

METHODS OF PREPARING ICOTINIB AND ICOTINIB HYDROCHLORIDE, AND INTERMEDIATES THEREOF

FIELD OF THE INVENTION

The present invention relates to the technical field of medicine, and in particular to preparation methods of Icotinib intermediates, Icotinib and Icotinib hydrochloride.

BACKGROUND OF THE INVENTION

Tyrosine kinase receptors are trans-membrane proteins involved in signal conversion. They propagate growth factor signals, which cascade to control cell proliferation, mutation, angiogenesis, apoptosis and other important features, from the surface of cellular to inner cellular. One class of such tyrosine kinase receptors, epidermal growth factor receptor (EGFR) tyrosine kinases, are over-expressed in many human tumor or cancers, including tumor or cancers of brain, lung, liver, bladder, chest, head and neck, esophagus, gastrointestinal track, breast, ovary, cervix, or thyroid.

EGFR is expressed in many types of tumor cells. After binding with its ligands including epidermal growth factor (EGF) or Transforming Growth Factor- α (TGF- α), EGFR activates tyrosine kinases in cytoplasmic domains and results in phosphorylation of the tyrosine at EGFR hydroxyl terminal. Then, EGFR controls multiple gene transcription through different signal transduction channels, thereby regulating cell proliferation, differentiation, and apoptosis. EGFR is closely related to tumor metastasis, vascular proliferation, and chemotherapy drug resistance.

Various molecular and cellular biology and clinical studies have demonstrated or proved that EGFR kinase inhibitor can block EGFR signal transductions related to cancer cell proliferation, metastasis and others responses, and thus achieve clinical anti-tumor therapeutic effects.

Two oral EGFR kinase inhibitors with similar chemical structures are Gefitinib (Iressa, AstraZeneca), approved by the U.S. FDA for advanced non-small cell lung cancer treatment in 2003, and Erlotinib Hydrochloride (Tarceva, Roche and OSI), approved by the U.S. FDA for advanced non-small cell lung cancer and pancreatic cancer treatment in 2004.

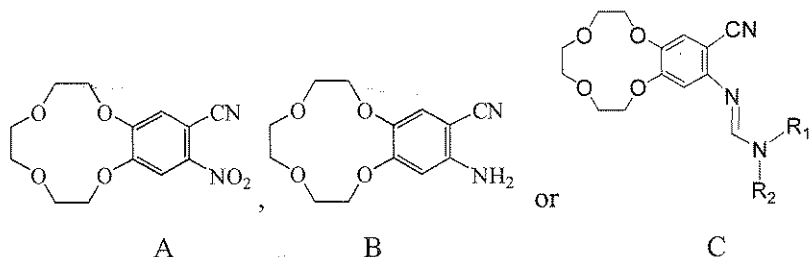
EGFR tyrosine kinase inhibitor (TKI) is a popular research field of a new generation of targeted anti-tumor drug in the world. US7078409B2 and CN130568C disclose preparation methods of Icotinib, and WO2010/003313 discloses a preparation method of Icotinib hydrochloride. However, the preparation methods

disclosed by US7078409B2 and CN130568C require use of highly toxic reagent, i.e., Chlorinating agent, such as $(\text{COCl})_2$ or phosphorus oxychloride. These highly toxic Chlorinating agents, especially Chlorinating agent containing phosphorus, are very difficult or costly to be completely removed in the later reactions. Therefore, the existing synthetic methods not only are very costly but also cause severe environment pollution problems, and present a significant threat to the health of producers and users. The preparation method disclosed in WO2010/003313 uses metal catalysts, which are also costly and difficult to be separated or recovered. Furthermore, any direct emission of such metal and phosphine ligand will cause severe environment pollutions.

The intermediary compounds designed by the present invention are used for preparing Icotinb or Icotinib hydrochloride. These preparation methods avoid use of high-toxic reagents, proceed in mild reaction conditions, and thus are easier, more economic, lower-toxic and safer than synthetic methods currently known in the art.

Summary of the Invention

In one aspect, there is provide a compound of formula **A**, **B**, or **C**:

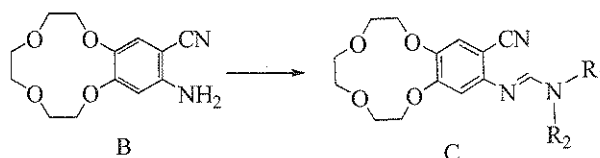


wherein:

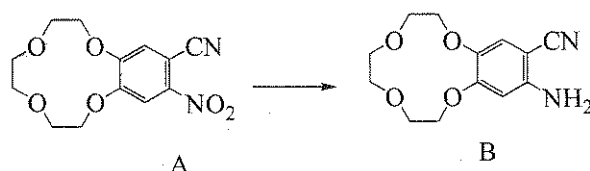
each of R_1 and R_2 independently is methyl, ethyl, propyl, or isopropyl; or

R_1 and R_2 , together with the N atom to which they are attached, form a 3 to 7-membered ring.

In one aspect, there is provide a method for preparing a compound as described herein, wherein compound **C** is prepared from compound **B**, and the method comprises the step of:



In one aspect, there is provide a method for preparing a compound as described herein, wherein compound **B** is prepared from compound **A**, and the method comprises the step of:



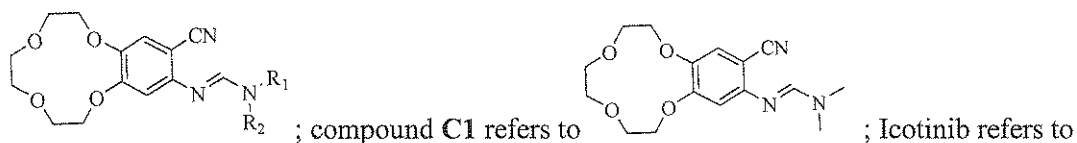
In one aspect, there is provide a method for preparing Icotinib from a compound as described herein, wherein the reaction between compound C and m-aminophenyl acetylene occurs in an organic acid.

In one aspect, there is provide a method for preparing Icotinib hydrochloride from a compound as described herein, wherein compound C is a raw material, and the method comprises using a method as described herein to prepare Icotinib, dissolving the Icotinib in a lower alcohol, adding hydrogen chloride gas or hydrochloric acid while stirring, and then filtering the Icotinib after the reaction is complete.

DESCRIPTION OF THE INVENTION

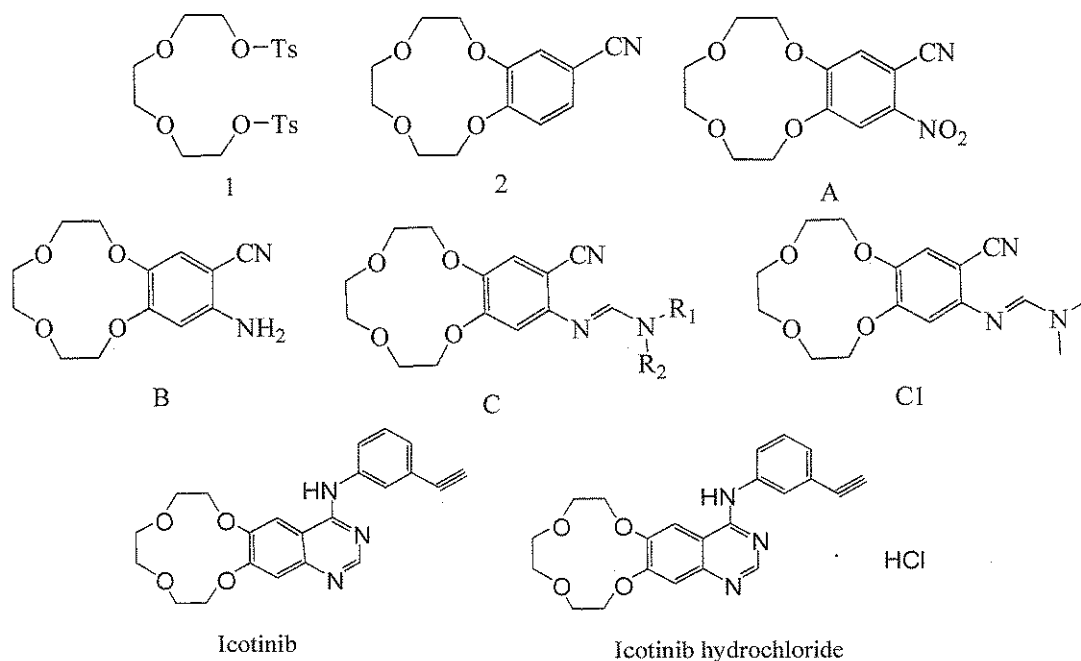
The present invention overcomes the problems of the existing technology and provides methods for preparing intermediates of Icotinib, i.e., compound A, compound B, and compound C, as well as methods for preparing Icotinib and Icotinib hydrochloride using those intermediates. These methods are more environmental friendly and economic, and can proceed in relatively mild reaction conditions and reduce environment pollutions.

For the convenience of illustration in the present application, compound 1 refers to 1,8-bis-(para-toluenesulfonate)-3,6-dioxo-octane; compound 2 refers to 3,4-benzo-12-crown-4-benzonitrile; compound A refers to 6-nitro-3,4-benzo-12-crown-4-benzonitrile; compound B refers to 6-amino-3,4-benzo-12-crown-4-benzonitrile; compound C refers to

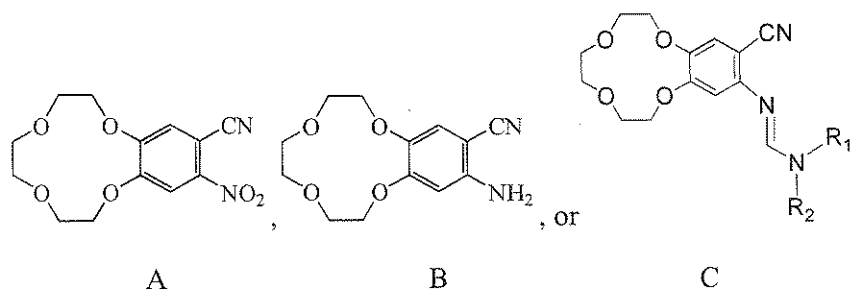


4-[(3-ethynylphenyl)amino]-quinazoline and [6,7-b]-12-crown-4; Icotinib refers to 4-[(3-ethynylphenyl)amino]-quinazoline and [6,7-b]-12-crown-4 hydrochloride. For these compounds, compound A can be used to prepare compound B, compound B can be used to prepare compound C, compound C can be used to prepare Icotinib or Icotinib hydrochloride, and all of the compounds A, B,

and C can be used to prepare Icotinib and Icotinib hydrochloride. Chemical structures of Compounds 1, 2, A, B, C, and C1, Icotinib and Icotinib hydrochloride are shown below, respectively:



The present invention firstly provides a compound of formula A, B or C:



wherein,

each R₁ and R₂ independently is methyl, ethyl, propyl, or isopropyl; or,

R₁ and R₂, together with the N atom to which they are attached, form a 3 to 7-membered ring.

Preferably, each of R₁ and R₂ independently is methyl or ethyl.

The present invention further provides some preferred technical solutions with regard to compound C:

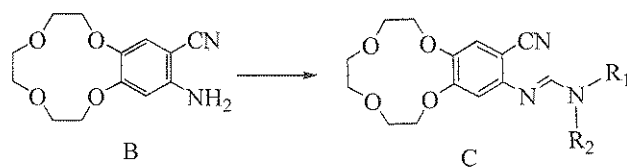
Preferably, R₁ and R₂ are both methyl.

Preferably, R₁ and R₂ are both ethyl.

Preferably, R₁ and R₂, together with the N atom to which they are attached, form a 3, 4 or 5-membered ring.

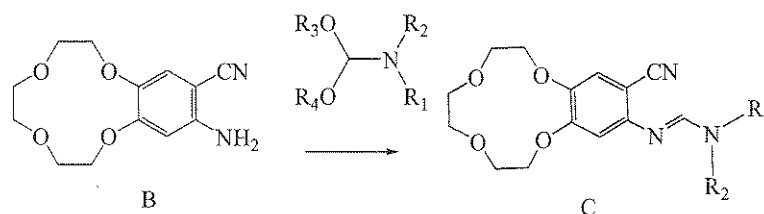
Preferably, R_1 and R_2 , together with the N atom to which they are attached, form a 5, 6 or 7-membered ring.

The present invention further provides a method for preparing a compound of formula **C**, wherein compound **C** is prepared from compound **B**, and the method comprises the following step:



The present invention further provides some preferred technical solutions for the preparation method of a compound of formula **C**.

Preferably, the methods comprise the following step:



wherein,

each of R_3 and R_4 independently is methyl, ethyl, propyl, isopropyl, n-butyl, sec-butyl, tert-butyl, isobutyl, or benzyl; or

R_3 and R_4 form a 3 to 7-membered ring.

Preferably, each of R_3 and R_4 independently is methyl, ethyl, isopropyl, tert-butyl, or benzyl.

Preferably, R_3 and R_4 are both methyl.

Preferably, R_3 and R_4 are both ethyl.

Preferably, compound **B** and $\begin{array}{c} R_4O \\ | \\ CH-N \\ / \quad \backslash \\ R_3O \quad R_2 \end{array} R_1$ react in dioxane or toluene under reflux state.

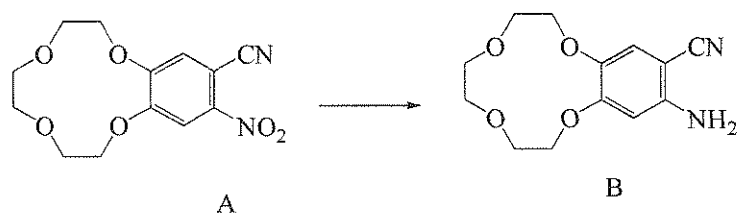
Preferably, the molar ratio of compound **B** and $\begin{array}{c} R_4O \\ | \\ CH-N \\ / \quad \backslash \\ R_3O \quad R_2 \end{array} R_1$ is 1:1.5 to 1:2.8.

Preferably, the molar ratio of compound **B** and $\begin{array}{c} R_4O \\ | \\ CH-N \\ / \quad \backslash \\ R_3O \quad R_2 \end{array} R_1$ is 1:2.0 to 1:2.5.

Preferably, 11-30 mmol of compound **B** and 25-67 mmol of $\begin{array}{c} R_4O \\ | \\ CH-N \\ / \quad \backslash \\ R_3O \quad R_2 \end{array} R_1$ react in 140-180mL of dioxane for 10-15 hours under reflux state.

Preferably, $\begin{array}{c} \text{R}_4\text{O} \\ | \\ \text{CH}-\text{N} \\ | \quad | \\ \text{R}_3\text{O} \quad \text{R}_1 \\ \quad \quad \text{R}_2 \end{array}$ is N,N-dimethylformamide dimethyl acetal, N,N-dimethylformamide diethyl acetal, or N,N-dimethylformamide di-tert-butyl acetal.

The present invention further provides a method for preparing a compound of formula **B**, wherein the compound of formula **B** is prepared from a compound of formula **A**, and the method comprises the following step:



The present invention further provides some preferred technical solutions for the preparation method of a compound of formula **B**:

Preferably, compound **A** reacts with proton-donating agent, metal hydrides, hydrazine, or alkali metal ammonia solution via catalytic hydrogenation reaction or metal-involved reduction reaction; the metal is Mg, Al, Zn, Fe, Sn, Pb, or Cu; the proton-donating agent is Acetic acid, formic acid, and/or trifluoroacetic acid; the catalyst applied in catalytic hydrogenation reaction is palladium/carbon or raney nickel; the metal hydride is sodium hydride or potassium hydride; and the alkali metal is sodium or potassium.

Preferably, compound **A**, ferrous powder, and solution of acetic acid in methanol are fully mixed and heated to reflux until the reaction is complete.

Preferably, 85mmol-0.2mol of compound **A**, 0.45-0.71mol of ferrous powder, and 900-1200mL of acetic acid in methanol solution are fully mixed and then heated to reflux until the reaction is complete. As for the solution of acetic acid in methanol, the mass percentage of acetic acid is 3-7%.

The present invention also provides a method for preparing Icotinib, where compound **C** and m-aminophenyl acetylene react in an organic acid.

The present invention further provides some preferred technical solutions for the preparation method of Icotinib:

Preferably, the molar ratio of compound **C** and m-aminophenyl acetylene is 1:1 to 1:2.

Preferably, the molar ratio of compound **C** and m-aminophenyl acetylene is 1:1 to 1:1.5.

Preferably, the organic acid is acetic acid, formic acid, and/or trifluoroacetic acid.

Preferably, compound **C**, m-aminophenyl acetylene, and the organic acid are fully mixed and then react at 70-150°C.

Preferably, the reaction temperature is 90-120°C and the organic acid is acetic acid.

Preferably, N,N-dimethyl-N'-(6-cyano-3,4-benzo-12-crown-4)formamidine, m-aminophenyl acetylene and the acetic acid are fully mixed and then react at 70-150°C.

Preferably, 9-25mmol of N,N-dimethyl-N'-(6-cyano-3,4-benzo-12-crown-4) formamidine, 15-21mmol of m-aminophenyl acetylene, and 150-320mL of acetic acid are fully mixed and then react at 90-120°C.

Preferably, 12-20mmol of N,N-dimethyl-N'-(6-cyano-3,4-benzo-12-crown-4) formamidine, 17-20mmol of m-aminophenyl acetylene, and 200-260mL of acetic acid are fully mixed and then react at 95-105°C.

The present invention provides a method for preparing Icotinib hydrochloride. Icotinib can be prepared from compound C according to the methods described in the present invention. Then, the resulting Icotinib is dissolved in a lower alcohol, and hydrogen chloride (gas or liquid) is added while stirring. After the reaction is complete, the reaction mixture is filtrated.

The present invention further provides some preferred technical solutions for the preparation method of Icotinib hydrochloride:

Preferably, the lower alcohol is methanol, ethanol, and/or isopropanol.

Preferably, the amount of Icotinib is 1.3-2.6mmol; the lower alcohol is methanol, the volume of which is 30-60mL.

Preferably, the amount of Icotinib is 1.8mmol; the lower alcohol is methanol, the volume of which is 40mL.

As used herein, the term "proton-donating agent" refers to solvents that can offer proton, such as formic acid, acetic acid, trifluoroacetic acid, etc.

As used herein, the term "lower alcohol" refers to C₁-C₄ straight-chain or branched-chain unit or polyol, such as methanol, ethanol, propanol, isopropanol, butanol, or ethylene glycol, etc.

As used herein, the term "R₁ and R₂, together with the N atom to which they are attached" means that R₁ and R₂ can join together (with the nitrogen atom attached to them) to form a 3 to 7-membered ring.

As used herein, the term "R₃ and R₄ form a 3 to 7-membered ring" means that R₃ and R₄ can join together (together with the oxygen atom attached to R₃, the carbon atom, and the oxygen atom attached to R₄) to form a 3 to 7-membered ring.

As used herein, the term "compound" refers to a compound or a pharmaceutically acceptable salt or solvate thereof.

The novel methods provided by the present invention can be a substitute for the methods disclosed in US7078409B2, CN130568C and WO2010/003313. Currently, the production of TKI type medicine is large. Our novel methods do not use high-toxic materials, and greatly reduce the emission of pollutants and environment pollution, thereby leading to significant economic benefits.

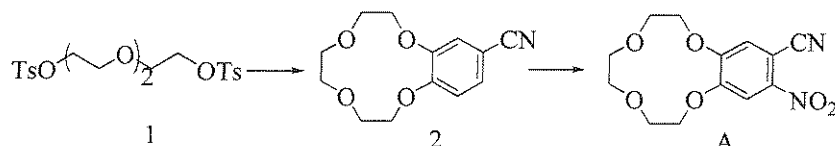
EXAMPLES

The present invention is further exemplified, but not limited to, by the following examples, which only aims to illustrate the preparation methods.

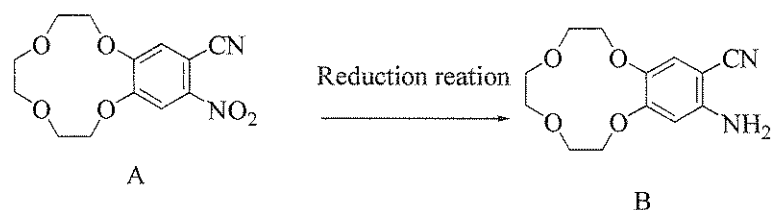
In the examples of the present invention, which only illustrate the embodiments to help people skilled in the art fully understand the invention but not restrict it. The techniques or methods of the embodiments in the present invention, unless expressly stated otherwise, are conventional techniques and methods in the art.

General Synthetic Scheme

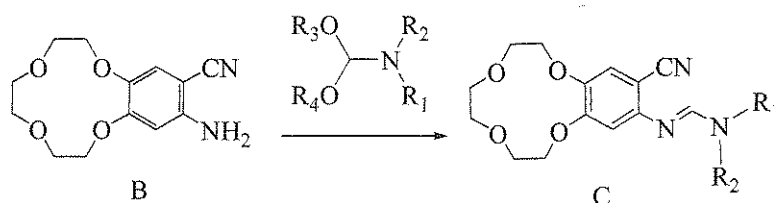
Compound **A** provided by the present invention can be prepared, but not limited to, by the following synthetic scheme:



Compound **B** provided by the present invention can be prepared, but not limited to, by the following synthetic scheme:



Compound **C** provided by the present invention can be prepared, but not limited to, by the following synthetic scheme:



wherein,

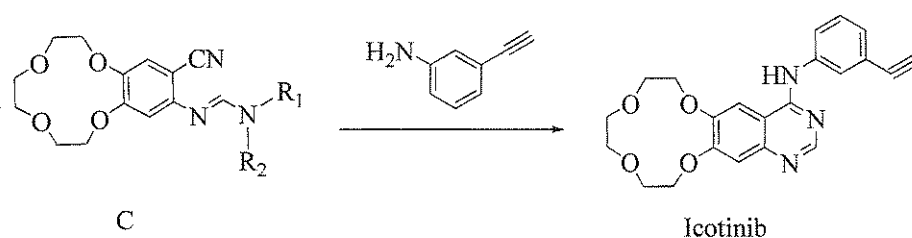
each of R₁ and R₂ independently is methyl, ethyl, propyl, or isopropyl; or

R₁ and R₂, together with the N atom to which they are attached, form a 3 to 7-membered ring.

each of R₃ and R₄ independently is selected from methyl, ethyl, propyl, isopropyl, n-butyl, sec-butyl, tert-butyl, isobutyl, and benzyl; or

R₃ and R₄ together form a 3 to 7-membered ring.

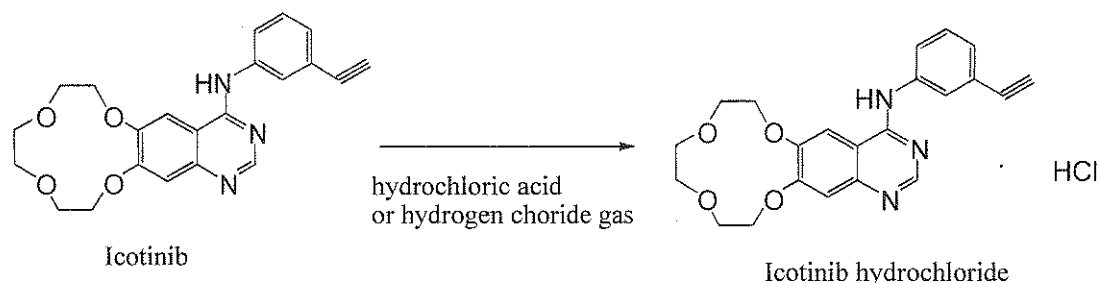
Compound **C** provided by the present invention can be used for the direct synthesis of Icotinib:



wherein,

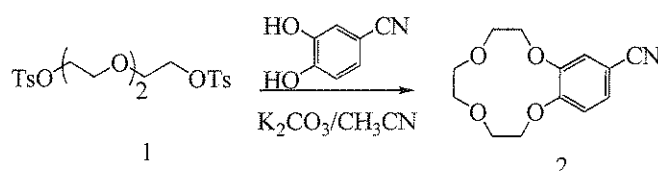
each of R_1 and R_2 independently is selected from methyl, ethyl, propyl, and isopropyl; or R_1 and R_2 , together with the N atom to which they are attached, form a 3 to 7-membered ring.

Icotinib hydrochloride can be prepared by a reaction between Icotinib and hydrochloric acid or hydrogen chloride gas:



Example 1 Synthesis of compound A

1. Synthesis of compound 2

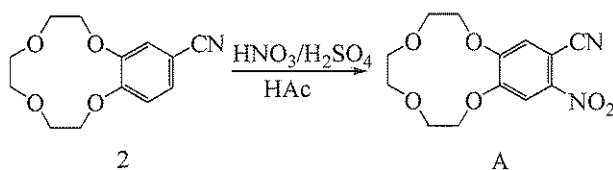


3,4-dihydroxyphenyl nitrile (79.5g), potassium carbonate (272g), and acetonitrile (6L) were added into the 10L of three-necked reaction flask. The reaction mixture was stirred to dissolve and heated to reflux. Then acetonitrile solution of compound 1 (compound 1, 200g; acetonitrile, 2L) was dropwise added under reflux condition. After its completion by HPLC monitoring, the reaction mixture was cooled to room temperature, filtered to remove the solvent. The resulting solid was dissolved in ethyl acetate and filtered. The filtrate was concentrated, and the remainder was dissolved in petroleum ether and evaporated. The residue was purified to give compound 2 (18.9g).

^1H NMR (CDCl_3 - δ ppm): 7.30~7.33 (m, 1H); 7.25 (s, 1H); 6.97-6.99 (d, 1H); 4.19~4.23 (m, 4H); 3.83~3.91 (m, 4H); 3.77 (s, 4H).

MS: $(\text{M}+\text{H})^+ 250$

2. Synthesis of compound A

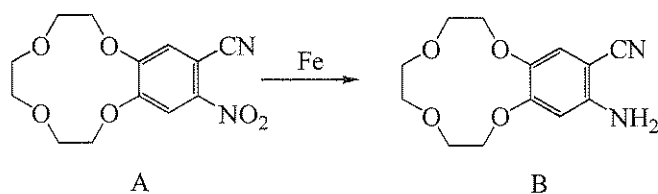


Compound 2 (41.6g) was dissolved in acetic acid (580mL) and heated to 30°C, fuming nitric acid

(83mL) was dropwise added to the solution. Then the concentrated sulfuric acid (42mL) was dropwise added. The reaction mixture was cooled to room temperature and reacted overnight. After the reaction was complete by TLC monitoring, the reaction solution was spread into ice water (4L) till precipitate appeared, filtrated, and the solid was washed with cold water (500mL×2), and dried in vacuum at 35°C to give crude products of compound A (46g), which was then purified by recrystallization with isopropanol to give compound A (33g).

¹HNMR (CDCl₃-δppm): 7.90 (s, 1H); 7.36 (s, 1H); 4.33~4.36 (m, 4H); 3.87~3.89 (m, 4H); 3.737 (s, 4H).

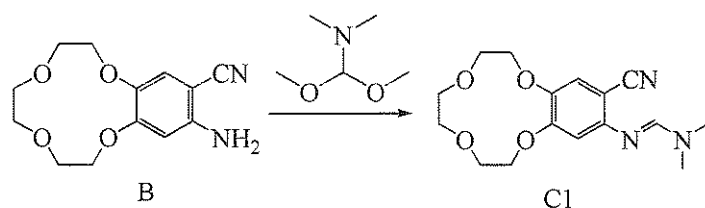
Example 2 Synthesis of compound B



Compound A (32g), ferrous powder (30.5g), 5% acetic acid in methanol solution (1070mL) were added into 2L of reaction flask and heated to reflux. The reaction mixture was cooled and concentrated after the reaction was complete by TLC monitoring. The concentrated reaction solution was dissolved in ethyl acetate, filtrated and dried by anhydrous sodium sulfate (Na₂SO₄), the solvent was removed to give compound B (23g).

¹HNMR (d₆-DMSO-δppm): 7.07 (s, 1H); 6.36 (s, 1H); 5.73 (s, 2H); 3.95~4.22 (m, 4H); 3.77~3.78(m, 2H); 3.34~3.62 (m, 6H).

Example 3 Synthesis of compound C1

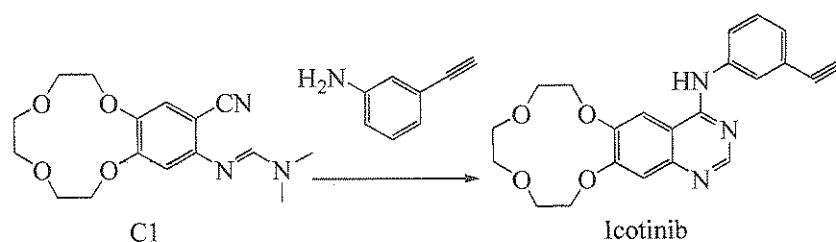


Compound B (5g), N,N-dimethylformamide dimethyl acetal (5g), and dioxane (160mL) were added

into 500mL of three-necked flask, heated to reflux, and the reaction was monitored by TLC. The mixture was reacted for 12 hours. After its completion, the reaction solution was cooled to room temperature and evaporated to give compound **C1** (5.8g).

^1H NMR (CDCl_3 - δ ppm): 7.56 (s, 1H); 7.15 (s, 1H); 6.51 (s, 1H); 4.12~4.18 (m, 4H); 3.89~3.91 (m, 2H); 3.78~3.80 (m, 6H); 3.07 (s, 6H)

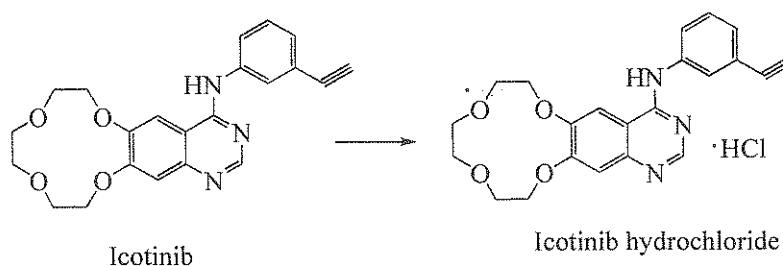
Example 4 Synthesis of Icotinib



Compound **C1** (5g), m-aminophenyl acetylene (2.2g), and acetic acid (230mL) were added into 500mL of reaction flask, heated to 100°C, and the reaction was monitored by TLC. After its completion, the reaction mixture was evaporated, methanol was added, and then the mixture was shock dispersed, filtrated, and washed with methanol to give Icotinib (5g).

^1H NMR (d_6 -DMSO- δ ppm): 11.98 (s, 1H); 9.50 (s, 1H); 8.53 (s, 1H); 8.14 (s, 1H); 8.04~8.05 (m, 1H); 7.90~7.92 (m, 1H); 7.38~7.42 (m, 1H); 7.31 (s, 1H); 7.20~7.22 (m, 1H); 4.29~4.30 (m, 4H); 4.21 (s, 1H); 3.74~3.81 (m, 4H); 3.64 (s, 4H); 1.91 (s, 3H);

Example 5 Synthesis of Icotinib hydrochloride

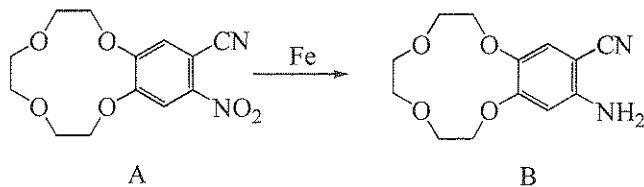


Icotinib (700mg) and methanol (40mL) were added into 100mL of reaction flask, hydrogen chloride gas or concentrated hydrochloric acid was added while stirring. After its completion, the reaction mixture was filtrated to give crude products of Icotinib hydrochloride, which was then purified by recrystallization with isopropanol to give Icotinib hydrochloride (760mg).

^1H NMR (d_6 -DMSO- δ ppm): 11.37 (s, 1H); 8.87 (s, 1H); 8.63 (s, 1H); 7.90 (s, 1H); 7.78~7.80 (d,

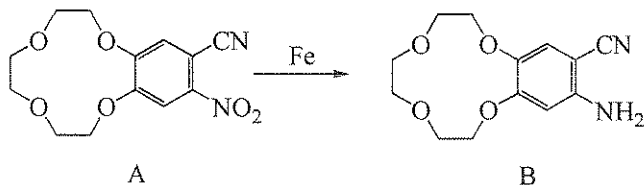
1H); 7.48~7.52 (m, 1H); 7.40~7.41 (m, 2H); 4.36~4.38 (d, 4H); 4.30 (s, 1H); 3.75~3.81 (d, 4H); 3.61 (s, 4H);

Example 6 Synthesis of compound B



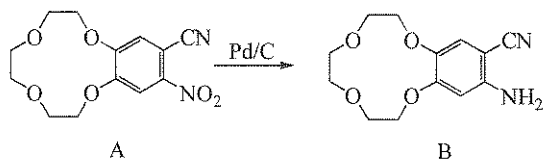
Compound A (25g), ferrous powder (25g), and 3% acetic acid in methanol solution (900mL) were used, and the others were the same as described in Example 2 to give compound B (16.6g).

Example 7 Synthesis of compound B



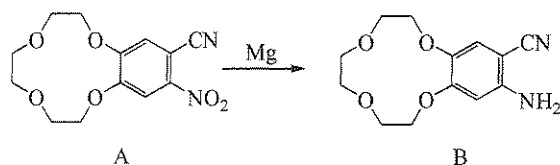
Compound A (40g), ferrous powder (40g), and 7% acetic acid in methanol solution (1200mL) were used, and the others were the same as described in Example 2 to give compound B (28.4g).

Example 8 Synthesis of compound B



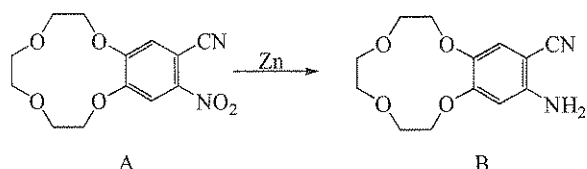
Compound A (25g), Pd/C (5g), and 3% acetic acid in methanol solution (900mL) were added into 2L of reaction flask, hydrogen gas was added, and the reaction was monitored by TLC. After its completion, the reaction mixture was filtrated, and the solvent was removed to give compound B (17g).

Example 9 Synthesis of compound B



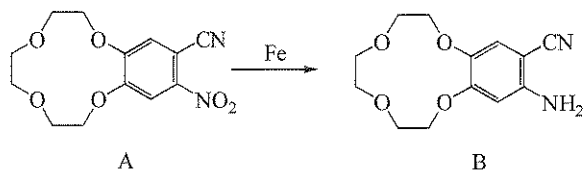
Compound **A** (40g), magnesium ribbon (17g), and 5% acetic acid in methanol solution (1200mL) were used, and the others were the same as described in Example 2 to give compound **B** (25.2g).

Example 10 Synthesis of compound B



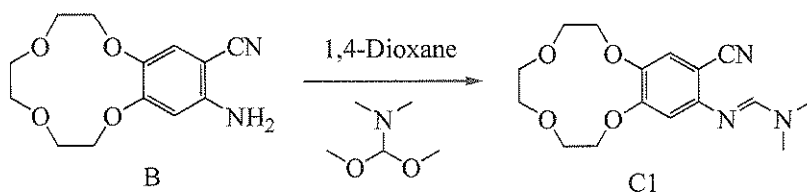
Compound **A** (25g), zinc powder (32.5g) and 5% acetic acid in methanol solution (900mL) were used, and the others were the same as described in Example 2 to give compound **B** (17.1g).

Example 11 Synthesis of compound B



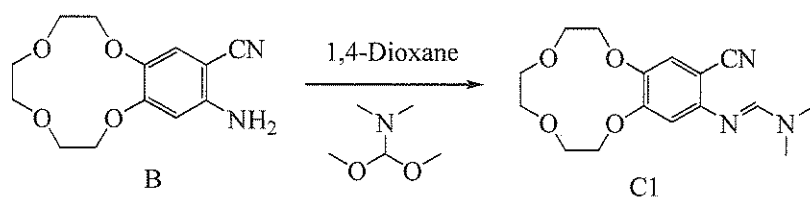
Compound **A** (25g), ferrous powder (28g) and 5% trifluoroacetic acid in methanol solution (700mL) were used, and the others were the same as described in Example 2 to give compound **B** (16g).

Example 12 Synthesis of compound C1



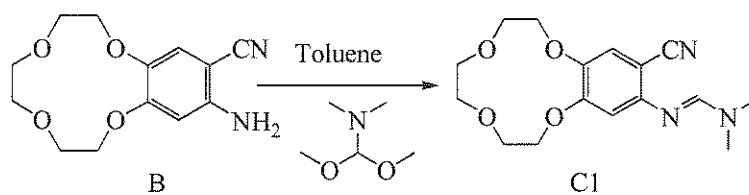
Compound **B** (3g), *N,N*-dimethylformamide dimethyl acetal (3g), dioxane (140mL) were used, the time of reflux was 10-11 hours, and the others were the same as described in Example 3 to give compound **C1** (3.2g).

Example 13 Synthesis of compound C1



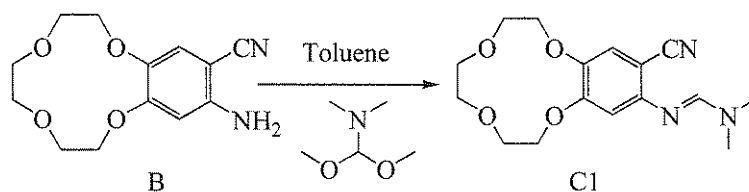
Compound **B** (8g), N,N-dimethylformamide dimethyl acetal (8g), dioxane (180mL) were used, the time of reflux was 12-13 hours, and the others were the same as described in Example 3 to give compound **C** (8.7g).

Example 14 Synthesis of compound C1



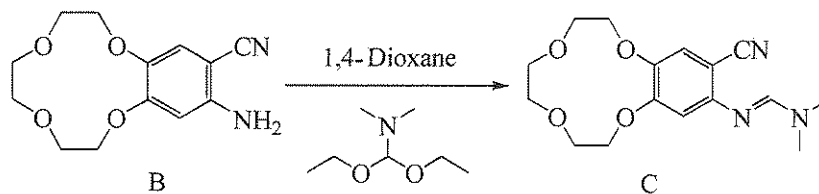
Compound **B** (3g), N,N-dimethylformamide dimethyl acetal (3g), toluene (140mL) were used, the time of reflux was 13-15 hours, and the others were the same as described in Example 3 to give compound **C1** (2.9g).

Example 15 Synthesis of compound C1



The reaction time was 10 hours, and the others were the same as described in Example 14 to give compound **C1** (2.6g).

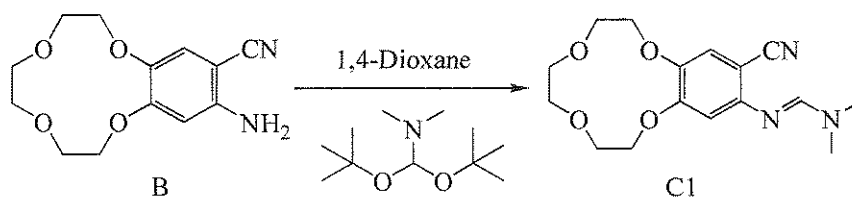
Example 16 Synthesis of compound C1



Compound **B** (3g), N,N-dimethylformamide diethyl acetal (3.7g) and dioxane (140mL) were added into 500mL of three-necked flask, heated to reflux, and the reaction was monitored by TLC. The reaction time was about 11-12 hours. After its completion, the reaction mixture was cooled to room

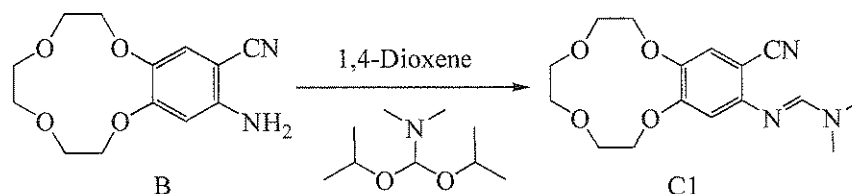
temperature and evaporated to give compound **C1** (2.5g).

Example 17 Synthesis of compound C1



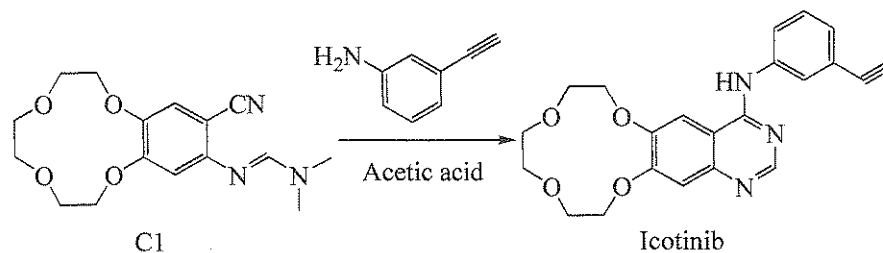
Compound **B** (3g) and N,N-Dimethylformamide di-t-butyl-acetal (5.1g) were dissolved in dioxane (140mL), heated to reflux, and the reaction was monitored by TLC. The reaction time was about 11-12 hours. After its completion, the reaction mixture was cooled to room temperature and evaporated to give compound **C1** (2.6g).

Example 18 Synthesis of compound C1



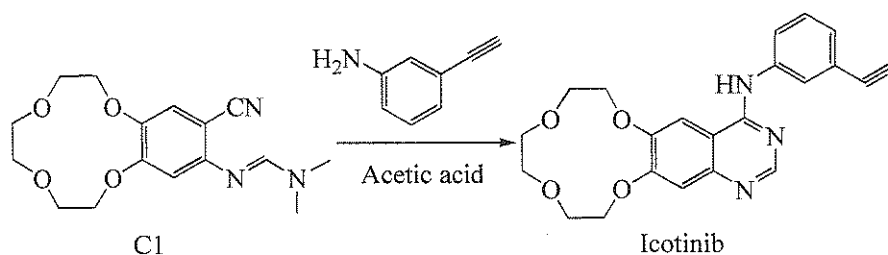
Compound **B** (3g) and N,N-dimethylformamide diisopropyl acetal (4.4g) were dissolved in dioxane (140mL), heated to reflux, and the reaction was monitored by TLC. The reaction time was about 11-12 hours. After its completion, the reaction mixture was cooled to room temperature and evaporated to give compound **C1** (2.4g).

Example 19 Synthesis of Icotinib



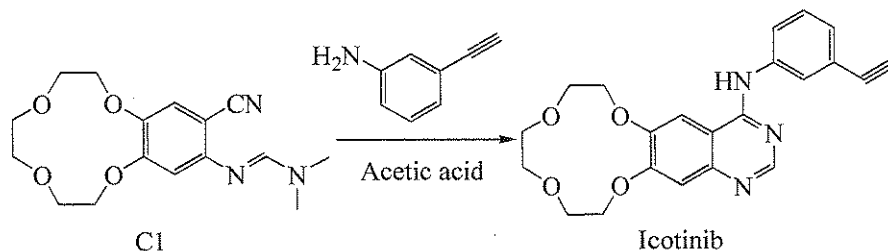
Compound **C1** (3g), m-aminophenyl acetylene (1.3g), and acetic acid (130mL) were added into 250mL of reaction flask, heated to 70-80°C, and the reaction was monitored by TLC. After its completion, the reaction mixture was evaporated, methanol was added, and then the mixture was shock dispersed, filtrated, and washed with methanol to give Icotinib (2.8g).

Example 20 Synthesis of Icotinib



Compound C1 (8g) and m-aminophenyl acetylene (3.5g) were dissolved in acetic acid (380mL), heated to 100-120°C, and the reaction was monitored by TLC. After its completion, the reaction mixture was evaporated, ethanol was added, and then the mixture was shock dispersed, filtrated, and washed with ethanol to give Icotinib (7.2g).

Example 21 Synthesis of Icotinib

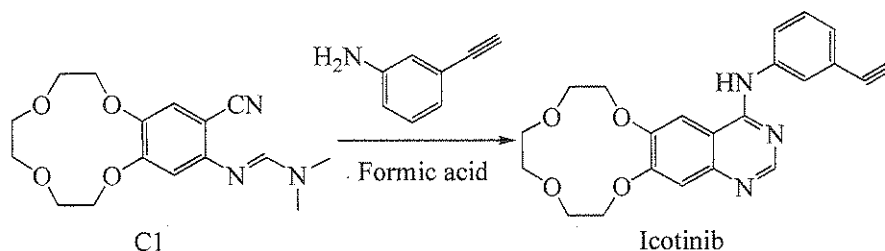


The reaction temperature was 120-150°C, and the others were the same as described in Example 4 to give Icotinib (2.2g).

Example 22 Synthesis of Icotinib

Compound C1 (3g), m-aminophenyl acetylene (1.8g), and acetic acid (130mL) were added into 250mL of reaction flask, heated to 90-100°C, and the reaction was monitored by TLC. After its completion, the reaction mixture was evaporated, isopropanol was added, and the mixture was then shock dispersed, filtrated, and washed with isopropanol to give Icotinib (2.9g).

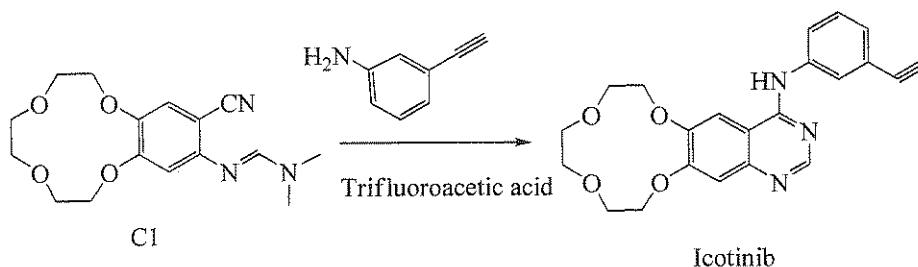
Example 23 Synthesis of Icotinib



Compound C1 (3g) and m-aminophenyl acetylene (1.3g) were dissolved in formic acid (130mL),

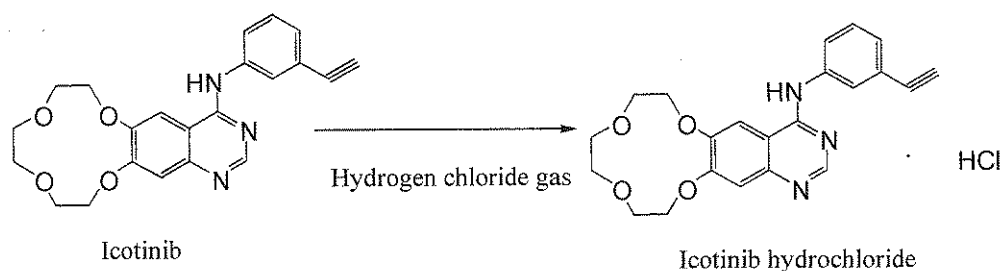
heated to 80-90°C, and the reaction was detected by TLC. After its completion, the reaction mixture was evaporated, methanol was added, and then the mixture was shocked dispersed, filtrated, and washed with methanol to give Icotinib (2.7g).

Example 24 Synthesis of Icotinib



Compound C1 (3g) and m-aminophenyl acetylene (1.3g) were dissolved in trifluoroacetic acid (130mL), heated to 70-80°C, and the reaction was monitored by TLC. The reaction system was evaporated, methanol was added, and then the mixture was shock dispersed, filtrated, and washed with methanol to give Icotinib (2.7g).

Example 25 Synthesis of Icotinib hydrochloride

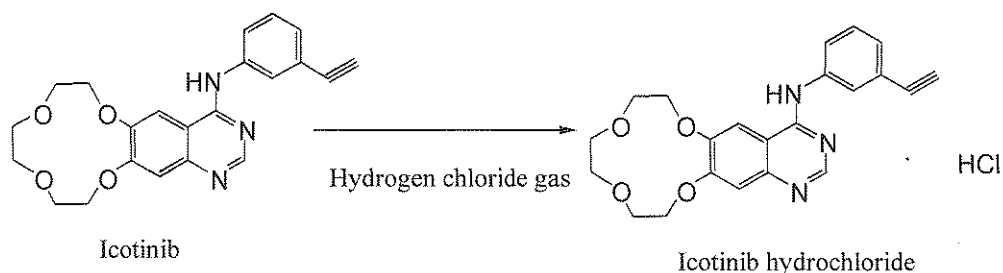


Icotinib (500mg) was added into 100mL of reaction flask and 30mL of ethanol was added. Hydrogen chloride gas was added while stirring. After its completion, the reaction mixture was filtered to give crude product of Icotinib hydrochloride. The crude product was further purified by recrystallization with isopropyl alcohol to give Icotinib hydrochloride (515mg).

Example 26 Synthesis of Icotinib hydrochloride

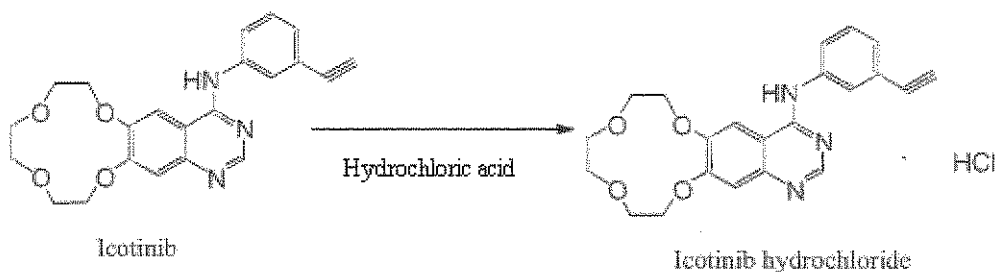
Icotinib (500mg) was added into 100mL of reaction flask and 40mL of THF was added. Hydrogen chloride gas was added while stirring. After its completion, the reaction mixture was filtered to give crude product of Icotinib hydrochloride. The crude product was further purified by recrystallization with isopropyl alcohol to give Icotinib hydrochloride (500mg).

Example 27 Synthesis of Icotinib hydrochloride



Icotinib (500mg) was added into 100mL of reaction flask and 50mL of isopropyl alcohol was added. Hydrogen chloride gas was added while stirring. After its completion, the reaction mixture was filtered to give crude product of Icotinib hydrochloride. The crude product was further purified by recrystallization with isopropyl alcohol to give Icotinib hydrochloride (500mg).

Example 28 Synthesis of Icotinib hydrochloride

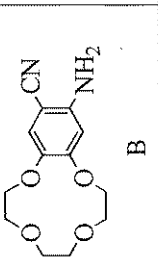
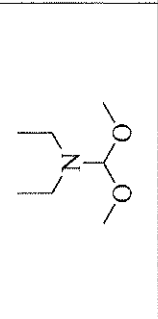
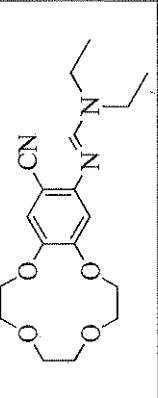
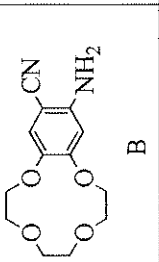
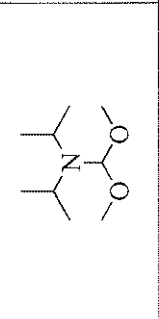
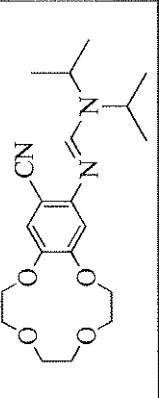
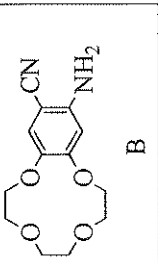
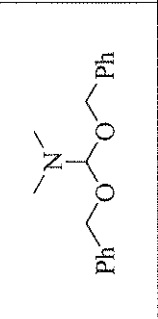
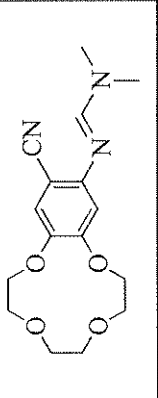
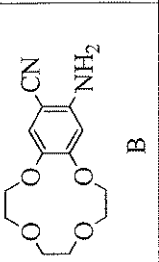
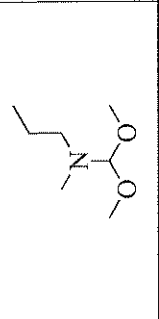
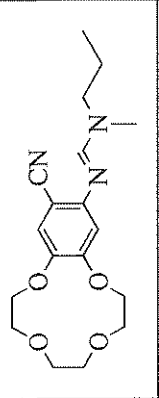
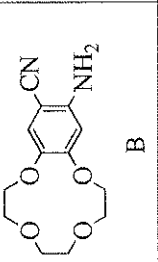
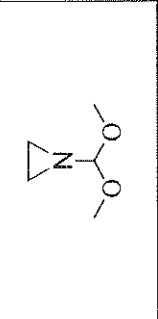
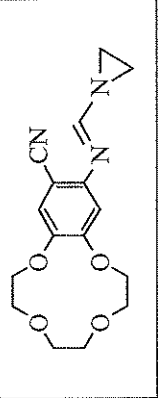
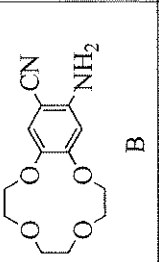
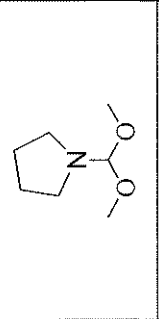
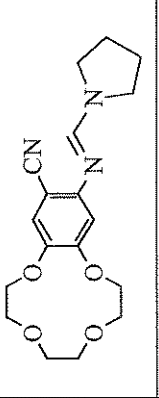
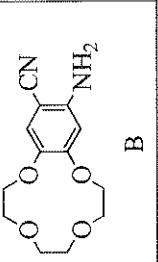
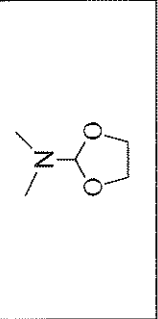
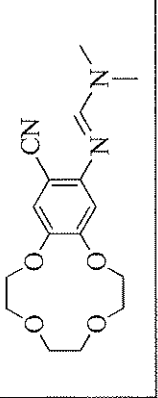


Icotinib (1000mg) was added into 100mL reaction flask and 60mL of methanol was added. The concentrated hydrochloric acid was added dropwise while stirring till pH was adjusted to 2.0. After its completion, the reaction mixture was filtered to give crude product of Icotinib hydrochloride. The crude product was further purified by recrystallization with isopropyl alcohol to give Icotinib hydrochloride (1000mg).

The following exemplary compounds in Table 1 were prepared by similar methods as described above.

Table 1

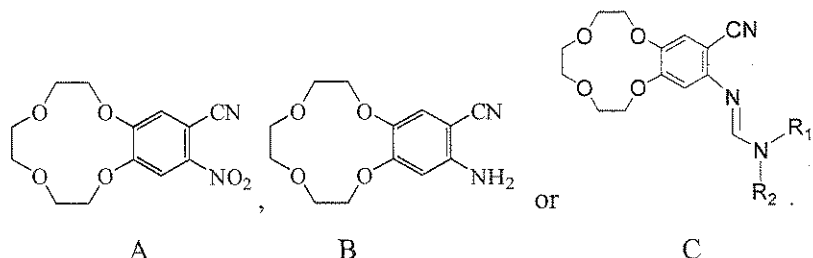
Example	Reactant 1	Reactant 2	Product	[M+H] ⁺
29	<p style="text-align: center;">B</p>			348.3
30	<p style="text-align: center;">B</p>			334.3

31				348.3
32				376.3
33				320.3
34				348.3
35				318.4
36				346.3
37				320.3

CLAIMS

What is claimed is:

1. A compound of formula **A**, **B**, or **C**:



wherein:

each of R_1 and R_2 independently is methyl, ethyl, propyl, or isopropyl; or

R_1 and R_2 , together with the N atom to which they are attached, form a 3 to 7-membered ring.

2. The compound of claim 1, wherein each of R_1 and R_2 independently is methyl or ethyl.

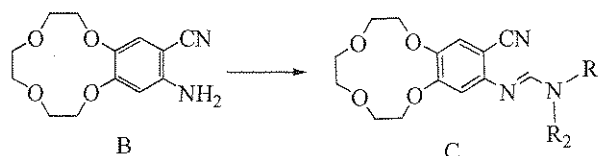
3. The compound of claim 1, wherein R_1 and R_2 are both methyl.

4. The compound of claim 1, wherein R_1 and R_2 are both ethyl.

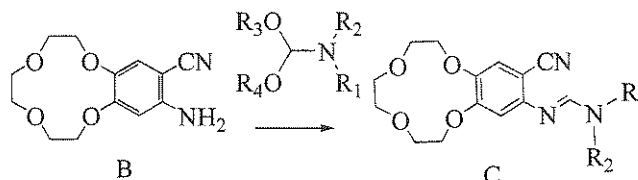
5. The compound of claim 1, wherein R_1 and R_2 , together with the N atom to which they are attached, form a 3, 4, or 5-membered ring.

6. The compound of claim 1, wherein R_1 and R_2 , together with the N atom to which they are attached, form a 5, 6, or 7-membered ring.

7. A method for preparing a compound of any of claims 1-6, wherein compound **C** is prepared from compound **B**, and the method comprises the step of:



8. The method of claim 7, comprising the step of:



wherein:

each of R_3 and R_4 independently is methyl, ethyl, propyl, isopropyl, normal-butyl, sec-butyl, tert-butyl, isobutyl, or benzyl; or

R_3 and R_4 together form a 3 to 7-membered ring.

9. The method of claim 8, wherein each of R_3 and R_4 independently is methyl, ethyl, isopropyl, tert-butyl, or benzyl.

10. The method of claim 8, wherein R_3 and R_4 are both methyl.

11. The method of claim 8, wherein R_3 and R_4 are both ethyl.

12. The method of claim 8, wherein compound **B** and $\begin{array}{c} R_4O \\ | \\ CH-N \\ / \quad \backslash \\ R_3O \quad R_1 \\ \quad \quad R_2 \end{array}$ react in dioxane or toluene under reflux.

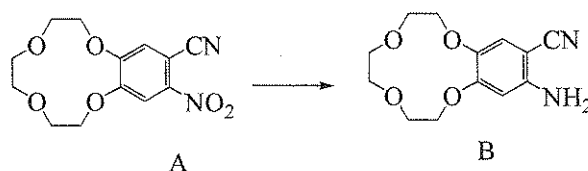
13. The method of claim 12, wherein the molar ratio of compound **B** and $\begin{array}{c} R_4O \\ | \\ CH-N \\ / \quad \backslash \\ R_3O \quad R_1 \\ \quad \quad R_2 \end{array}$ is 1:1.5-1:2.8.

14. The method of claim 12, wherein the molar ratio of compound **B** and $\begin{array}{c} R_4O \\ | \\ CH-N \\ / \quad \backslash \\ R_3O \quad R_1 \\ \quad \quad R_2 \end{array}$ is 1:2.0-1:2.5.

15. The method of claim 12, wherein 11-30mmol compound **B** and 25-67mmol $\begin{array}{c} R_4O \\ | \\ CH-N \\ / \quad \backslash \\ R_3O \quad R_1 \\ \quad \quad R_2 \end{array}$ react in 140-180mL of dioxane under reflux for 10-15 hours.

16. The method of claim 12, wherein $\begin{array}{c} R_4O \\ | \\ CH-N \\ / \quad \backslash \\ R_3O \quad R_1 \\ \quad \quad R_2 \end{array}$ is N,N-dimethylformamide dimethyl acetal, N,N-dimethylformamide diethyl acetal, or N,N-dimethylformamide di-tert-butyl acetal.

17. A method for preparing a compound of any of claims 1-6, wherein compound **B** is prepared from compound **A**, and the method comprises the step of:



18. The method of claim 17, wherein compound **A** reacts with proton-donating agent, metal hydride, hydrazine or alkali metal ammonia solution via catalytic hydrogenation reaction or metal-involved reduction reaction; the metal is Mg, Al, Zn, Fe, Sn, Pb or Cu; the proton-donating agent is acetic acid, formic acid and/or trifluoroacetic acid (TFA); the catalyst applied in the catalytic hydrogenation reaction is Pd/Carbon or Raney Ni; the metal hydride is sodium hydride or potassium hydride; and the alkali metal is sodium or potassium.

19. The method of claim 18, wherein compound **A**, ferrous powder, and acetic acid in methanol solution are fully mixed, and heated to reflux until the reaction is complete.

20. The method of claim 18, wherein 85mmol-0.2mol compound **A**, 0.45-0.71mol of ferrous powder, and 900-1200mL of acetic acid in methanol solution are fully mixed, and heated to reflux until the reaction is complete, and the mass percentage of acetic acid in the acetic acid in methanol solution is 3-7%.

21. A method for preparing Icotinib from a compound of any of claims 1-6, wherein the reaction between compound **C** and m-aminophenyl acetylene occurs in an organic acid.

22. The method of claim 21, wherein the molar ratio of compound C and m-aminophenyl acetylene is 1:1-1:2.

23. The method of claim 21, wherein the molar ratio of compound C and m-aminophenyl acetylene is 1:1-1:1.5.

24. The method of claim 21, wherein the organic acid is acetic acid, formic acid, and/or trifluoroacetic acid.

25. The method of claim 21, wherein compound C, m-aminophenyl acetylene, and the organic acid are fully mixed and react at 70-150°C.

26. The method of claim 21, wherein the reaction temperature is 90-120°C, and the organic acid is acetic acid.

27. The method of claim 21, wherein N,N-dimethyl-N'-(6-cyano-3,4-benzo-12-crown-4)formamidine, m-aminophenyl acetylene, and acetic acid are fully mixed and react at 70-150°C.

28. The method of claim 21, wherein 9-25mmol of N,N-dimethyl-N'-(6-cyano-3,4-benzo-12-crown-4)formamidine, 15-21mmol of m-aminophenyl acetylene, and 150-320mL of acetic acid are fully mixed and react at 90-120°C.

29. The method of claim 21, wherein 12-20mmol of N,N-dimethyl-N'-(6-cyano-3,4-benzo-12-crown-4)formamidine, 17-20mmol of m-aminophenyl acetylene, and 200-260mL of acetic acid are fully mixed and react at 95-105°C.

30. A method for preparing Icotinib hydrochloride from a compound of any of claims 1-6, wherein compound C is a raw material, and the method comprises using a method of any of claims 21-29 to prepare Icotinib, and then dissolving the Icotinib in a lower alcohol, adding hydrogen chloride gas or hydrochloric acid while stirring, and then filtering after the reaction is complete.

31. The method of claim 30, wherein the lower alcohol is methanol, ethanol, and/or isopropanol.

32. The method of claim 30, wherein the amount of Icotinib is 1.3-2.6mmol; the lower alcohol is methanol, and its volume is 30-60mL.

33. The method of claim 30, wherein the amount of Icotinib is 1.8mmol; the lower alcohol is methanol, and its volume is 40mL.

ABSTRACT

The present invention relates to the technical field of medicine. Provided are methods of preparing icotinib, icotinib hydrochloride, and intermediates thereof. The methods avoid the use of phosphoryl chloride, thereby greatly reducing the emission of pollutants, which is of major benefit to the economy and environment.

[No suitable Figure]