), 45.7 (CH_2), 37.2 (CH_2), 48.6 (CH), 71.0 (C), 126.2 (CH), 128.0 (CH), 130.6 (CH), 137.2 (C).

Typical procedure for synthesis of 2-phenylcycloheptanone (**15**)

Isopropylmagnesium bromide (11 mmol in 10 mL diethyl ether) was added dropwise to an ice-cooled solution of 1-(bromo(phenyl)methyl)cyclohexan-1-ol (**14**) (10 mmol) in 30 mL anhydrous benzene. The ice bath was then removed and the resulting solution was heated under reflux for 3 h. The brown solution was then cooled and added to a solution of ammonium chloride in water (6 mmol in 10 mL). The benzene layer was separated and washed with 10 % sodium carbonate followed by water. The benzene solution was then dried over magnesium sulfate and the solvent was subsequently removed under vacuum. The residue was purified by column chromatography on silica gel, with *n*-hexane then ethyl acetate as eluents, furnishing 2-phenylcycloheptanone in 81 % yield (1.5 g). ^1H NMR (250 MHz, $CDCl_3$) δ: 1.40–1.61 (4H, m), 1.93–2.10(4H, m), 2.53–2.73 (2H, m), 3.71 (1H, dd, $^3J_{H\text{-}H} = 7.5$ and 4 Hz), 7.20–7.33 (5H, m).; ^{13}C NMR (62.90 MHz, $CDCl_3$) δ: 25.3 (CH_2), 28.7 (CH_2), 30 (CH_2), 32 (CH_2), 42 (CH_2), – 58.0 (CH), 126.5 (CH), 127.5 (CH), 128.5 (CH), 140.0 (CH), 213.1 (CO).

Typical procedure for synthesis of 6-phenyl-1-oxa-4-thiaspiro[4.6]undecane (**16**)

2-Phenylcycloheptanone (10 mmol), 2-mercaptoethanol (11 mmol), and dry diethyl ether (20 mL) were heated under reflux in a three-necked, round-bottomed flask purged with nitrogen gas and equipped with a reflux condenser. $BF_3.Et_2O$ (10 mmol) dissolved in diethyl ether (10 mL) was added dropwise to the mixture over a period of 1 h, and heating under reflux was continued for 1 h. The mixture was then cooled and washed with 20 mL $NaHCO_3$ (1 M) and saturated NaCl. The organic layer was separated and dried over $MgSO_4$. After evaporation of the solvent, purification by column chromatography gave 2.1 g (83 % yield) white crystals of 6-phenyl-1-oxa-4-thiaspiro[4.6]undecane (**16**). Mp 28–30 °C.;^1H NMR for two diastereoisomers (250 MHz, $CDCl_3$) δ: 1.53–2.31 (20H, m, for two diastereoisomers), 2.51(1H, m, diastereoisomer 1), 2.68 (1H, m, diastereoisomer 2), 2.98 (1H, d, $^3J_{HH} = 9.5$ Hz, diastereoisomer 2), 3.13 (1H, d, $^3J_{HH} = 9.5$ Hz, diastereoisomer 1), 3.51 (1H, m, diastereoisomer 2), 3.71–3.79 (5H, m, 2H for diastereoisomer 2 and 3H for diastereoisomer 1), 7.15–7.35 (10H, m); ^{13}C NMR (62.90 MHz, $CDCl_3$) δ: 22.8, 23.0, 27.8, 28.1, 28.5, 28.8, 31.3, 33.4, 43.9, 44.6, 56.2, 57.4, 70.6, 71.9, 72.7, 93.3, 102.6, 125.8, 125.9, 126.8, 127.1, 130.2, 130.4, 137.5, 160.1.

Typical procedure for synthesis of 3-bromo-6-phenyl-1-oxa-4-thiaspiro[4.6]undecane (**17**)

6-Phenyl-1-oxa-4-thiaspiro[4.6]undecane (**16**) (15 mmol) was added to a vessel containing 20 mL anhydrous carbon tetrachloride, 1 equiv. *N*-bromosuccinimide, and benzoyl peroxide (0.1 g). The mixture was brought to reflux for 4 h then cooled in an ice bath and the succinimide was isolated by suction filtration. The carbon tetrachloride was removed under vacuum by rotary evaporation to furnish 2.0 g brown oil (61 % yield). ^{1}H NMR (250 MHz, $CDCl_3$) δ: 1.43–2.65 (10H, m), 3.70 (1H, dd, $^3J_{HH} = 7.5$ and 4.0 Hz), 4.21–4.27 (3H, m), 7.21–7.43 (5H, m).; ^{13}C NMR (62.90 MHz, $CDCl_3$) δ: 22.3 (CH_2), 26.0 (CH_2), 29.8 (CH_2), 35.8 (CH_2), 37.2 (CH_2), 58.6 (CH_2), 60.8 (CH), 70.3 (CH_2), 75.1 (CSBr), 126.1 (CH), 127.9 (CH), 128.8 (CH), 130.4 (CH), 135.2 (C).

Typical procedure for synthesis of 2,6-dibromo-2-phenylcycloheptanone (**19**)

2-Phenylcycloheptanone (**15**) (5 mmol) was added to a vessel containing 20 mL anhydrous carbon tetrachloride, 2 equiv. *N*-bromosuccinimide, and benzoyl peroxide (0.1 g) under an N_2 atmosphere. The mixture was brought to reflux for 4 h then cooled in an ice bath and the succinimide was isolated by suction filtration. The carbon tetrachloride was removed under vacuum by rotary evaporation to furnish 1.5 g light yellow oil (86 % yield). ^{1}H NMR (250 MHz, $CDCl_3$) δ: 1.52–1.99 (6H, m), 2.35–2.62 (2H, m), 4.62 (1H, br), 7.17–7.66 (5H, m); ^{13}C NMR (62.90 MHz, $CDCl_3$) δ: 22.1 (CH_2), 26.4 (CH_2), 29.9 (CH_2), 35.0 (CH_2), 37.9 (CH_2), 60.2 (C), 72.5 (C), 126.1 (CH), 127.2 (CH), 128.6 (CH), 130.9 (CH), 139.3 (C), 211.9 (C).

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References

1. C.L. Stevens, U.S. Patent 3,254,124 (1966)
2. S. Loix, M. De Kock, P. Henin, Acta Anaesthesiol. Belg. **62**, 47–58 (2011)
3. J.L. Ward, M.T. Harting, C.S. Cox, D.W. Mercer, J. Trauma **70**, 1471–1479 (2011)
4. Y.S. Shibakawa, Y. Sasaki, Y. Goshima, N. Echigo, Y. Kamiya, K. Kurahashi, Y. Yamada, T. Andoh, Br. J. Anaesth. **95**, 803–810 (2005)
5. T.E. Peck, S.A. Hill, M. Williams, *Pharmacology for Anaesthesia and Intensive Care* (3rd ed). Cambridge: Cambridge University Press, p. 111 (2008)
6. S.A. Bergman, Anesth. Prog. **46**, 10–20 (1999)

7. N. Diazgranados, L. Ibrahim, N.E. Brutsche, A. Newberg, P. Kronstein, S. Khalife, W.A. Kammerer, Z. Quezado, D.A. Luckenbaugh, G. Salvadore, R. Machado-Vieira, H.K. Manji, C.A. Zarate Jr, Arch. Gen. Psychiatry **67**, 793–802 (2010)
8. A.E. Autry, M. Adachi, E. Nosyreva, E.S. Na, M.F. Los, P. Cheng, E.T. Kavalali, L.M. Monteggia, Nature **475**, 91–95 (2011)
9. N.L. Harrison, M.A. Simmonds, Br. J. Pharm. **84**, 381–391 (1985)
10. K. Hirota, K.S. Sikand, D.G. Lambert, J. Anest. **13**, 107–109 (1999)
11. M. Narita, K. Yoshizawa, K. Aoki, M. Takagi, M. Miyatake, T. Suzuki, Addict. Biol. **6**, 373–376 (2001)
12. Pharmaceutical Society of Australia. "2.1.1 IV general anaesthetics". Australian Medicines Handbook. 2011. Australian Medicines Handbook Pty Ltd. p. 13
13. Chen et al., J. Neurosci. **29**, 600–609 (2009)
14. L. Levy, D.E. Cameron, R.C. Aitken, Am. J. Psychiatry **116**, 843–844 (1960)
15. S.A. Maisto, M. Galizio, G.J. Connors, *Drug Use and Abuse*. T. Wadsworth (2004)
16. A. Kalir, H. Edery, Z. Pelah, D. Balderman, G. Porath, J. Med. Chem. **12**, 473–477 (1969)
17. T. Klockgether, L. Turski, M. Schwarz, K.-H. Sontag, J. Lehmann, J. Brain Res. **461**, 343–348 (1988)
18. H. Elhawi, H. Eini, A. Douvdevani, G. Byk, Molecules **17**, 6784–6807 (2012)
19. R.F. Parcel, J.P. Sanchez, J. Org. Chem. **46**, 5055–5060 (1981)
20. P. Zarantonello, E. Bettini, A. Paio, C. Simoncelli, S. Terreni, F. Cardullo, Bioorg. Med. Chem. Lett. **21**, 2059–2063 (2011)
21. R.S. Sulake, C. Chen, H.R. Lin, A.C. Lua, Bioorg. Med. Chem. Lett. **21**, 5719–5721 (2011)
22. A. Moghimi, S. Faraji, S. Taghvaei, R. Zare, Iran. J. Org. Chem. **3**, 585–589 (2011)
23. Y.H. Lai, Synthesis, 585 (1981)
24. A.J. Sisti, J. Org. Chem. **33**, 453–454 (1968)
25. C.L. Stevens, R.D. Elliott, B.L. Winch, I.L. Klundt, J. Am. Chem. Soc. **84**, 2272–2274 (1962)
26. C.L. Stevens, R.D. Elliott, B.L. Winch, J. Am. Chem. Soc. **85**, 1464–1470 (1963)