

Preparation method for pyrrolidine-2-carboxylic acid derivatives

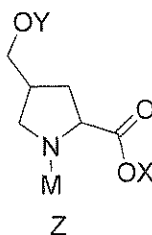
This application claims the priority of China Patent Application No. 201310261857.4, 201310580894.1 and 201410255311.2 filed with the Patent Office of China on June 26, 2013, November 19, 2013 and June 10, 2014 successively titled "Preparation method for pyrrolidine-2-carboxylic acid derivatives", the contents of which are incorporated herein by reference in their entirety.

FIELD OF THE INVENTION

The present invention relates to the field of medical synthesis, in particular to a preparation method for pyrrolidine-2-carboxylic acid derivatives.

BACKGROUD OF THE INVENTION

The following compound Z is the most common intermediate used in the field of medical synthesis,



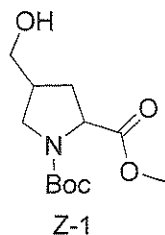
Wherein Y is a hydrogen atom or C₁~C₆ alkyl.

M is a hydrogen atom or a protecting group on nitrogen.

X is a hydrogen atom or a protecting group of carboxyl.

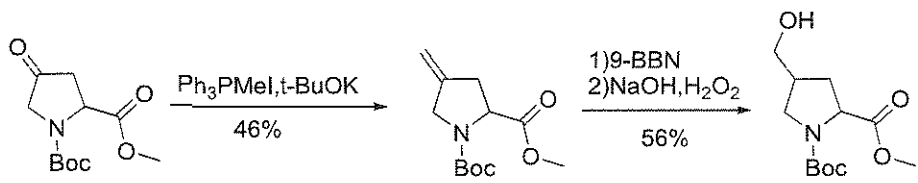
Currently, there are a limited number of routes for preparing the above-mentioned compound, in which the yields are mostly low and the starting material is difficult to be produced.

When Y is a hydrogen atom, M is t-butyloxycarbonyl (Boc), and X is methyl, compound Z has the following structure of formula Z-1,



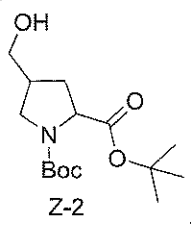
The PCT patent application No. WO2009118759 disclosed a method for preparing compound

Z-1, which can be summarized as follows:



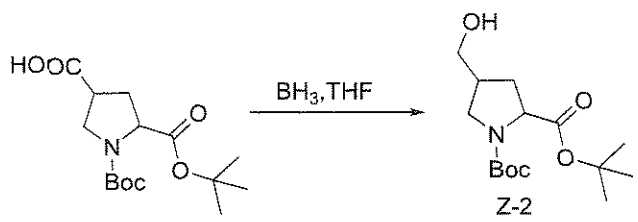
Wherein 9-BBN is abbreviation for 9-Borabicyclo[3.3.1]nonane, the yield is 46% in the first step, and it's 56% in the second step.

- 5 When Y is a hydrogen atom, M is t-butyloxycarbonyl (Boc), and X is tert-butyl, the said compound is represented by the following formula:



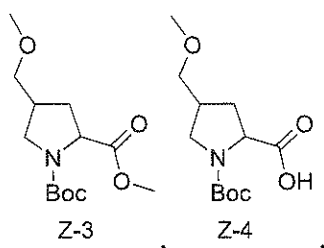
The same route for preparing the above-mentioned compound was disclosed in both Bioorganic & Medicinal Chemistry Letters, 21, (12), 3771-3773, 2011 and PCT patent application No.

- 10 WO2004039367, which can be summarized as follows:



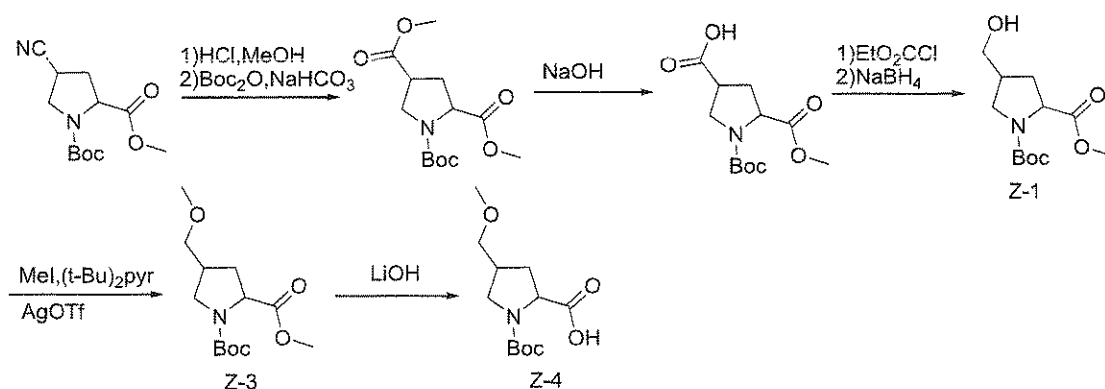
The yield is 41% in Bioorganic & Medicinal Chemistry Letters, 21, (12), 3771-3773, 2011, and 27% in WO2004039367.

- 15 When Y is methyl, M is t-butyloxycarbonyl and X is methyl, the said compound can be represented by formula Z-3. When Y is methyl, M is t-butyloxycarbonyl (Boc) and X is a hydrogen atom, the compound has the structure of formula Z-4:



PCT patent application with publication No. WO 2012068234 disclosed the following method

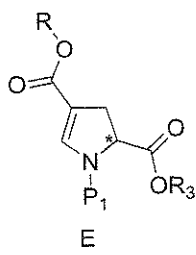
for preparing the two aforesaid compounds on page 876.



The above-mentioned methods are difficult to realize commercial production due to the use of high toxicity chemical such as 9-BBN, borane and sodium cyanide etc., and difficult operation processes. Therefore, it is necessary to provide novel methods to prepare the compound of formula Z.

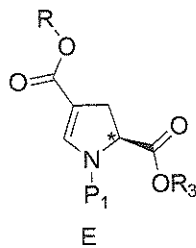
SUMMARY OF THE INVENTION

The present invention adopts the following technical solution: providing a compound having a structure of formula E,



wherein the position marked with * represents a chiral center, specifically, the configuration of carbon marked with * may be R, or may be S, or even may be the mixture of R and S.

Preferably, the compound E has the following configuration,



R is R₁ or R₂, R₁ is C₁~C₆ alkyl, benzyl, p-methoxybenzyl, p-nitrobenzyl, R₂ is a hydrogen

atom;

R_3 is a protecting group for carboxyl;

P_1 is a protecting group of nitrogen.

Specifically, R_1 is methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, tert-butyl, n-amyl or

5 n-hexyl;

R_3 is n-propyl, isopropyl, n-butyl, isobutyl, tert-butyl, n-amyl, n-hexyl, benzyl, triphenylmethyl, p-methoxybenzyl or p-nitrobenzyl.

P_1 is acetyl, trifluoroacetyl, allyloxycarbonyl, t-butyloxycarbonyl(Boc), trimethylsilyl (TMS), tert-butyldimethylsilyl (TBDMS), benzoyl, triphenylmethyl, p-methoxybenzyl, benzyloxycarbonyl (Cbz), p-methoxybenzyloxycarbonyl (Moz), p-nitrobenzyl, m-nitrobenzyl, p-chlorobenzyl, m-chlorobenzyl, p-bromobenzyl, m-bromobenzyl or benzyl.

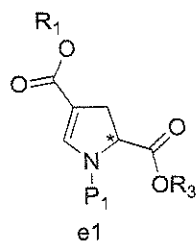
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Preferably, R_1 is $C_1\sim C_6$ alkyl; R_3 is tert-butyl, benzyl, p-methoxybenzyl or p-nitrobenzyl; P_1 is t-butyloxycarbonyl, p-methoxybenzyl or carboxybenzyl.

More preferably, R_1 is methyl; R_3 is tert-butyl or benzyl; P_1 is t-butyloxycarbonyl.

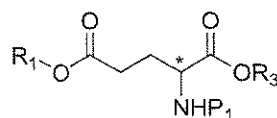
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Preferably, the compound E can be described by the compound of formula e1 when R is R_1 :



wherein R_1 , R_3 and P_1 are as defined above.

The compound of formula e1 is obtained from the compound of formula g and formic mixed anhydride or alkyl formate by cyclization reaction.



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wherein R_3 , R_1 and P_1 are as defined above.

The cyclization reaction was performed in the presence of strong base which has the ability to remove a-H.

Further, the reaction yield can be improved by adding an acid.

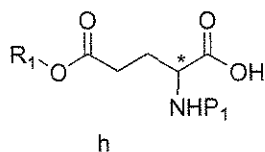
The formic mixed anhydride can be selected from formic anhydride, acetic formic anhydride, formic pivalic anhydride and formic benzoic anhydride.

The alkyl formate can be selected from methyl formate, ethyl formate, propyl formate and isopropyl formate.

5 The strong base may be selected from lithium bis(trimethylsilyl)amide, lithium diisopropylamide, n-butyllithium, sodium hydride, sodium alcoholate and potassium alcoholate. The preferable sodium alcoholate may be selected from sodium methoxide, sodium ethoxide and sodium isopropylate; the preferable potassium alcoholate may be potassium methoxide, potassium ethoxide, potassium isopropoxide.

10 The acid may be trifluoroacetic acid or acetic acid.

The compound g was obtained by reacting the compound of formula h with $(R_3CO)_2$ or R_3X in the presence of base,

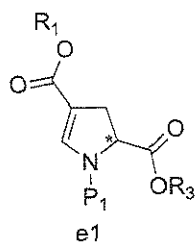


wherein R_1 , R_3 and P_1 is as defined above, X is a halogen atom, preferably Br or Cl.

15 The said base may be 4-(dimethylamino)pyridine (DMAP), triethylamine, pyridine, tetramethyl guanidine, 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU), sodium carbonate, potassium carbonate or lithium carbonate.

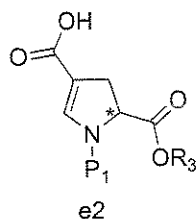
The preferred solvent employed may include R_3OH , DMF, THF or acetonitrile.

The compound E can be represented by formula e1 when R is R_1 ,



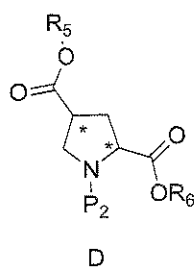
wherein R_1 , R_3 and P_1 is as defined above.

The compound E is represented by formula e2 when R is R_2 (a hydrogen atom).



In this case, the said compound of formula e1 is hydrolyzed to generate the compound of formula e2. The preferred reaction reagent for the hydrolysis may be alkali base, such as lithium hydroxide, sodium hydroxide, potassium hydroxide and so on.

- 5 In another aspect, the compound of formula E is subjected to catalytic hydrogenation to obtain the compound of formula D,



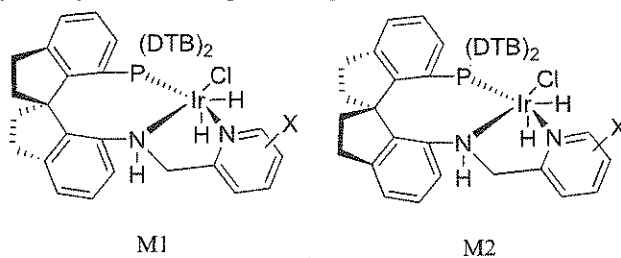
wherein R₅ is a hydrogen atom or C₁~C₆ alkyl, the specific example is methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, tert-butyl, n-pentyl and n-hexyl.

- 10 R₆ is a hydrogen atom, n-propyl, isopropyl, n-butyl, isobutyl, tert-butyl, n-pentyl or n-hexyl.

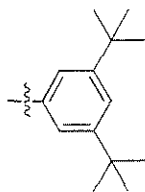
P₂ is a hydrogen atom, acetyl, trifluoroacetyl, allyloxycarbonyl, t-butyloxycarbonyl (Boc), trimethylsilyl (TMS), tert-butyldimethylsilyl (TBDMS) or benzoyl.

The catalyst for catalytic hydrogenation may be selected from palladium on carbon, platinum oxide, Raney Ni as well as chiral catalyst.

- 15 The said chiral catalyst may be the compound represented by formula M1 or formula M2

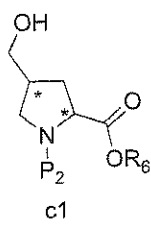


wherein DTB is



X is C₁~C₄ alkyl.

Furthermore, the compound of formula D is reduced to the compound of formula c1.

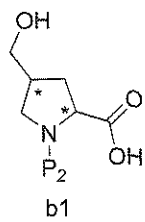


5 wherein R₆ and P₂ are as defined above.

The reducing agent employed in the process above may be tributyltin hydride, triphenyltin hydride, triethyl silicane, trichlorosilane, sodium borohydride, sodium trimethoxyborohydride, lithium tri-sec-butylhydridoborate, potassium Tri-Sec-Butylborohydride, lithium triethylborohydride, diisobutyl aluminium hydride (DIBAH) or sodium
 10 bis(2-methoxyethoxy)aluminiumhydride; preferably, when R₅ of compound D is a hydrogen atom, the carboxyl group can be reduced to the hydroxy group under mild reaction condition with the decrease of the formation of impurities by the activation with the addition of alkyl chloroformate such as ClCOOEt, ClCOOMe and so on to generate a mixed acid anhydride first.

Racemization doesn't occur during the preparation of the compound of formula c1 from the
 15 compound of formula E according to the reduction steps described above if the compound of formula E is a single enantiomer of chiral compound, and only cis isomer of the compound of formula c1 is obtained.

Furthermore, the compound of formula c1 can convert to the compound of formula b1 by removal of the carboxyl group.



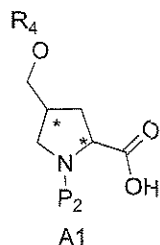
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wherein P_1 and P_2 are as defined above.

The reagent employed in the process of removing the carboxyl group may be selected from formic acid, trifluoroacetic acid, hydrochloric acid, acetic acid and p-toluenesulfonic acid, etc.

The compound of formula b1 is subjected to alkylation to produce the compound of formula

5 A1,



wherein R_4 is $C_1 \sim C_6$ alkyl.

Alkylating reagent may be selected from iodomethane, bromoethane, dimethyl sulfate, diethyl sulfate, methyl methanesulfonate, methyl p-toluenesulfonate, methyl trifluoromethanesulfonate, oxalic acid dimethyl ester and methyl carboxylate etc.

In order to improve the nucleophilicity of the hydroxy group of compound b1 or b2, the hydroxyl group may be activated with strong base such as metallic sodium, sodium hydride, n-butyllithium and so on to form the corresponding sodium alkoxide or lithium alkoxide, which reacts with alkylating reagent in the presence of phase transfer catalyst, for example, quaternary ammonium salt, polyethylene glycol and etc.

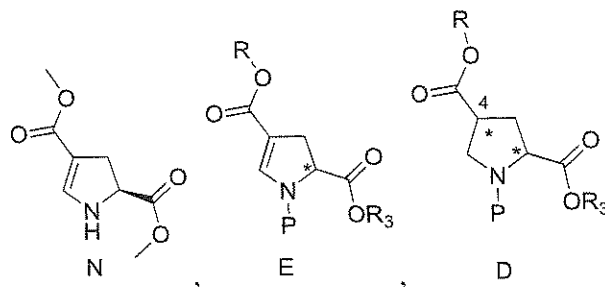
The compound of formula c1 is converted to the compound of formula A1 without racemization after the steps of removal the protecting group of carboxyl group and alkylation if it is a single enantiomer of chiral compound.

Alternatively, the compound of formula c1 can be converted to the compound of formula A1 directly by alkylation process.

The compound c1 is alkylated directly to give the compound A1 which will be racemized if the carboxyl group in 2-position of compound c1 is a single chiral.

The present invention provides the preparation method for pyrrolidine-2-carboxylic acid derivatives and has advantages that the compound of formula D is obtained as cis isomer by the catalytic hydrogenation of double bond in the compound of formula E when the compound E is a single enantiomer of chiral compound. But in general, a person skilled in the art knows that the

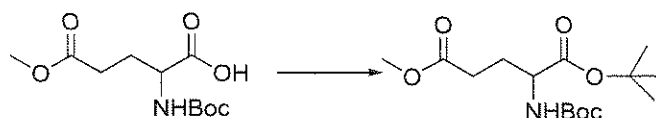
product is a racemic mixture when the double bond of alkene is subjected to catalytic hydrogenation. For example, the compound of formula N which has a similar structure as the compound provided by the present invention undergoes catalytic hydrogenation to produce a product with racemization at 4 position (see comparison example 1). This has not been clearly indicated in common knowledge. Therefore, the compound E provided by the present invention has achieved an unexpected technical effect.



The method also has the advantages of cheap raw materials, simple operation, mild conditions, and effectively decreases the production cost.

DETAILED EMBODIMENTS

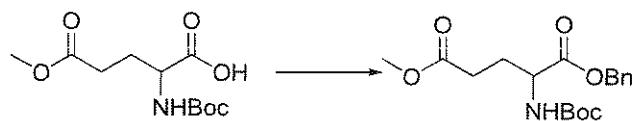
Example 1: The preparation of 1-tert-butyl-5-methyl-2-((tert-butyloxycarbonyl) amino) pentanedioate



To a 100 ml one-necked flask was added 5-methyl-2-((tert-butyloxycarbonyl) amino)-pentanedioate (7.8g, 24.6mmol), di-tert-butyl dicarbonate (5.9g, 27mmol), 4-dimethylaminopyridine (0.9g, 7.38mmol) and 30 ml tertiary butanol. After the mixture was stirred at 25°C overnight, the solvent was evaporated and the residue was purified by column chromatography to afford 7.17 g 1-tert-butyl-5-methyl-2-((tert-butyloxycarbonyl)amino) pentanedioate as white solid with a yield of 91.9%.

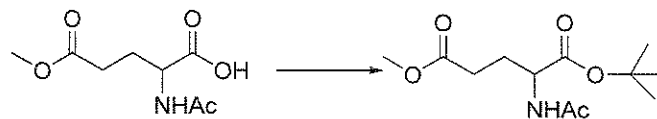
Example 2: The preparation of 1-benzyl-5-methyl-2-((tert-butyloxycarbonyl) amino)

pentanedioate



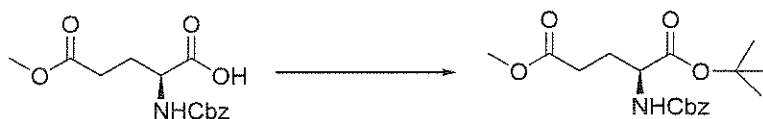
To a 100 ml one-necked flask was added 5-methyl-2-((tert-butyloxycarbonyl) amino)-pentanedioate (7.8g, 24.6mmol), di-benzyl dicarbonate (6.86g, 27mmol), triethylamine (0.75g, 7.4mmol) and 30 ml methanol. After the mixture was stirred at 30°C for one night, the solvent was evaporated and the residue was purified by column chromatography to afford 7.1 g 1-benzyl-5-methyl-2-((tert-butyloxycarbonyl) amino) pentanedioate as white solid with a yield of 82.3%.

Example 3: The preparation of 1-tert-butyl -5-methyl-2-acetamino pentanedioate



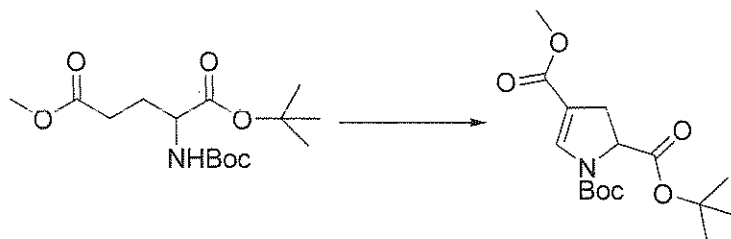
The procedure of example 1 was repeated by using 5g 5-methyl-2-acetamino pentanedioate as starting material to obtain 5.5 g 1-tert-butyl -5-methyl-2-acetamino pentanedioate with a yield of 86.6%.

Example 4: The preparation of (S)-1-tert-butyl -5-methyl-2-benzyloxycarbonylamino pentanedioate



The procedure of example 1 was repeated by using 2.95 g 5-methyl-2-benzyloxycarbonylamino pentanedioate as starting material to obtain 3.5g with a yield of 99%.

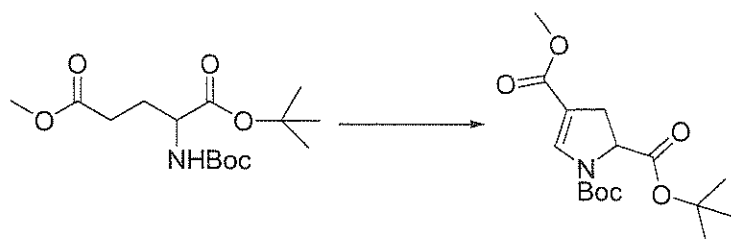
Example 5: The preparation of N- t-butyloxycarbonyl-2-t-butyloxycarbonyl-4-methoxycarbonyl-2,3-dihydro-1H-pyrrole



60 ml lithium bis(trimethylsilyl)amide (7.6g, 45.4mmol) was charged into a 250 ml three-necked flask under the protection of nitrogen and cooled to -78°C . A solution of 1-tert-butyl-5-methyl-2-((tert-butoxycarbonyl) amino) pentanedioate (8.0g, 25.2mmol) in 20ml THF was added dropwise. After the addition, the mixture was maintained at -78°C for 1h. A solution of acetic formic anhydride (2M, 40mmol) in 20 ml THF was added dropwise slowly. The inner temperature was maintained below -70°C . After the addition, the mixture was maintained at -78°C for 3h, then heated to 5°C . The resulting mixture was quenched with 4.0ml of acetic acid and 30ml of water, extracted with ethyl acetate and the combined organic phase was dried over MgSO_4 , filtered and concentrated to give a light yellow oil. Then the above mentioned oil was dissolved in methylene chloride, cooled to 5°C , after the addition of TFA (3.16g, 27.7mmol), the mixture was stirred for 4 hours at 25°C , concentrated and purified by column chromatography to afford 6.8g N-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-methoxycarbonyl-2,3-dihydro-1H-pyrrole as white solid with a yield of 82.9%.

^1H NMR (400Mz, CDCl_3): $\delta=1.48\text{-}1.49$ (m, 18H), $\delta=2.80\text{-}2.87$ (m, 1H), $\delta=3.15\text{-}3.28$ (m, 1H), $\delta=4.56\text{-}4.67$ (m, 1H), $\delta=7.42\text{-}7.58$ (d, 1H).

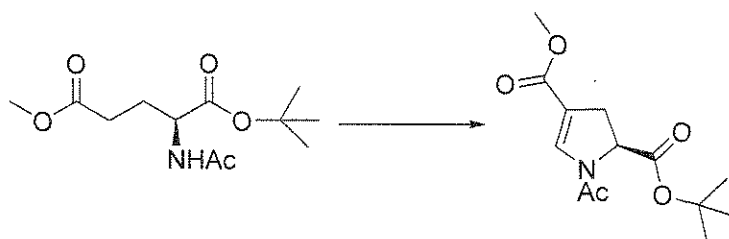
Example 6: The preparation of N-benzyloxycarbonyl-2-tert-butoxycarbonyl-4-methoxycarbonyl-2,3-dihydro-1H-pyrrole



To a 250ml of three-necked bottle was added 60ml of LHMDs (7.6g, 45.4mmol) with the protection of nitrogen, then cooled to -78°C , after the addition of a solution of 1-tert-butyl 5-methyl 2-((tert-butoxycarbonyl)amino)pentanedioate (8.8g, 27.8mmol) in 20 ml THF, the mixture was stirred for another 1 hour at -78°C , then a solution of acetic formic anhydride in 20ml of THF was

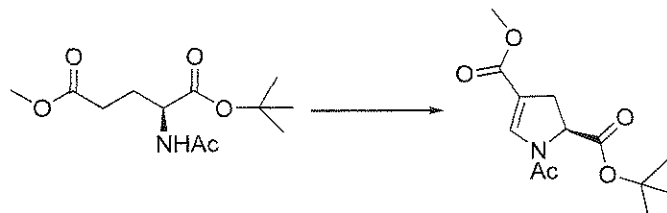
added dropwise to maintain the inner temperature below -70°C . After addition, the mixture was stirred for another 3 hours at -78°C , the reaction solution was warmed to 5°C , then quenched the reaction with 4.0ml of acetic acid and 30ml of water, extracted with ethyl acetate and combined the organic phase then dried over MgSO_4 , filtered and concentrated to give a light yellow oil. Then the above mentioned oil was dissolved in methylene chloride, cooled to 5°C , after the addition of TFA (3.16g, 27.7mmol), the mixture was stirred for 4 hours at 25°C , after the addition of 40 ml water, then concentrated, and extracted with DCM ($50\text{ml} \times 3$), combined the organic phase and evaporated to dryness to give 8.7 g of N-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-methoxycarbonyl-2,3-dihydro-1H-pyrrole in 95.7% yield.

Example 7: The preparation of (S)-N-acetyl-2-tert-butoxycarbonyl-4-methoxycarbonyl-2,3-dihydro-1H-pyrrole



To a 250ml of three-necked bottle was added a solution of 25ml $n\text{BuLi}$ in hexane (1.6M, 40mmol) under the protection of nitrogen, then cooled to -78°C , after the addition of the solution of (S)-1-tert-butyl-5-methyl-2-acetamino pentanedioate (6.5g, 25.1mmol) in 20 ml THF, the mixture was stirred for another 1 hour at -78°C , then a solution of formic pivalic anhydride in 20ml of THF (2M, 40mmol) was added dropwise slowly to maintain the inner temperature below -70°C , after the addition, stirred at -78°C for 3 hours, and warmed to 5°C , then quenched with 4.0ml of acetic acid and 30ml of water, extracted with ethyl acetate. The combined organic phase was dried over MgSO_4 , filtered and concentrated to give a light yellow oil. Then the above mentioned oil was dissolved in methylene chloride, cooled to 5°C , after the addition of TFA (3.16g, 27.7mmol), the mixture was stirred for 4 hours at 25°C , then concentrated, and then purified by column chromatography to give 5.7 g of (S)-N-acetyl-2-tert-butoxycarbonyl-4-methoxycarbonyl-2,3-dihydro-1H-pyrrole in 84.4% yield.

Example 7-2: The preparation of (*S*)-*N*-acetyl-2-*tert*-butoxycarbonyl-4-methoxycarbonyl-2,3-dihydro-1*H*-pyrrole



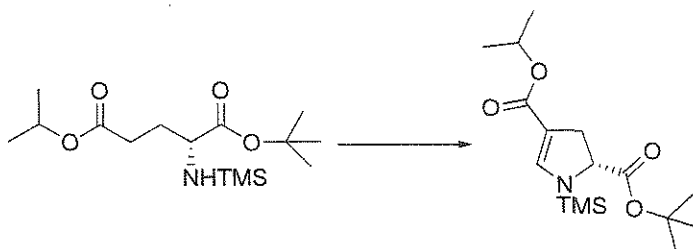
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To a 250ml of three-necked bottle was added a solution of 25ml ⁿBuLi in hexane(1.6M, 40mmol) under the protection of nitrogen, then cooled to -78°C, after the addition of the solution of (*S*)-1-*tert*-butyl-5-methyl-2-acetaminopentanedioate (6.5g, 25.1mmol) in 20 ml THF, the mixture was stirred for another 1 hour at -78°C, then a solution of formic pivalic anhydride in 20ml of THF (2M, 40mmol) was added dropwise slowly to maintain the inner temperature below -70°C, after the addition, stirred at -78°C for 3 hours, and warmed to °C, then quenched with 4.0ml of acetic acid and 30ml of water, extracted with ethyl acetate. The combined organic phase was dried over MgSO₄, filtered and concentrated to give a light yellow oil. Then the above mentioned oil was dissolved in methylene chloride, cooled to 5 °C, after the addition of TFA (3.16g, 27.7mmol), the mixture was stirred for 4 hours at 25°C, then concentrated, after the addition of 40 ml water, extracted with DCM (3X50ml), then purified by column chromatography to give 6.1 g of (*S*)-*N*-acetyl-2-*tert*-butoxycarbonyl-4-methoxycarbonyl-2,3-dihydro-1*H*-pyrrole in 90.5% yield.

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Example 8: The preparation of (*R*)-*N*-trimethylsilyl-2-*tert*-butoxycarbonyl-4-isopropoxycarbonyl-2,3-dihydro-1*H*-pyrrole

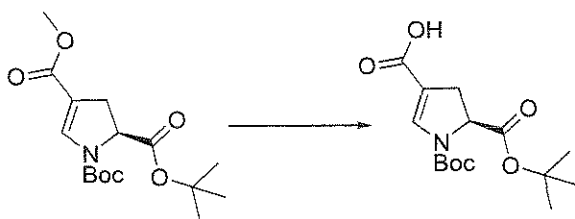
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To a 250ml of three-necked bottle was added LDA (3.0g, 28mmol) with the protection of nitrogen, then cooled to -78°C, after the addition of (*R*)-1-*tert*-butyl-5-isopropyl

2-((trimethylsilyl)amino)pentanedioate (4.8g, 15.1mmol) (prepared according to Example 1) in 15ml of THF, the mixture was stirred for another 1.5 hours at -78°C, then a solution of formic acetic anhydride in 12ml of THF(2M, 24mmol) was added dropwise slowly to maintain the inner temperature below -70°C, after addition, stirred for another 4 hours at -78°C, the reaction solution was warmed to 5°C, then quenched the reaction with 3.0ml of acetic acid and 20ml of water, extracted with ethyl acetate and the combined organic phase was dried over MgSO₄, filtered and concentrated to give a light yellow oil. Then the above mentioned oil was dissolved in methylene chloride, cooled to 5°C, after the addition of TFA (3.16g, 27.7mmol), the mixture was stirred for 4 hours at 25°C, then concentrated, purified by column chromatography to give 3.74 g of (*R*)-*N*-trimethylsilyl -2-tert-butoxycarbonyl-4-isopropoxycarbonyl-2,3-dihydro-1*H*-pyrrole in 75.6% yield.

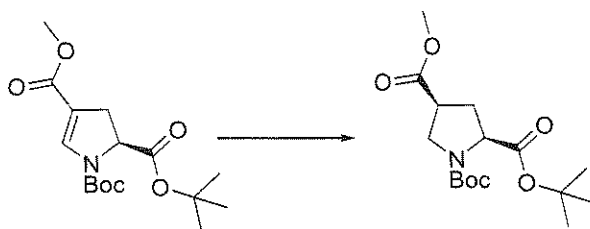
Example 9: The preparation of (*S*)-*N*-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-carboxyl -2,3-dihydro-1*H*-pyrrole



To a 100ml of single-necked bottle was added (*S*)-*N*-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-methoxycarbonyl-2,3-dihydro-1*H*-pyrrole (3.2g, 10mmol) (prepared by the method of Example 5), LiOH (0.63g, 15mmol), 15ml of water and 15ml of THF, then the mixture was stirred at 25°C overnight, extracted with ethyl acetate to remove the organic impurities, the aqueous phase was adjust to PH=3, then extracted with ethyl acetate (3×15ml) , dried over MgSO₄, filtrated and evaporated to afford 3.1g of (*S*)-*N*-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-carboxyl -2,3-dihydro-1*H*-pyrrole in 100% yield.

¹HNMR (400Mz, CDCl₃): δ=1.49-1.53 (m, 18H), δ=2.83-2.86 (m, 1H), δ=3.16-3.29 (m, 1H), δ=4.59-4.70 (m, 1H), δ=7.54-7.72 (d, 1H)。

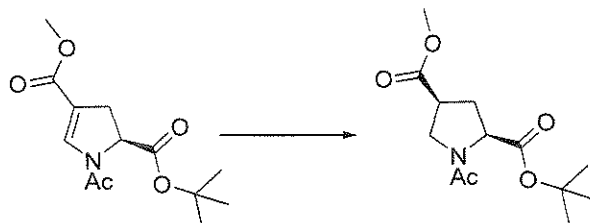
Example 10: The preparation of (2*S*,4*S*)-*N*-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-methoxycarbonyl pyrrolidine



To a 100ml of single-necked bottle was added (S)-N-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-methoxycarbonyl-2,3-dihydro-1H-pyrrole (3.27g, 10mmol) (prepared by the method of Example 5), 10% wet Pd/C (0.7g, 30%), one drop of acetic acid and 5ml of methanol, then the mixture was stirred at 25°C overnight, after filtration and evaporation, 3.3g of (2S,4S)-N-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-methoxycarbonyl pyrrolidine was obtained in 100% yield, ee 99%.

¹HNMR (400Mz, CDCl₃): δ=1.42-1.45 (m, 18H), δ=2.26-2.34 (m, 1H), δ=2.46-2.51 (m, 1H), δ=3.00-3.07 (m, 1H), δ=3.69 (s, 3H), δ=3.69 - 3.86 (m, 1H), δ=4.12-4.20 (m, 1H).

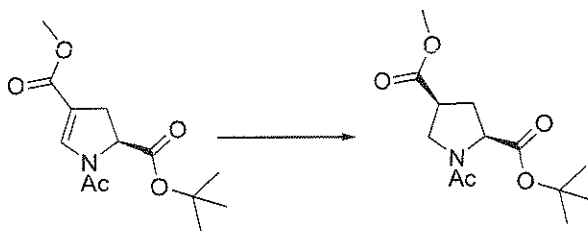
Example 11: The preparation of (2S,4S)-N-acetyl-2-tert-butoxycarbonyl-4-methoxycarbonyl pyrrolidine



To a 100ml of single-necked bottle was added (S)-N-acetyl-2-tert-butoxycarbonyl-4-methoxycarbonyl-2,3-dihydro-1H-pyrrole (2.7g, 10mmol), 10% wet Pd/C(0.7g, 30%), one drop of acetic acid and 5ml of methanol, then the mixture was stirred at 25°C overnight, after filtration and evaporation, 2.7g of (2S,4S)-N-acetyl-2-tert-butoxycarbonyl-4-methoxycarbonyl pyrrolidine was obtained in 100% yield, ee 97.5%.

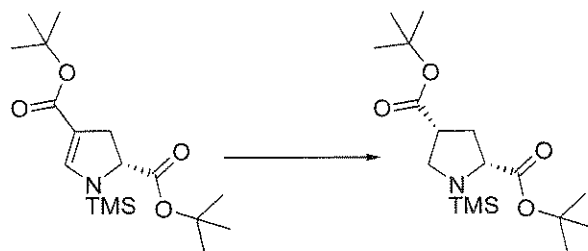
Example 11-2: The preparation of (2S,

4S)-N-acetyl-2-tert-butoxycarbonyl-4-methoxycarbonyl pyrrolidine



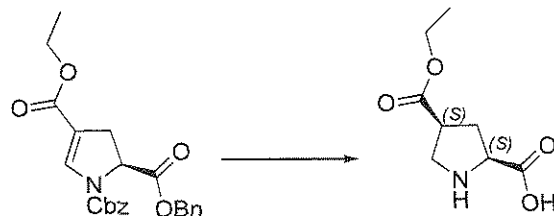
To a 100ml of single-necked bottle was added (S)-N-acetyl-2-tert-butoxycarbonyl-4-methoxycarbonyl-2,3-dihydro-1H-pyrrole (2.7g, 10mmol), 0.3g of Raney nickel, one drop of acetic acid and 5ml of methanol, then the mixture was stirred at 25°C overnight, after filtration and evaporation, 2.7g of (2S,4S)-N-acetyl-2-tert-butoxycarbonyl-4-methoxycarbonyl pyrrolidine as colourless oil was obtained in 100% yield, ee 97.6%.

Example 12: The preparation of (2R,4R)-N-(trimethylsilyl)-2,4-di(tert-butoxycarbonyl) pyrrolidine



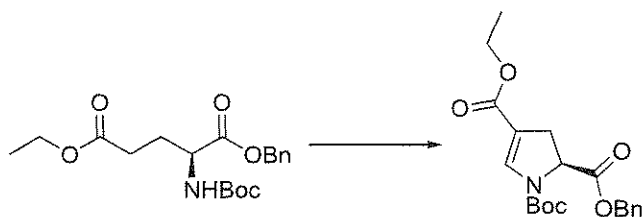
To a 100ml of single-necked bottle was added (R)-N-(trimethylsilyl)-2,4-di(tert-butoxycarbonyl)-2,3-dihydro-1H-pyrrole (3.4g, 10mmol), 10% wet Pd/C(0.7g, 30%) and 5ml of methanol, then the mixture was stirred at 25°C overnight, after filtration and evaporation, 3.4g of (2R,4R)-N-(trimethylsilyl)-2,4-di(tert-butoxycarbonyl)pyrrolidine as colourless oil was obtained in 99% yield, ee 98%.

Example 13: the preparation of (2S,4S)-2-carboxyl-4-(ethoxycarbonyl) pyrrolidine



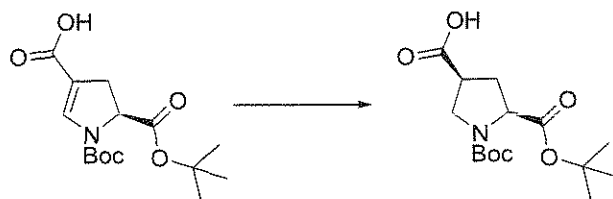
To a 100ml of single-necked bottle was added (S)-N- benzyloxycarbonyl-2-benzyloxycarbonyl-4-ethoxycarbonyl-2,3-dihydro-1H-pyrrole (4.0g, 10mmol) (obtained according the example 5), 10% wet Pd/C(0.7g, 30%), one drop of acetic acid and 5ml of methanol, then the mixture was stirred at 25°C overnight after filtration and evaporation, 4 g of (2S,4S)-2-carboxyl-4-(ethoxycarbonyl) pyrrolidine was obtained in 100% yield, ee 98.7%.

Example 14: The preparation of (S)-N-tert-butoxycarbonyl-2-benzyloxycarbonyl-4-ethoxycarbonyl-2,3-dihydro-1H-pyrrole



To a 250ml of three-necked bottle was added ^tBuONa(3.8g, 40 mmol) with the protection of nitrogen, then cooled to -70°C, after the addition a solution of (S)-1-benzyl-5-ethyl 2-((tert-butoxycarbonyl)amino)pentanedioate (9.2g, 25.1mmol) in 20m THF, the mixture was stirred for another 3 hour at -70°C, then a solution of propylformate in 20ml of THF (2M, 40mmol) was added dropwise slowly to maintain the inner temperature below -70°C, after addition and maintained at -70°C for another 5 hours. The reaction solution was warmed to 5°C, then quenched the reaction with 4.0ml of acetic acid and 30ml of water, extracted with ethyl acetate, dried over MgSO₄, filtered and concentrated to give a light yellow oil. Then the above mentioned oil was dissolved in methylene chloride, cooled to 5°C, after the addition of TFA (3.16g, 27.7mmol), the mixture was warmed to for 25°C with stirring for 4 hours, then concentrated, after 40 ml of water was added and extracted with DCM (50ml × 3) to give 9 g of N-tert-butoxycarbonyl-2-benzyloxycarbonyl- 4-ethoxycarbonyl-2,3-dihydro-1H-pyrrole in 95.7% yield. ee 98.3%.

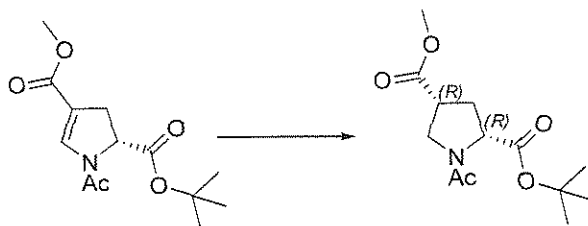
Example 15: the preparation of (2S,4S)-N-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-carboxyl pyrrolidine



To a 100ml of single-necked bottle was added (*S*)-*N*-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-carboxyl-2,3-dihydro-1H-pyrrole (3.13g, 10mmol), 10% wet Pd/C(0.7g, 30%), one drop of acetic acid and 5ml of methanol, then the mixture was stirred at 25°C overnight, after filtration and evaporation, 3.15g of (*2S,4S*)-*N*-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-carboxyl pyrrolidine was obtained in 100% yield, ee 98.8%.

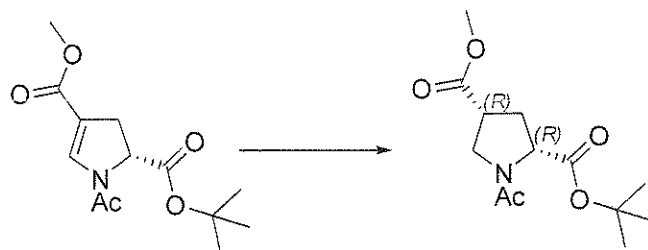
¹HNMR (400Mz, CDCl₃): δ=1.45-1.47 (m, 18H), δ=2.32-2.39 (m, 1H), δ=2.49-2.55 (m, 1H), δ=3.06-3.13 (m, 1H), δ=3.72-3.89 (m, 2H), δ= 4.16-4.25 (m, 1H).

Example 16: the preparation of (*2R,4R*)-*N*-acetyl-2-tert-butoxycarbonyl-4-methoxycarbonyl pyrrolidine



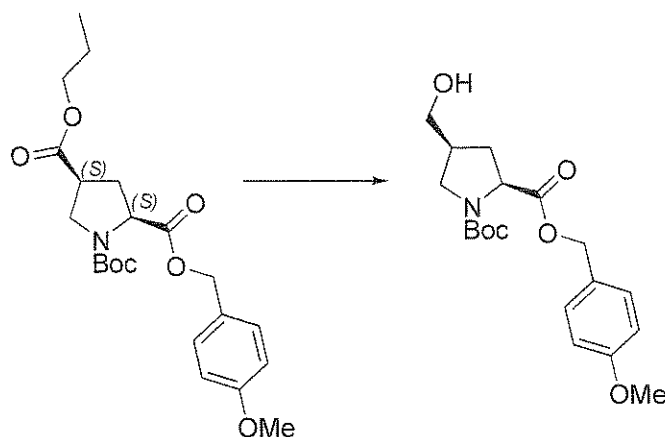
To a 100ml of single-necked bottle was added (*R*)-*N*-acetyl-2-tert-butoxycarbonyl-4-methoxycarbonyl-2,3-dihydro-1H-pyrrole (2.7g, 10mmol), 10% wet Pd/C(0.7g, 30%), 5ml of Methanol, then the mixture was stirred at 25°C overnight, after filtration and evaporation, 2.7g of (*2R,4R*)-*N*-acetyl-2-tert-butoxycarbonyl-4-methoxycarbonyl pyrrolidine as colorless oil was obtained in 100% yield, ee 97.5%.

Example 16-2: The preparation of (*2R,4R*)-*N*-acetyl-2-tert-butoxycarbonyl-4-methoxycarbonyl pyrrolidine



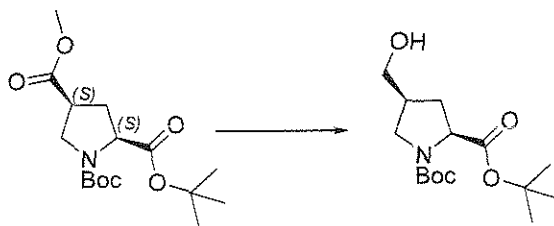
To a 100ml of single-necked bottle was added (R)-N-acetyl-2-tert-butoxycarbonyl-4-methoxycarbonyl-2,3-dihydro-1H-pyrrole (2.7g, 10mmol), 0.3g of Raney nickel, 5ml of Methanol, then the mixture was stirred at 25°C overnight, after filtration and evaporation, 2.7g of (2R,4R)-N-acetyl-2-tert-butoxycarbonyl-4-methoxycarbonyl pyrrolidine was obtained in 100% yield, ee 97.5%.

Example 17: The preparation of (2S,4S)-N-tert-butoxycarbonyl-2-(p-methoxybenzyloxy)carbonyl-4-hydroxyethyl pyrrole



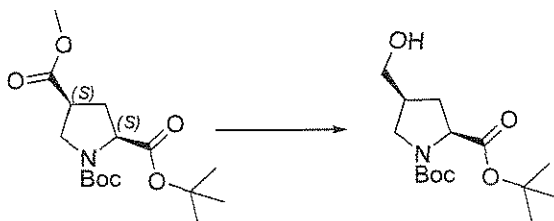
To a mixture of (2S,4S)-N-tert-butoxycarbonyl-2-(p-methoxybenzyloxy)carbonyl-4-propoxy pyrrolidine (3g, 8.26mmol) in 20ml of methanol was added diisobutyl aluminium hydride (3.55g, 25mmol), then the mixture was stirred at 25°C overnight, quenched by dilute HCl, extracted with ethyl acetate, then purified by column chromatography to give 2.45g of (2S,4S)-N-tert-butoxycarbonyl-2-(p-methoxybenzyloxy)carbonyl-4-hydroxyethyl pyrrole in 81.2% yield, ee 96.8%.

Example 18: The preparation of (2S,4S)-N-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-hydroxyethyl pyrrolidine



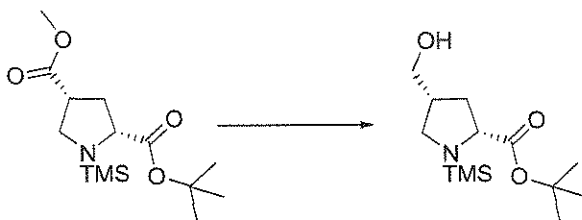
To a mixture of (2*S*,4*S*)-*N*-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-methoxycarbonyl pyrrolidine (2g, 6.1mmol) in 20ml of isopropanol was added sodium borohydride (0.74g, 20mmol), then the mixture was stirred at 25°C overnight, quenched by dilute HCl, extracted with ethyl acetate, then purified by column chromatography to give 1.5g of (2*S*,4*S*)-*N*-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-hydroxyethyl pyrrolidine as oil in 81.9% yield, ee 81.9%.

Example 18-2: The preparation of (2*S*,4*S*)- *N*-tert-butoxycarbonyl-2- tert-butoxycarbonyl -4-hydroxyethyl pyrrolidine



To a mixture of (2*S*,4*S*)-*N*-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-methoxycarbonyl pyrrolidine (2g, 6.1mmol) in 20ml of isopropanol was added NaBH₄ (0.74g, 20mmol), then the mixture was stirred at 25°C overnight, quenched by dilute HCl, extracted with ethyl acetate, then combined and concentrated the organic phase which was further purified via recrystallization by ethanol to give 1.7g of (2*S*,4*S*)- *N*-tert-butoxycarbonyl-2- tert-butoxycarbonyl-4-hydroxyethyl pyrrolidine as white solid in 93.2% yield, ee 98.4%.

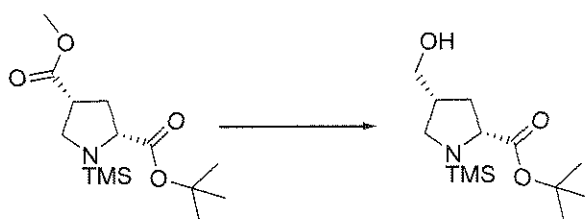
Example 19: The preparation of (2*R*,4*R*)-*N*- trimethylsilyl -2-tert-butoxycarbonyl-4-hydroxyethyl pyrrolidine



To a mixture of (2*R*,4*R*)-*N*-trimethylsilyl-2-tert-butoxycarbonyl-4-methoxycarbonyl

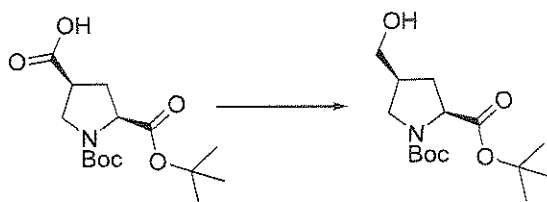
pyrrolidine (2.5g, 7.3mmol) in 20ml of THF was added red aluminum (4.04g, 20mmol), then the mixture was stirred at 25°C overnight, quenched by dilute HCl, extracted with ethyl acetate, then the combined organic phase was concentrated, and then purified by column chromatography to give 1.59g of (2*R*,4*R*)-*N*-trimethylsilyl -2-*tert*-butoxycarbonyl-4-hydroxyethyl pyrrolidine in 79.9% yield.

Example 19-2: The preparation of (2*R*,4*R*)-*N*-trimethylsilyl -2-*tert*-butoxycarbonyl-4-hydroxyethyl pyrrolidine



To a mixture of (2*R*,4*R*)-*N*-trimethylsilyl-2-*tert*-butoxycarbonyl-4-methoxycarbonyl pyrrolidine (2.5g, 7.3mmol) in 20ml of THF was added red aluminum (4.04g, 20mmol), then the mixture was stirred at 25°C overnight, quenched by dilute HCl, extracted with ethyl acetate, then combined and concentrated the organic phase which was recrystallized by ethanol to give 1.82g of (2*R*,4*R*)-*N*-trimethylsilyl-2-*tert*-butoxycarbonyl-4-hydroxyethyl pyrrolidine in 91.1% yield, ee 97.9%.

Example 20: The preparation of (2*S*,4*S*)-*N*-*tert*-butoxycarbonyl-2-*tert*-butoxycarbonyl-4-hydroxyethyl pyrrolidine

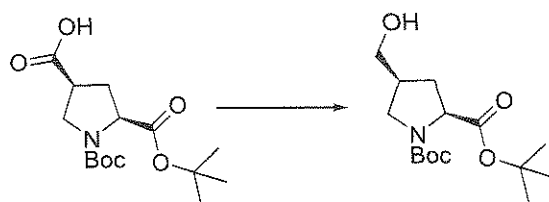


To a 100ml of single-necked flask was added (2*S*,4*S*)-*N*-*tert*-butoxycarbonyl-2-*tert*-butoxycarbonyl-4-carboxyl pyrrolidine (0.66g, 2.11mmol), TEA (0.4ml, 2.74mmol) and 5ml of methylene chloride, then ethyl chloroformate (252mg, 2.32mmol) was added dropwise, after stirring for another 1hour at 25°C, washed with water and organic phase was concentrated, then the residue was dissolved in THF and water, NaBH₄ (230mg,

6mmol) was added, after stirring for another 3 hours at 25°C, quenched by dilute HCl, and extracted with ethyl acetate, dried over MgSO₄, then filtered and evaporated to give 540mg of (2*S*,4*S*)-N-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-hydroxyethyl pyrrolidine as colorless oil in 85.2% yield.

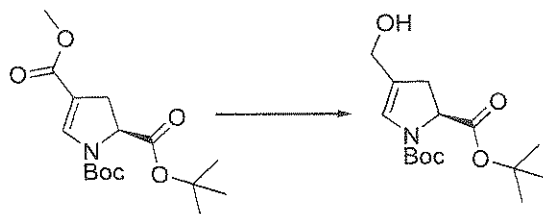
5

Example 20-2: The preparation of N-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-hydroxyethyl pyrrolidine



10 To a 100ml of single-necked flask was added (2*S*,4*S*)-N-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-carboxyl pyrrolidine (0.66g, 2.11mmol), TEA (0.4ml, 2.74mmol) and 5ml of methylene chloride, then ethyl chloroformate (252mg, 2.32mmol) was added dropwise, after stirring for another 1hour at 25°C, washed with water and organic phase was concentrated, then the residue was dissolved in THF and water, NaBH₄ (230mg, 15 6mmol) was added, after stirring for another 3 hours at 25°C, quenched by dilute HCl, and extracted with ethyl acetate, dried over MgSO₄, then filtered, evaporated and recrystallized with ethanol to give 566mg of N-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-hydroxyethyl pyrrolidine as colorless oil in 89.2%, ee 97.6%.

20 **Example 21: The preparation of (2*S*,4*S*)-N-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-hydroxyethyl-2,3-dihydro-1*H*-pyrrole**

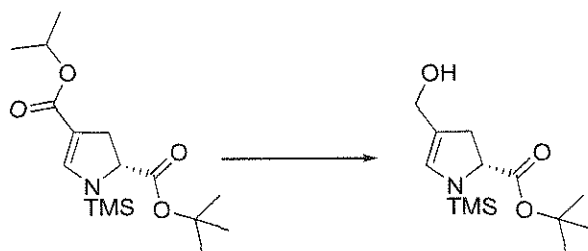


To a mixture of (2*S*,4*S*)-N-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-methoxycarbonyl 2,3-dihydro-1*H*-pyrrole (3g, 9.2mmol) dissolved in 20ml of THF, diisobutyl aluminium

hydride(5.6g, 46mmol) was added, after stirred overnight at 25 °C, quenched by dilute HCl, and extracted with ethyl acetate, concentrated, then recrystallized by ethanol to give 2.52g of (2*S*,4*S*)-*N*-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-hydroxyethyl-2,3-dihydro-1*H*-pyrrole in 91.7% yield.

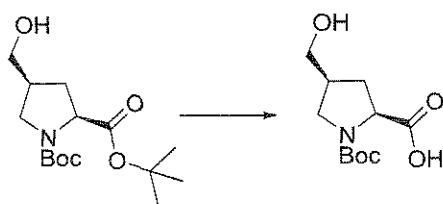
5

Example 22: the preparation of (2*R*,4*R*)-*N*-trimethylsilyl-2-tert-butoxycarbonyl-4-hydroxyethyl-2,3-dihydro-1*H*-pyrrole



To a mixture of (2*R*,4*R*)-*N*-trimethylsilyl-2,4-di(tert-butoxycarbonyl)-2,3-dihydro-1*H*-pyrrole (1.9g, 5.9mmol) in 20ml of THF, red aluminum (5.7g, 28mmol) was added, after stirring overnight at 25°C, quenched by dilute HCl, and extracted with ethyl acetate, then purified by column chromatography to give 1.08g of (2*R*,4*R*)-*N*-trimethylsilyl-2-tert-butoxycarbonyl-4-hydroxyethyl-2,3-dihydro-1*H*-pyrrole as oil in 67.5% yield.

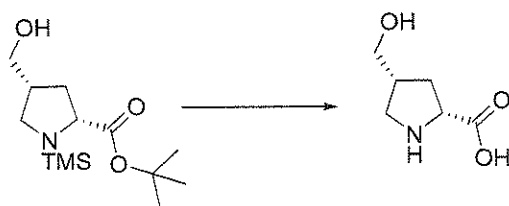
15 **Example 23: the preparation of (2*S*,4*S*)-*N*-tert-butoxycarbonyl-2-carboxyl-4-hydroxyethyl pyrrolidine**



(2*S*,4*S*)-*N*-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-hydroxyethyl pyrrolidine (3g, 10mmol) was dissolved in 20ml of hydrochloride ethanol solution. After stirring for 3 hours at 25°C, the solvent was evaporated, then 15% NaOH and (Boc)₂O(3.27g, 1.5eq) were added, stirred for 3 hours, and extracted with ethyl acetate, then adjusted to PH=2, extracted with ethyl acetate again, concentrated to give 2.2g of white solid in 89.7% yield.

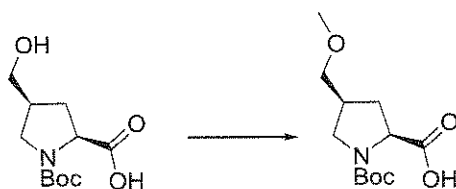
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Example 24: the preparation of (2R,4R)-2-carboxyl-4-hydroxyethyl pyrrolidine



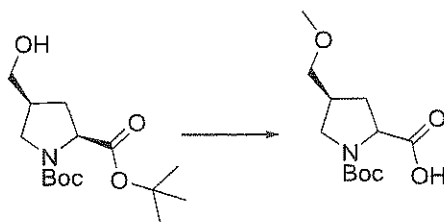
(2R,4R)-N-trimethylsilylamino-2-tert-butoxycarbonyl-4-hydroxyethyl pyrrolidine (2.7g, 10mmol) was dissolved in 20ml of hydrochloride ethanol solution. After stirring for 3 hours at 25°C, the solvent was evaporated to give 1.2g of (2R,4R)-2-carboxyl-4-hydroxyethyl pyrrolidine in 82.7% yield.

Example 25: the preparation of (2S,4S)-N-tert-butoxycarbonyl-2-carboxyl-4-methoxyethyl pyrrolidine



(2S,4S)-N-tert-butoxycarbonyl-2-carboxyl-4-hydroxyethyl pyrrolidine (2.45g, 10mmol) was dissolved in 50% of NaOH, then methyl iodide (4.26g, 0mmol) was added, after stirring for 3 hours at 2 °C, the resulting mixture was extracted with ethyl acetate, then adjusted to PH=2, extracted with ethyl acetate, the organic phase was washed with water, dried over MgSO₄, concentrated to give 2.5g of white solid in 96.5% yield.

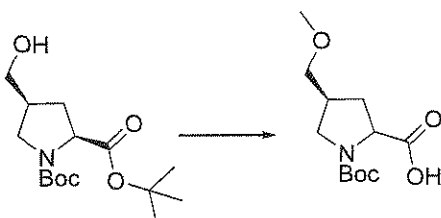
Example 26: the preparation of (2S,4S)-N-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-methoxyethyl pyrrolidine



(2S,4S)-N-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-hydroxyethyl pyrrolidine (3.0g, 10mmol) was dissolved in 50% of NaOH, then methyl iodide (4.26g, 0mmol) was added. After

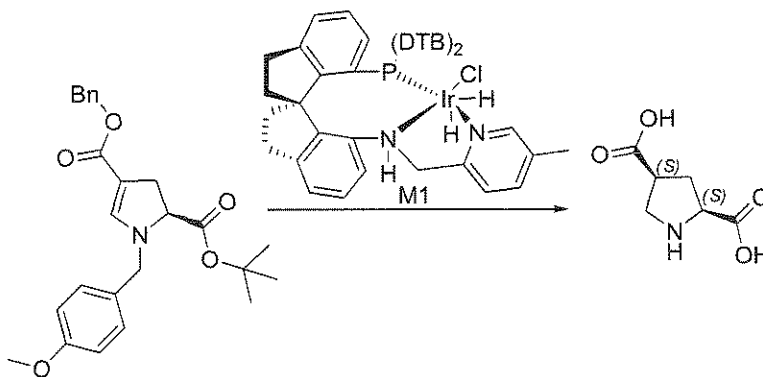
stirring for 3 hours at 25 °C, the resulting mixture was extracted with ethyl acetate, then adjusted to PH=2, extracted with ethyl acetate, and the organic phase was washed with water, dried over MgSO₄, and concentrated to give 2.5g of white solid in 96.5% yield.

5 **Example 26-2: the preparation of (2*S*,4*S*)- N-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-methoxyethyl pyrrolidine**



To a mixture of (2*S*,4*S*)-N-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-hydroxyethyl pyrrolidine (3.0g, 10mmol) in ethyl acetate, Bu₄NBr (0.65g, 2mmol) and methyl sulphate (2.5g, 20mmol) were added, after dissolving completely, 2g of NaOH solution (40%) was added dropwise with maintaining the inner temperature at -5 °C to 5 °C. After the addition, the mixture was maintained at this temperature for 3 hours, and extracted with ethyl acetate, and then the organic phase was washed with dilute HCl aqueous solution and dilute NaOH aqueous solution respectively. The organic solvent was concentrated then recrystallized by hexane to give 2.47g of white solid in 95.2% yield.

Example 27: the preparation of (2*S*,4*S*)-2,4-dicarboxyl pyrrolidine



Chiral catalyst M (7.0mg, 0.007mmol), EtONa (38mg, 0.71mmol) and (S)-N-p-methoxybenzyl-2-tert-butoxycarbonyl-4-benzyloxycarbonyl-2,3-dihydro-1*H*-pyrrole (3g, 7.1mmol) were weighted into a reaction inner tube under the protection of N₂ atmosphere, then

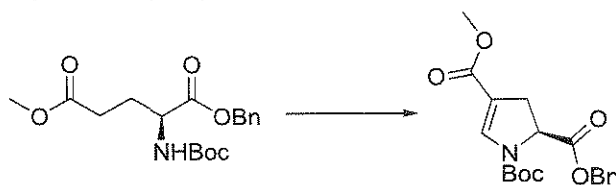
15ml of ethanol and 3ml of DMF were added. The reaction tube was placed into an autoclave. The original atmosphere was displaced with hydrogen atmosphere. The hydrogen pressure inside the autoclave was ultimately maintained at 1.4-1.5 MPa and then heated to 50°C in an oil bath with reacting for 3h. Starting material was consumed completely until the inside pressure did not continue to decrease, then the reaction was stopped and the resulting mixture was concentrated. 30ml of water and 30ml of ethyl acetate were added, and aqueous phase was extracted with ethyl acetate (2×20ml). the combined organic phase was washed with saturated brine, dried over MgSO₄, filtered and concentrated to give 1.0g of (2*S*,4*S*)-2,4-dicarboxyl pyrrolidine in 88.6% yield. The product was analyzed by chiral HPLC, the chiral purity is 97.5% ee.

Example 28: the preparation of (S)-1-benzyl-5-methyl-2-((tert-butoxycarbonyl)amino)pentanedioate



To a 100ml of single-necked bottle was added (S)-5-methyl-2-((tert-butoxycarbonyl)amino)pentanedioate (7.8g, 24.6mmol), benzyl chloride(3.4g, 27mmol), K₂CO₃(3.1g, 29.5mmol) and 30ml of DMF, the mixture was maintained at 40 to 60 °C for 6 hours, after the completion of the reaction, the solvent was evaporated, extracted with methyl tert-butyl ether after the addition of water, and then the organic phase was evaporated to dryness to give 8.45g of (S)-1-benzyl-5-methyl-2-((tert-butoxycarbonyl)amino)pentanedioate as light yellow oil in 97.9% yield.

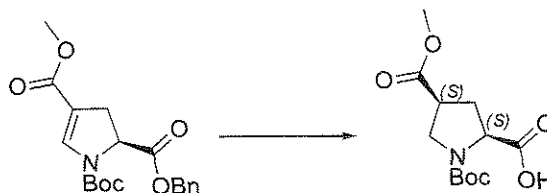
Example 29: the preparation of (S)-N-tert-butoxycarbonyl-2-benzyloxycarbonyl-4-methoxycarbonyl-2,3-dihydro-1H-pyrrole



To a 250ml of three-necked bottle was added 60ml of LHMDS (7.6g, 45.4mmol) under the protection of nitrogen, then cooled to -70°C to -78°C, after the addition of

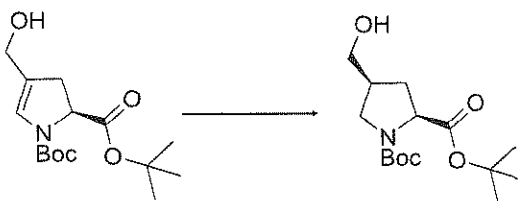
(S)-1-tert-butyl-5-methyl-2- (tert-butoxycarbonyl)amino pentanedioate (8.0g, 25.2mmol) in 40ml of THF, the mixture was maintained at this temperature for 1 hour, then ethyl formate (4.4g, 60mmol) was added dropwise slowly and the inner temperature was maintained below -70°C. After the addition, the mixture was maintained at this temperature for 8 hours. After the completion of the reaction, the reaction solution was warmed to about -40°C, 3.5ml of acetic acid was added, and then quenched with 30ml of water, extracted with ethyl acetate, dried over MgSO₄, filtered and concentrated to give a light yellow oil. Then the above mentioned oil was dissolved in methylene chloride. After the addition of TFA (3.16g, 27.7mmol), the mixture was stirred for 4 hours at 25 °C, then concentrated to dryness to give 8.8 g of (S)-N-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-methoxycarbonyl-2,3-dihydro-1H-pyrrole in 96.7% yield.

Example 30: the preparation of (2S,4S)-2-carboxyl-4-methoxycarbonyl pyrrolidine



To a 100ml of single-necked bottle was added (S)-N-tert-butoxycarbonyl-2-benzyloxycarbonyl-4-methoxycarbonyl-2,3-dihydro-1H-pyrrole (3.0g, 8.3mmol) (prepared by the method of Example 5), 10% wet Pd/C(0.7g, 30%), one drop of acetic acid and 5ml of Methanol, then the mixture was stirred at 25 °C overnight, after filtration and evaporation, 2.27g of (2S,4S)-2-carboxyl-4-methoxycarbonyl pyrrolidine as colorless oil was obtained in 100% yield, ee 98.8%.

Example 31: the preparation of (2S,4S)-N-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-hydroxyethyl pyrrolidine

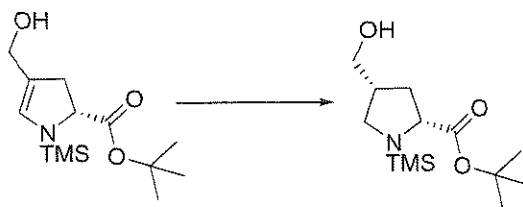


The procedure of example 15 was repeated to afford

(2*S*,4*S*)-*N*-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-hydroxyethyl pyrrolidine containing (2*S*,4*R*)-*N*-tert-butoxycarbonyl-2-tert-butoxycarbonyl-4-hydroxyethyl pyrrolidine, ee 61.1%%.

Example 32: the preparation of

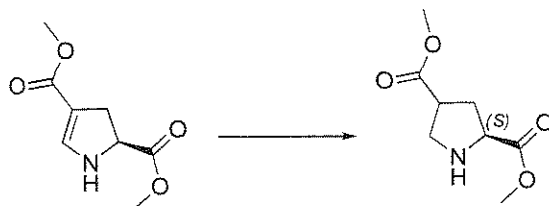
5 (2*R*,4*R*)-*N*-trimethylsilyl-2-tert-butoxycarbonyl-4-hydroxyethyl pyrrolidine



The procedure of example 15 was repeated to afford (2*R*,4*R*)-*N*-trimethylsilyl-2-tert-butoxycarbonyl-4-hydroxyethyl pyrrolidine containing (2*R*,4*S*)-*N*-trimethylsilyl-2-tert-butoxycarbonyl-4-hydroxyethyl pyrrolidine, ee 55.4%.

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Comparison Example 1: the preparation of (2*S*)-2,4-dimethoxycarbonyl pyrrolidine

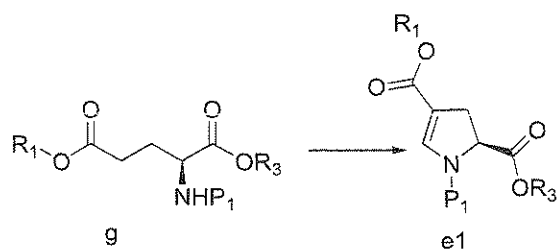


To a 100ml of single-necked bottle was added (2*S*)-2,4-dimethoxycarbonyl-2,3-dihydro-1*H*-pyrrole (1.85g, 10mmol), 10% wet Pd/C(0.7g, 30%), one drop of acetic acid and 5ml of methanol, then the mixture was stirred at 25°C overnight, after filtration and evaporation, 1.80g of (2*S*)-2,4-dimethoxycarbonyl pyrrolidine as colorless oil was obtained in 96.2% yield.

Thus it can be seen from the comparison example that, the product (2*S*)-2,4-dimethoxycarbonyl pyrrolidine is racemic at 4 position.

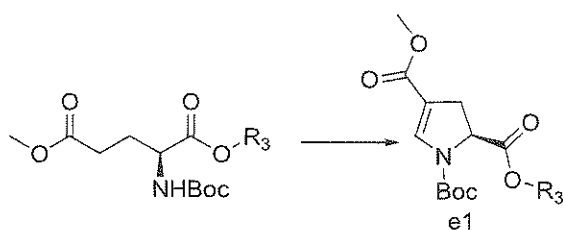
The experimental results presented below are got in accordance with example 6 when R_1 , R_3 , P_1 are different substituents.

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Product	R ₁	R ₃	P ₁	Yield
e1-1	methyl	t-Bu	trifluoroacetyl	73.2%
e1-2	methyl	t-Bu	allyloxycarbonyl	77.0%
e1-3	methyl	t-Bu	triphenylmethyl	80.4%
e1-4	methyl	t-Bu	benzyl	85.7%
e1-5	methyl	t-Bu	Cbz	90.1%
e1-6	methyl	t-Bu	p-chlorobenzyl	87.6%
e1-7	isopropyl	t-Bu	Boc	85.1%
e1-8	isopropyl	t-Bu	Cbz	84.2%
e1-9	isopropyl	t-Bu	benzyl	82.2%
e1-10	n-hexyl	t-Bu	Boc	61.3%
e1-11	methyl	benzyl	benzyl	86.7%
e1-12	methyl	benzyl	p-chlorobenzyl	88.9%
e1-13	methyl	benzyl	Cbz	94.3%
e1-14	isopropyl	benzyl	Boc	74.7%
e1-15	methyl	isopropyl	Boc	78.7%
e1-16	methyl	n-hexyl	Boc	70.0%
e1-17	methyl	p-nitrobenzyl	Boc	83.5%
e1-18	methyl	ethyl	Boc	86.9%
e1-19	benzyl	t-Bu	Boc	88.8%

The experimental results presented below are got in accordance with example 6 in the presence of different reaction reagents.



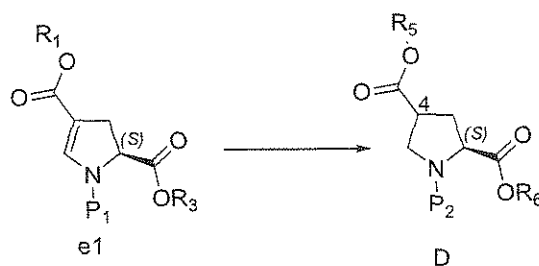
Product	R ₃	base	formic mixed	Yield
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			anhydride / alkyl formate	
e1-20	t-Bu	lithium bis(trimethylsilyl)amide	formic anhydride	85.3%
	t-Bu	lithium bis(trimethylsilyl)amide	pivalic formic anhydride	78.0%
	t-Bu	lithium bis(trimethylsilyl)amide	benzoic formic anhydride	73.5%
	t-Bu	lithium diisopropylamide	formic anhydride	79.1%
	t-Bu	lithium diisopropylamide	acetic formic anhydride	86.7%
	t-Bu	lithium diisopropylamide	pivalic formic anhydride	71.9%
	t-Bu	sodium ethoxide	acetic formic anhydride	86.9%
	t-Bu	sodium propoxide	acetic formic anhydride	87.2%
	t-Bu	lithium bis(trimethylsilyl)amide	ethyl formate	94.8%
	t-Bu	sodium methoxide	pivalic formic anhydride	67.2%
	t-Bu	sodium methoxide	n-propylformate	65.9%
e1-21	benzyl	lithium bis(trimethylsilyl)amide	formic anhydride	82.5%
	benzyl	lithium bis(trimethylsilyl)amide	pivalic formic anhydride	78.7%
	benzyl	lithium bis(trimethylsilyl)amide	benzoic formic anhydride	70.3%
	benzyl	lithium bis(trimethylsilyl)amide	acetic formic anhydride	96.6%
	benzyl	lithium bis(trimethylsilyl)amide	methyl formate	84.5%
	benzyl	lithium	n-propylformate	85.7%

bis(trimethylsilyl)amide

benzyl	n-butyllithium	acetic formic anhydride	89.1%
benzyl	n-butyllithium	ethyl formate	87.4%
benzyl	sodium methoxide	acetic formic anhydride	90.9%
benzyl	sodium methoxide	ethyl formate	89.7%
benzyl	sodium methoxide	methyl formate	70.4%
benzyl	potassium isopropoxide	benzoic formic anhydride	63.0%
	potassium isopropoxide	n-propylformate	68.1%
benzyl	sodium hydride	ethyl formate	79.8%
benzyl	sodium hydride	methyl formate	63.6%
benzyl	sodium isopropoxide	pivalic formic anhydride	70.2%

The experimental results presented below are got in accordance with example 10 when R₅, R₆, P₂ are different substituents.

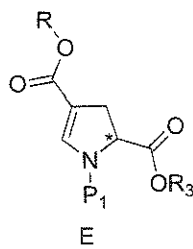


Substrate	Product	R ₅	R ₆	P ₂	Yield	ee (4S)
e1-1	D-1	methyl	t-Bu	trifluoroacetyl	97.8%	97.2%
e1-2	D -2	methyl	t-Bu	allyloxycarbonyl	60.1%	95.7%
e1-3	D -3	methyl	t-Bu	H	83.6%	96.2%
e1-4	D -4	methyl	t-Bu	H	100%	97.6%
e1-5	D -5	methyl	t-Bu	Cbz	100%	97.7%
e1-6	D -6	methyl	t-Bu	H	100%	98.8%
e1-7	D -7	isopropyl	t-Bu	Boc	100%	91.9%
e1-8	D -8	isopropyl	t-Bu	Cbz	100%	91.2%
e1-9	D -9	isopropyl	t-Bu	H	100%	89.7%
e1-10	D -10	n-hexyl	t-Bu	Boc	100%	78.7%

e1-11	D -11	methyl	H	H	100%	96.8%
e1-12	D -12	methyl	H	H	98.8%	96.9%
e1-13	D -13	methyl	H	Cbz	100%	97.9%
e1-14	D -14	isopropyl	H	Boc	100%	89.1%
e1-15	D -15	methyl	isopropyl	Boc	100%	80.3%
e1-16	D -16	methyl	n-hexyl	Boc	100%	89.7%
e1-17	D -17	methyl	H	Boc	99.0%	98.2%
e1-18	D -18	methyl	ethyl	Boc	100%	65.3%
e1-19	D -19	H	t-Bu	Boc	100%	56.9%

Claims

1. A compound of formula E,



wherein R is R₁ or R₂, R₁ is C₁~C₆ alkyl, benzyl, p-methoxybenzyl or p-nitrobenzyl, R₂ is a hydrogen atom;

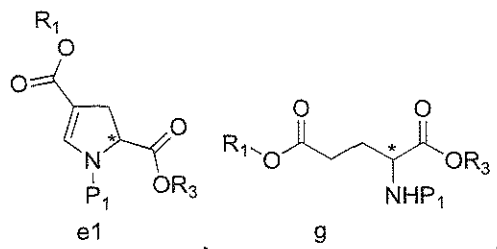
R₃ is a protecting group for carboxyl;

P₁ is a protecting group of nitrogen.

2. The compound according to claim 1, R₁ is C₁~C₆ alkyl, R₃ is tert-butyl, benzyl, p-methoxybenzyl or p-nitrobenzyl; P₁ is t-butyloxycarbonyl, p-methoxybenzyl or benzyloxycarbonyl.

3. The compound according to claim 2, R₁ is methyl, R₃ is tert-butyl or benzyl, P₁ is t-butyloxycarbonyl.

4. A method for preparing the compound of formula (e1), comprising subjecting the compound of formula (g) to cyclization reaction,



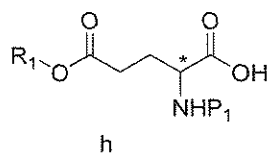
Wherein R₁, R₃ and P₁ are as defined in claim 1.

5. The method according to claim 4, the reagent employed in the process of cyclization reaction is base/ formic mixed anhydride or alkyl formate/acid, the base is selected from lithium bis(trimethylsilyl)amide, lithium diisopropylamide, n-butyllithium, sodium alcoholate and potassium alcoholate; the formic mixed anhydride is selected from acetic formic anhydride, formic pivalic anhydride and formic benzoic anhydride; the acid is selected from trifluoroacetic acid and acetic acid, the alkyl formate is selected from methyl formate, ethyl formate, propyl formate.

6. The method according to claim 5, the base is lithium bis(trimethylsilyl)amide.

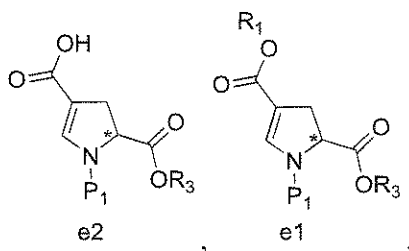
7. The method according to claim 5, the formic mixed anhydride is acetic formic anhydride; the alkyl formate is ethyl formate.

8. The method according to claim 4, further comprising the step of, reacting the compound of formula (h) with $(R_3CO)_2$ or R_3X in the presence of a base to afford the compound of formula (g),



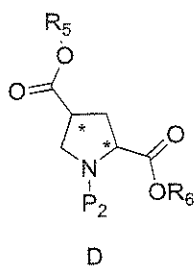
wherein R_1 , R_3 and P_1 are as defined in claim 1, X is a halogen atom.

9. A method for preparing the compound of formula (e2), including subjecting the compound of formula (e1) to hydrolyzation reaction to generate the compound of formula (e2), the reagent employed for the hydrolysis is alkali base,



wherein R_1 , R_3 and P_1 are as defined in claim 1.

10. The use of compound (E) according to claim 1, including the compound of formula (E) being subjected to catalytic hydrogenation to obtain the compound of formula (D),



wherein R_5 is a hydrogen atom or C_1 - C_6 alkyl, R_1 is methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, tert-butyl, n-pentyl and n-hexyl;

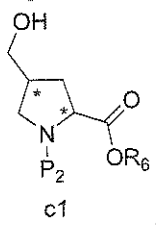
R_6 is a hydrogen atom, n-propyl, isopropyl, n-butyl, isobutyl, tert-butyl, n-pentyl or n-hexyl;

P_2 is a hydrogen atom, acetyl, trifluoroacetyl, allyloxycarbonyl, t-butyloxycarbonyl,

trimethylsilyl, *tert*-butyldimethylsilyl or benzoyl.

11. The use according to claim 10, the catalyst for catalytic hydrogenation may be selected from palladium on carbon, platinum oxide or Raney Ni.

12. The use according to claim 10, further comprising the step of, the compound of formula (D) being reduced to the compound of formula (c1),

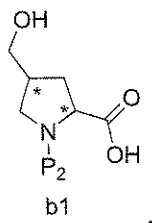


wherein R₆ and P₂ are as defined in claim 10.

13. The use according to claim 12, the reducing reagent employed is selected from tributyltin hydride, triphenyltin hydride, triethyl silicane, trichlorosilane, sodium borohydride, sodium trimethoxyborohydride, lithium tri-*sec*-butylhydridoborate, potassium tri-*sec*-butylborohydride, lithium triethylborohydride, diisobutyl aluminium hydride (DIBAH) and sodium bis(2-methoxyethoxy)aluminiumhydride.

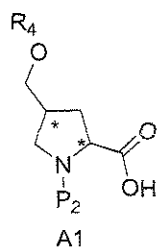
14. The use according to claim 10, when R₅ is a hydrogen atom, further comprising the addition of alkyl chloroformate before the step of subjecting the carboxyl group of compound (D) to reduction reaction.

15. The use according to claim 12, further comprising the step of, converting the compound of formula (c1) to the compound of formula (b1) by removing the carboxyl group,



wherein P₂ is as defined in claim 10.

16. The use according claim 15, further comprising the step of converting the compound of formula (b1) to the compound of formula (A1) by alkylation reaction,



wherein R_4 is $C_1\sim C_6$ alkyl, P_2 is as defined in claim 10.