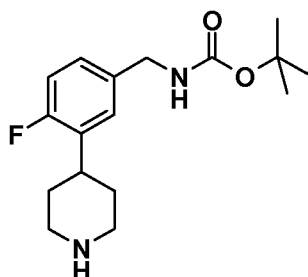


**SYNTHESIS OF (4-FLUORO-3-PIPERIDIN-4-YL-BENZYL)-CARBAMIC
ACID TERT-BUTYL ESTER AND INTERMEDIATES THEREOF**

FIELD OF THE INVENTION

This invention is directed to a method of synthesis of 4-fluoro-3-(piperidin-4-yl)-benzyl)-carbamic acid tert-butyl ester (I), and the intermediates thereof.

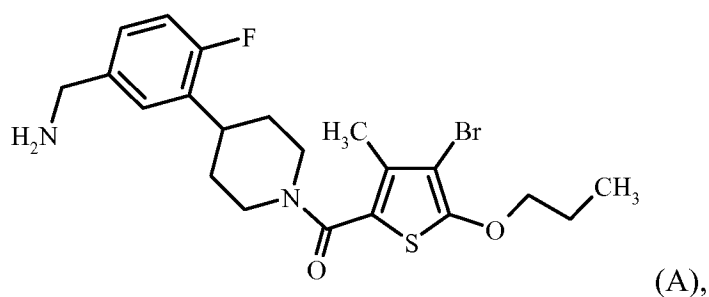


(I)

BACKGROUND OF THE INVENTION

WO2001/13811 discloses compounds including [(benzylamine)-piperidin-1-yl] (aryl or heteroaryl)methanone as tryptase inhibitors, and describes potential uses for such compounds due to tryptase being implicated in a variety of biological processes, including degradation of vasodilating and bronchorelaxing neuropeptides (Caughey, et al., J. Pharmacol. Exp. Ther., 1988, 244, pages 133-137; Franconi, et al., J. Pharmacol. Exp. Ther., 1988, 248, pages 947-951; and Tam, et al., Am. J. Respir. Cell Mol. Biol., 1990, 3, pages 27-32) and modulation of bronchial responsiveness to histamine (Sekizawa, et al., J. Clin. Invest., 1989, 83, pages 175-179).

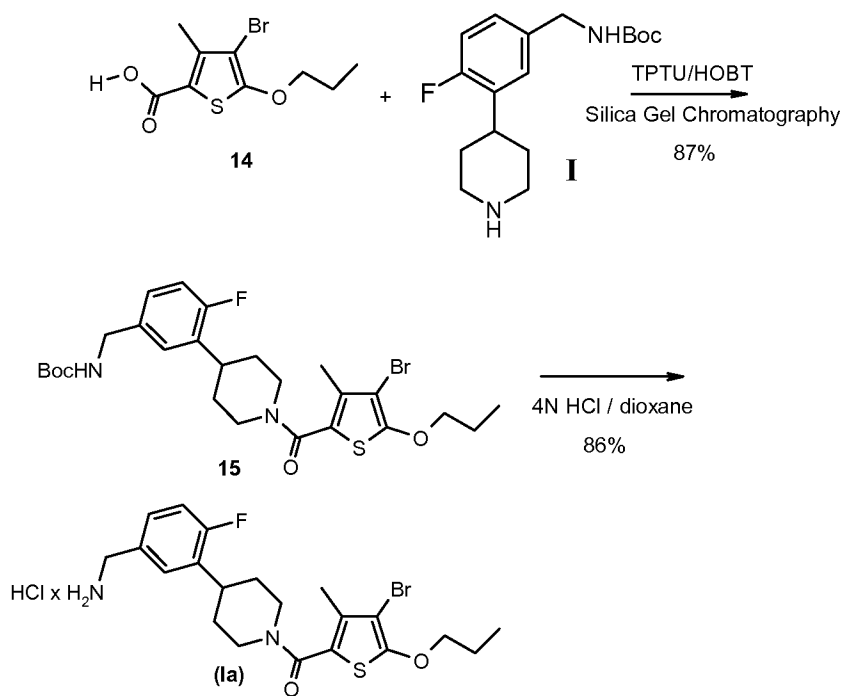
WO2005/097780 more particularly discloses the (benzylamine)-piperidin-1-yl thienylmethanone compound of formula A, its preparation, and use for treating disease states



capable of being modulated by the inhibition of tryptase. WO2005/097780 also discloses that the compound of the formula A is prepared through the coupling of the following compounds 14 and I as shown in Scheme A, and subsequent deprotection of the coupled product.

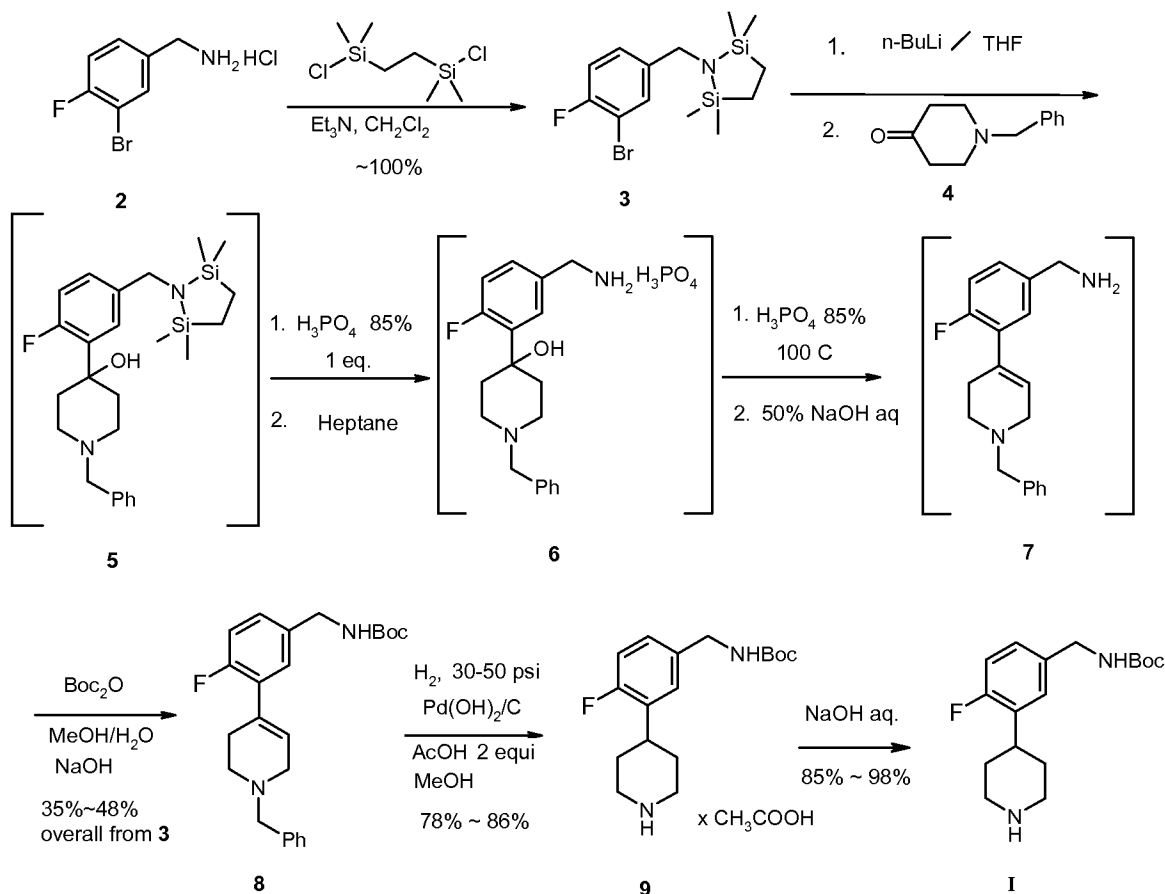
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Scheme A



Compound I was prepared by the seven step synthesis as shown in the below Scheme

10 B.

Scheme B

While the aforesaid synthesis works to prepare compound I on a laboratory scale, compound I would be better prepared employing fewer steps. The instant invention represents a significant improvement over the Scheme B synthesis route as it is significantly shorter.

SUMMARY OF THE INVENTION

The present invention is directed to an improved method for preparing 4-fluoro-3-(piperidin-4-yl-benzyl)-carbamic acid tert-butyl ester (I); more particularly, to its synthesis in three steps. The first step comprises a boronic acid formation by treatment of (4-fluoro-benzyl)-carbamic acid tert-butyl ester under boronation conditions. The second step involves reacting the resultant 5-((tert-butoxycarbonyl)aminomethyl)-2-fluorobenzeneboronic acid of the first step with a 4-halo-pyridine such as 4-chloro-pyridine or 4-bromo-pyridine under Suzuki coupling conditions to yield (4-fluoro-2-pyridin-4-yl-benzyl)-carbamic acid tert-butyl ester. The third step involves employing selective hydrogenation conditions on the product of the second step to yield compound I. The invention is also directed to the intermediates 5-((tert-

Butoxycarbonyl)aminomethyl)-2-fluorobenzeneboronic acid (compound 11), and (4-fluoro-2-pyridin-4-yl-benzyl)-carbamic acid tert-butyl ester (compound 13).

DETAILED DESCRIPTION OF THE INVENTION

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As used throughout the specification, the following abbreviations and definitions, unless otherwise indicated, shall be understood to have the following meanings:

List of Abbreviations

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n-BuOAc *n*-butyl acetate

n-BuLi *n*-butyl lithium

t-Bu *tert*-butyl

t-BuOH *tert*-butanol

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DCM dichloromethane, CH₂Cl₂ or methylenechloride

DMF dimethylformamide

DMSO dimethylsulfoxide

dppf 1,1'-bis(diphenylphosphino)ferrocene

eq equivalent(s)

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Et ethyl

Et₂O diethyl ether

EtOH ethanol

EtOAc ethyl acetate

HPLC high performance liquid chromatography

25

Me methyl

MTBE methyl *t*-butyl ether

MeOH methanol

Na₂CO₃ sodium carbonate

Na₂SO₄ sodium sulfate

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NMR nuclear magnetic resonance

Pd(PPh₃)₄ tetrakis(triphenylphosphine) palladium

Pd(PPh₃)₂Cl₂ bistriphenylphosphine palladium (II) dichloride

PdCl₂dppf 1,1'-bis(diphenylphosphino) ferrocene palladium (II) dichloride

	Pd(dtbpf)Cl ₂	(1,1'-Bis(di- <i>t</i> -butylphosphino)ferrocene palladium dichloride
	Pd ₂ (dba) ₃	tris(dibenzylideneacetone)dipalladium(0)
	Pd(OAc) ₂	palladium(II) acetate
	P(Cy) ₃	tricyclohexylphosphine
5	<i>t</i> -Bu ₃ P	tri- <i>t</i> -butylphosphine
	PPh ₃	triphenylphosphine
	PrOH	propanol
	<i>i</i> -PrOH	<i>iso</i> -propanol
	<i>i</i> -PrOAc	<i>iso</i> -propyl acetate
10	<i>t</i> -BuOK	potassium <i>tert</i> -butoxide
	PPSE	poly-phosphoric acid trimethylsilylester
	rt	room temperature
	R _t	Retention time
	TFA	trifluoroacetic acid
15	TFAA	trifluoroacetic anhydride
	THF	tetrahydrofuran
	TLC	thin layer chromatography

Terms

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“aqueous acid” means an aqueous solution of an inorganic (mineral) acid such as hydrochloric acid, phosphoric acid and the like, or an aqueous solution of an organic acid such as acetic acid and the like.

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“boronation conditions” mean conditions using a superbases, a boronic acid forming agent, boronation solvent, and boronation reaction temperature.

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“superbase” means an extremely strong base, such as combination of an organolithium reagent of formula RLi where R is an alkyl or aryl group having 1-12 carbons and a bulky potassium alkoxide such as potassium *tert*-butoxide or potassium *tert*-pentoxyde and the like.

“boronic acid forming agent” means a trialkyl boronate such as trimethyl borate, triethyl borate, tripropyl borate, triisopropyl borate, tributylborate and the like.

“boronation solvent” means a solvent an ether solvent such as diethyl ether, THF, 2-methyltetrahydrofuran, MTBE, dimethoxyethane and the like

“boronation temperature” means from about –30 to –100 °C.

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“4-halopyridine” means 4-(iodo, bromo or chloro)pyridine, or salt thereof

“Suzuki coupling conditions” mean conditions using a Suzuki coupling solvent, Suzuki coupling catalyst and Suzuki coupling reaction temperature.

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“Suzuki coupling solvent” means an alcohol solvent with a boiling point $\geq$ of isopropyl alcohol, such as *n*-propyl alcohol, *n*-butyl alcohol or the like; polar aprotic solvent such as dimethylformamide, 1-methyl-2-pyrrolidone, dimethylsulfoxide, or the like; ether solvent such as THF, 2-methylTHF, dimethoxyethane, MTBE or the like; or mixture of any of the aforesaid mentioned solvents and water or toluene.

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“Suzuki coupling catalyst” means a Pd catalyst such as $\text{Pd}(\text{PPh}_3)_4$, $\text{Pd}(\text{PPh}_3)_2\text{Cl}_2$, $\text{Pd}_2(\text{dba})_3$, PdCl_2dppf , $\text{Pd}(\text{dtbpf})\text{Cl}_2$, or the like; or Pd catalyst such as $\text{Pd}(\text{OAc})_2$, $\text{Pd}_2(\text{dba})_3$ or the like in conjunction with a phosphine ligand such as PPh_3 , dppf, *t*-Bu₃P, $\text{P}(\text{Cy})_3$ or the like.

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“Suzuki coupling reaction temperature” means a temperature from about 60 °C to about 100°C, the temperature of the boiling point of the Suzuki coupling reaction mixture.

“hydrogenation conditions” means conditions using a hydrogenation catalyst, hydrogenation solvent, hydrogenation reaction temperature, and hydrogenation pressure.

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“hydrogenation reaction solvent” means an ester solvent such as EtOAc, *i*-PrOAc, BuOAc and the like; alcohol solvent such as methanol, ethanol, isopropyl alcohol and the like; or AcOH; or a mixture of an alcohol or ester solvent and water and acetic acid

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“hydrogenation catalyst” means Pt/C, PtO₂, Pd/C, Pd(OH)₂, Rh/C and the like, with or without added inorganic acid such as HCl and the like, or organic acid such as acetic acid and the like.

“hydrogenation reaction temperature” means from about 10 to about 60 °C.

“hydrogenation pressure” means from about 10 to about 1000 psi of hydrogen (upper limit dictated by equipment capability).

5 Particular Embodiments

 In a particular embodiment of the method according to the present invention, the superbase means combination of *n*-butyl lithium and potassium tert-butoxide (“Schlosser base”).

10 In another particular embodiment of the method according to the present invention, “boronation solvent” means THF.

 In another particular embodiment of the method according to the present invention, “boronic acid forming agent” means triisopropyl borate.

15 In another particular embodiment of the method according to the present invention, the boronation temperature is about -70°C to about -45°C.

 In another particular embodiment of the method according to the present invention, the Suzuki coupling solvent is dimethoxyethane.

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 In another particular embodiment of the method according to the present invention, the Suzuki coupling catalyst is Pd(PPh₃)₄.

25 In another particular embodiment of the method according to the present invention, the Suzuki coupling is effected at about 85°C.

 In another particular embodiment of the method according to the present invention, the hydrogenation solvent is EtOAc.

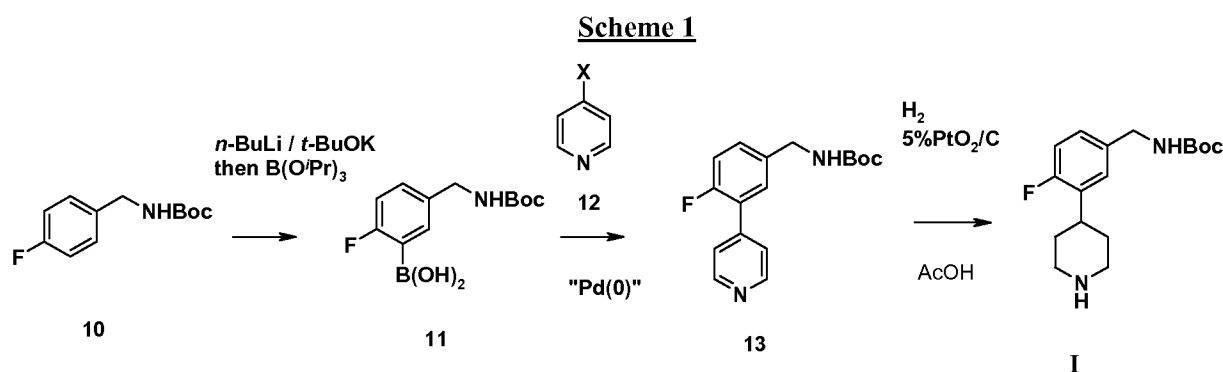
30 In another particular embodiment of the method according to the present invention, the hydrogenation catalyst is Pt/C.

In another particular embodiment of the method according to the present invention, the hydrogenation reaction temperature is at about ambient temperature.

In another particular embodiment of the method according to the present invention, the hydrogenation pressure is from about 10 to about 60 psi.

Preparatory Details

The starting materials for preparing compound I according to Scheme 1 below are commercially available.



4-(tert-Butoxycarbonylaminomethyl)-fluorobenzene (compound 10), prepared according to the method of Tetrahedron 2965, 57, 2001 which is incorporated herein by reference, is reacted with a superbase, in an ether solvent at a sufficiently low temperature as for example from about -100°C to about -30°C. The resultant mixture is reacted with boronic acid forming agent. Quenching the resultant mixture with an aqueous acid provides 5-((tert-butoxycarbonylaminomethyl)-2-fluorophenylboronic acid (compound 11). Compound 11 is reacted with a 4-halopyridine (compound 12) or their hydrohalide salt forms in an alcoholic solvent with a boiling point of at least that of isopropyl alcohol, a polar aprotic solvent or an ether solvent. Compound 11 and compound 12 in mixture of any of the above mentioned solvents and water in the presence of a suitable Suzuki coupling catalyst at Suzuki coupling reaction temperature provides compound 13.

Compound 13 is reduced under hydrogenation conditions to compound I by treatment with hydrogen in the presence of a hydrogenation catalyst, with or without added inorganic acid such as HCl and the like, or organic acid such as acetic acid and the like, in a

hydrogenation reaction solvent; at hydrogenation reaction temperature, and hydrogenation pressure.

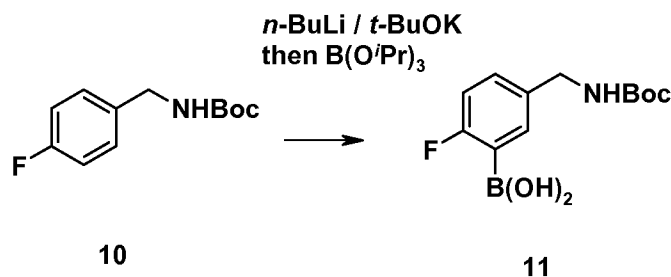
Example

The present invention may be better understood by reference to the following non-limiting Example, which is exemplary of the invention. The following example is presented in order to more fully illustrate a particular embodiment of the invention. They should in no way be construed, however, as limiting the broad scope of the invention.

In the nuclear magnetic resonance spectra (NMR), reported *infra*, the chemical shifts are expressed in ppm relative to tetramethylsilane. Abbreviations have the following significances: br = broad, dd = double doublet, s = singlet; m = multiplet.

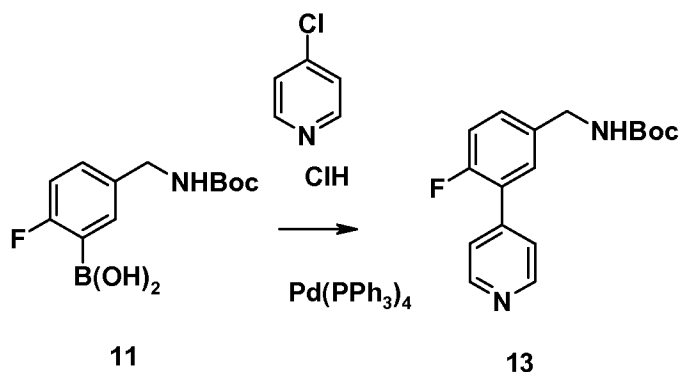
EXAMPLE 1

Step A: Preparation of 5-((tert-Butoxycarbonyl)aminomethyl)-2-fluorobenzeneboronic acid (11)



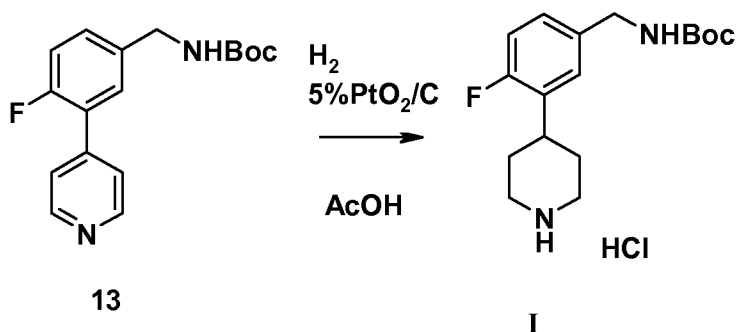
To a mixture of 4-((tert-Butoxycarbonyl)aminomethyl)-fluorobenzene (*Tetrahedron* 2001, 57, page 2965 which is incorporated herein by reference) (2.84 g 12.6 mmol) and *t*-BuOK (2.83 g, 12.6 mmol) in THF (40 mL) at -60 to -70 °C, is added *n*-BuLi (15.75 mL, 1.6 M, 25.2 mmol) over a period of approximately 10 min. The reaction mixture is stirred at this temperature for additional 1.5 h, after which triisopropyl borate (2.37 g, 12.6 mmol) is added. The mixture is allowed to warm to -45 °C, after which it was quenched with 2N aqueous HCl. The reaction mixture is allowed to warm to room temperature with stirring overnight. The resulting suspension is isolated by filtration and dried in a vacuum oven to afford 1.9 g (56 %) of compound 11 as a white solid. ¹H NMR (300 MHz, CDCl₃) δ 7.72 (m, 1H), 7.38 (m, 1H), 7.01 (m, 1H), 5.22 (d, J = 6.1 Hz, 2H), 4.28 (d, J = 5.4 Hz, 2H), 1.45 (s, 9H).

Step B: Preparation of (4-fluoro-3-pyridin-4-yl-benzyl)-carbamic acid *tert*-butyl ester (13)



A mixture of compound 11 (135 mg, 0.5 mmol), 4-chloropyridine hydrochloride (107 mg, 0.713 mmol), tetrakis(triphenylphosphine)palladium (45 mg, 0.04 mmol) and Na₂CO₃ (160 mg, 1.51 mmol) in dimethoxyethane (2.2 mL) and water (0.7 mL) mixture, is heated to 85 °C for 5 h. The mixture is cooled to rt and partitioned between water and EtOAc. The organic phase is dried using Na₂SO₄ and concentrated on rotary evaporator to afford 100 mg (59 %) of compound 13. ¹H NMR (300 MHz, CDCl₃) δ 8.68-8.62 (m, 2H), 7.80-7.42 (m, 2H), 7.40-7.35 (m, 1H), 7.36-7.24 (m, 1H), 7.18-7.08 (m, 1H), 5.26-5.18 (br s, 1H), 4.25 (d, J = 5.5 Hz, 2H), 1.44 (s, 9H).

Step C: Preparation of (4-Fluoro-3-piperidin-4-yl-benzyl)-carbamic acid *tert*-butyl ester hydrochloride (I)



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A mixture of compound 13 (1.25g, 4.1 mmol) and PtO₂ (200 mg) in EtOAc (20 mL) and acetic acid (10 mL) is hydrogenated in a Parr shaker under H₂ (50 psi -60 psi) overnight. *n*-BuOAc is added (40 mL) to the mixture. The resultant suspension is filtered through celite, and concentrated up to around 30 mL of crude solution. The crude solution was introduced to a solution of 2N HCl in ethyl ether (5 mL) and MTBE (35 mL) at 0°C. The resultant solid is collected by filtration followed by washing with an additional MTBE and drying in oven at 50°C to give 0.93 (65%) g of product I as an HCl salt.

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¹H NMR (300 MHz, DMSO-d₆) δ 9.30-9.10 (br s, 2H), 7.44-7.35 (m, 1H), 7.16-7.03 (m, 3H), 4.08 (d, *J* = 6.0 Hz, 2H), 3.31 (br s, 2H), 3.20-2.87 (m, 3H), 1.95-1.80 (m, 4H), 1.39 (s, 9H).

We Claim:

1. A method for preparing 5-((*tert*-butoxycarbonyl)aminomethyl)-2-fluorobenzene-boronic acid, comprising boronation of 4-((*tert*-butoxycarbonyl)aminomethyl)-fluorobenzene with
5 a boronic acid forming agent under boronation conditions, and then quenching the resultant mixture with an aqueous acid to yield 5-((*tert*-butoxycarbonyl)aminomethyl)-2-fluorobenzeneboronic acid.

2. The method of claim 1 wherein the boronation conditions uses a superbase.

3. The method of claim 2 wherein the superbase is a combination of an organolithium reagent of formula RLi where R is an alkyl or aryl group having 1-12 carbons and a bulky potassium alkoxide such as potassium *tert*-butoxide or potassium *tert*-pentoxide and the like.

4. The method of claim 3 wherein the superbase is a combination of *n*-butyllithium and potassium *tert*-butoxide.

5. The method of claim 1 wherein the boronation conditions uses a boronic acid forming agent which is a trialkyl boronate.

6. The method of claim 5 wherein the trialkyl boronate is selected from trimethyl borate, triethyl borate, tripropyl borate, triisopropyl borate, tributylborate and the like.

7. The method of claim 6 wherein the trialkyl boronate is triisopropyl borate.

8. The method of claim 1 wherein the boronation conditions uses a boronation solvent which is an ether solvent selected from diethyl ether, THF, 2-methyltetrahydrofuran, MTBE, dimethoxyethane and the like.

9. The method of claim 8 wherein the ether solvent is THF.

10. The method of claim 1 wherein the boronation conditions uses a boronation reaction temperature from about -100°C to about -30°C.

11. The method of claim 10 wherein the boronation reaction temperature is from about -70 to about -45 °C.

12. The method of claim 1 wherein the aqueous acid is HCl or H₃PO₄.

13. The method of claim 12 wherein the aqueous acid is HCl.

14. A method for preparing (4-fluoro-3-pyridin-4-yl-benzyl)-carbamic acid *tert*-butyl ester comprising coupling 5-((*tert*-butoxycarbonyl)aminomethyl)-2-fluorobenzeneboronic acid according to claim 1 and a 4-halopyridine under Suzuki coupling conditions to yield 4-fluoro-3-pyridin-4-yl-benzyl)-carbamic acid *tert*-butyl ester.

15. The method according to claim 14 wherein the Suzuki coupling conditions uses a Suzuki coupling solvent selected from an alcoholic solvent with a boiling point of at least that of *i*-propyl alcohol, polar aprotic solvent, or ether solvent, or mixture of any of the aforesaid mentioned solvents and water or toluene.

16. The method according to claim 15 wherein the Suzuki coupling solvent is an ether solvent selected from THF, toluene, 2-methylTHF, or dimethoxyethane.

17. The method according to claim 16 wherein the ether solvent is dimethoxyethane.

18. The method according to claim 14 wherein the Suzuki coupling conditions uses a Suzuki catalyst selected from Pd catalyst such as Pd(PPh₃)₄, Pd(PPh₃)₂Cl₂, Pd₂(dba)₃, PdCl₂dppf, Pd(dtbpf)Cl₂, or the like; or Pd catalyst such as Pd(OAc)₂, Pd₂(dba)₃ or the like in conjunction with a phosphine ligand such as PPh₃, dppf, *t*-Bu₃P, P(Cy)₃ or the like, and a strong base.

19. The method according to claim 18 wherein the Suzuki coupling catalyst is Pd(PPh₃)₄.

20. The method according to claim 14 wherein the Suzuki coupling conditions uses a Suzuki coupling reaction temperature of from about 60°C to about 100°C.

21. The method according to claim 20 wherein the Suzuki coupling reaction temperature is at about 85°C.

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22. The method in claim 14 wherein the 4-halopyridine is 4-chloropyridine.

23. A method for preparing (4-fluoro-3-piperidin-4-yl-benzyl)-carbamic acid *tert*-butyl ester hydrochloride (I), comprising reducing (4-fluoro-3-pyridin-4-yl-benzyl)-carbamic acid *tert*-butyl ester according to claim 11 under hydrogenation reducing conditions, and then followed by HCl work-up to yield fluoro-3-piperidin-4-yl-benzyl)-carbamic acid *tert*-butyl ester hydrochloride.

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24. The method according to claim 18 wherein the hydrogenation reducing conditions uses a hydrogenation catalyst selected from Pt/C, PtO₂, Pd/C, Pd(OH)₂, Rh/C and the like, with or without added inorganic acid such as HCl and the like, or organic acid such as acetic acid and the like.

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25. The method according to claim 24 wherein the hydrogenation catalyst is PtO₂.

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26. The method according to claim 18 wherein the hydrogenation reducing conditions uses a hydrogenation solvent selected from an ester solvent such as EtOAc, *i*-PrOAc, BuOAc and the like; alcohol solvent such as methanol, ethanol, isopropyl alcohol and the like; or AcOH; or a mixture of an alcohol or ester solvent and water and acetic acid.

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27. The method according to claim 26 wherein the hydrogenation solvent *i*-PrOAc.

28. The method according to claim 18 wherein the hydrogenation reducing conditions uses a hydrogenation reaction temperature from about 10 to about 60 °C.

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29. The method according to claim 18 wherein the hydrogenation reaction temperature is at about ambient temperature.

30. The method according to claim 18 wherein the hydrogenation reducing conditions uses a hydrogenation pressure from about 10 to about 1000 psi.

31. The method in claim 30 wherein the hydrogenation pressure is from about 50 to about
5 60 psi.