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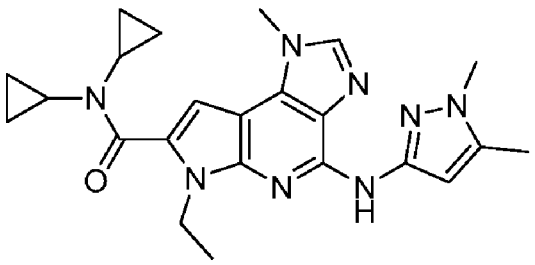
[Continued on next page]

(54) Title: PROCESS FOR THE PREPARATION OF N,N-DICYCLOPROPYL-4-(1,5-DIMETHYL-1H-PYRAZOL-3-YLAMINO)-6-ETHYL-1-METHYL-1,6-DIHYDROIMIDAZO[4,5-d]PYRROLO[2,3-b]PYRIDINE-7-CARBOXAMIDE

(57) Abstract: The invention relates to an improved process for synthesizing *N,N*-dicyclopropyl-4-(1,5-dimethyl-1*H*-pyrazol-3-ylamino)-6-ethyl-1-methyl-1,6-dihydroimidazo[4,5-d]pyrrolo[2,3-b]pyridine-7-carboxamide of the formula: (I) Compound (I) is currently in clinical trials for the treatment of myeloproliferative disorders, such as polycythaemia vera, thrombocythaemia and primary myelofibrosis.



(I)

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(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

PROCESS FOR THE PREPARATION OF *N,N*-DICYCLOPROPYL-4-(1,5-DIMETHYL-1*H*-PYRAZOL-3-YLAMINO)-6-ETHYL-1-METHYL-1,6-DIHYDROIMIDAZO[4,5-d]PYRROLO[2,3-b]PYRIDINE-7-CARBOXAMIDE

CROSS REFERENCE TO RELATED APPLICATIONS

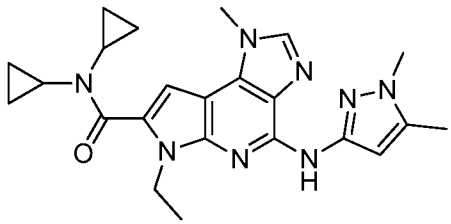
This application claims priority from U.S. Provisional Application No. 61/871,510 filed August 29, 2013, the disclosure of which is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

The invention generally relates to several improved processes for the preparation of *N,N*-dicyclopropyl-4-(1,5-dimethyl-1*H*-pyrazol-3-ylamino)-6-ethyl-1-methyl-1,6-dihydroimidazo[4,5-d]pyrrolo[2,3-b]pyridine-7-carboxamide, a JAK2 inhibitor currently in clinical trials for the treatment of myeloproliferative disorders, which include polycythaemia vera, thrombocythaemia and primary myelofibrosis.

BACKGROUND OF THE INVENTION

There are disclosed significantly improved processes for the preparation of *N,N*-dicyclopropyl-4-(1,5-dimethyl-1*H*-pyrazol-3-ylamino)-6-ethyl-1-methyl-1,6-dihydroimidazo[4,5-d]pyrrolo[2,3-b]pyridine-7-carboxamide, of formula I:

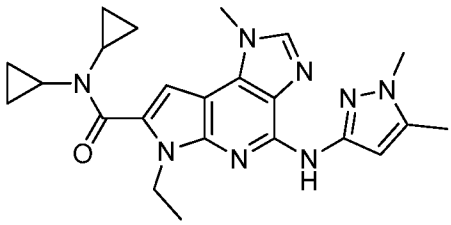


(I)

Compound I, compositions comprising Compound I, and methods of using Compound I are disclosed in U.S Patent No. 8,202,881 B2, which is assigned to the present assignee and is incorporated herein by reference in its entirety.

SUMMARY OF THE INVENTION

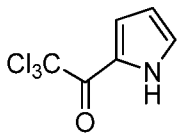
In a first aspect, the invention provides a process for preparing Compound I of the formula:



(I)

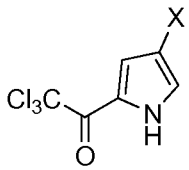
comprising the steps of

a) reacting Compound 1 of the formula



Compound 1

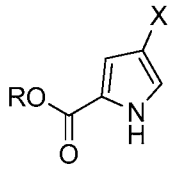
with a halogenating agent, such as NBS, in a suitable solvent to afford Compound 2 of the formula



Compound 2

wherein X is Cl, Br or I;

b) reacting Compound 2 with an alcohol, and optionally a base, to afford Compound 3 of the formula



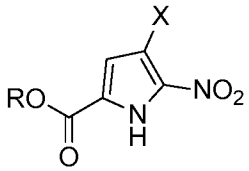
Compound 3

wherein

R is Me, Et, i-Pr, n-Pr, n-Bu, sec-Bu or t-Bu; and

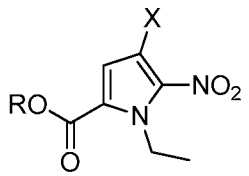
X is as defined above;

c) subsequently reacting Compound 3 with a nitrating agent to afford Compound 4 of the formula



Compound 4

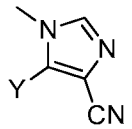
d) reacting Compound 4, first, with an ethylating agent to afford Compound 5 of the formula



Compound 5

wherein R and X are as previously defined

and, subsequently with a suitably substituted imidazole of the formula,



Compound 33

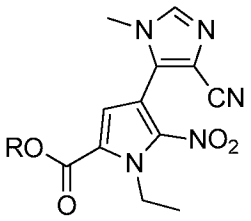
wherein

Y is H, Cl, Br, I or $-B(OR')_2$;

R' is Me, Et, i-Pr, n-Pr, n-Bu, sec-Bu, t-Bu, $-(CH_2)_n$ or $-C(Me)_2C(Me)_2-$; and

n is 2, 3, 4 or 5;

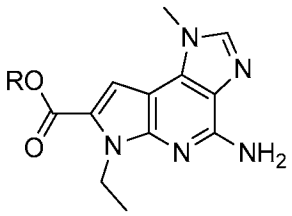
in the presence of a suitable catalytic metal, a ligand, an inorganic salt and optionally an organic base, to afford Compound 6 of the formula



Compound 6

wherein R is as previously defined;

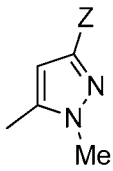
e) which is then reacted with hydrogen in the presence of a suitable catalytic metal and optionally a base, to afford Compound 7 of the formula



Compound 7

wherein R is as defined above;

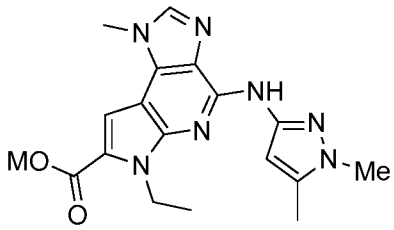
f) which is reacted with the Compound 24 of the formula



Compound 24

wherein Z is Cl, Br, I, -OP(O)(OR'')$_2$ or -OS(O)CF$_3$;

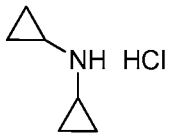
in the presence of a suitable metal, a ligand, and base, to afford Compound 26 of the formula



Compound 26

wherein R'' is Ph or t-Bu and M is Li, Na, K, Cs, Rb, Mg or Ca;

g) which is reacted with Compound 27 of the formula

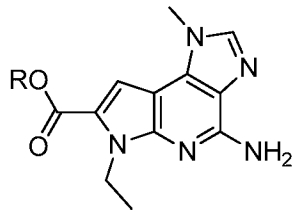


Compound 27

in a the presence of a suitable activator, a suitable solvent, such as DCM, and optionally a base, to afford Compound I.

The term "ligand" as used herein refers to a phosphine derivative that ligates palladium such as a mono or bi-dentate aryl or alkyl phosphine, which is capable of complexing a palladium atom. The term is well known to one skilled in the particular art.

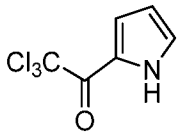
In a second aspect, there is provided a process for the preparation of Compound 7 of the formula:



Compound 7

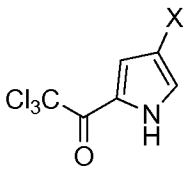
which comprises:

a) reacting Compound 1 of the formula



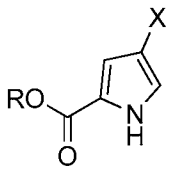
Compound 1

with a halogenating agent, such as NBS, in a suitable solvent to afford Compound 2 of the formula



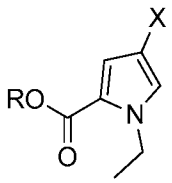
Compound 2

b) reacting Compound 2 with base and an alcohol to afford Compound 3 of the formula



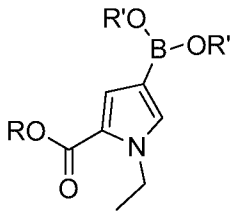
Compound 3

c) reacting Compound 3 with an ethylating agent to afford Compound 14



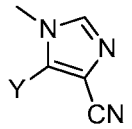
Compound 14

d) reacting Compound 14 with an appropriate diboron reagent, in the presence of a catalytic metal, ligand and base to afford Compound 15



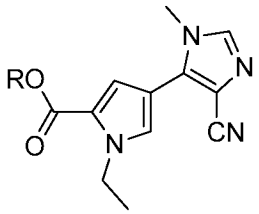
Compound 15

e) reacting Compound 15 with Compound 33 of the formula,



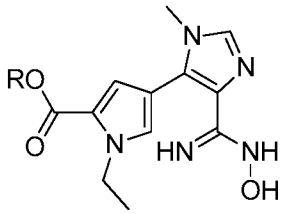
Compound 33

in the presence of a catalytic metal, ligand and an appropriate base, to afford Compound 16



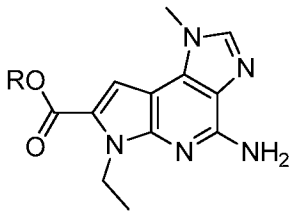
Compound 16

f) reacting Compound 16 with a suitable hydroxylamine derivative to afford Compound 17



Compound 17

g) and, reacting Compound 17 with a suitable metal, hydrogen and, optionally, an activating group, to afford Compound 7



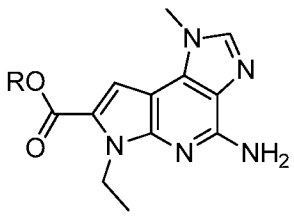
Compound 7

wherein:

R, R' and X are as previously defined.

In a preferred embodiment, R' is $-C(Me)_2C(Me)_2-$.

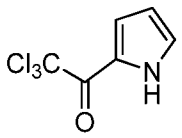
In a third aspect, the invention provides another process for preparing Compound 7 of the formula:



Compound 7

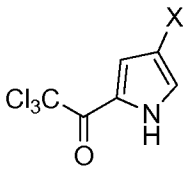
which comprises

a) reacting Compound 1 of the formula



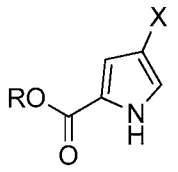
Compound 1

with a halogenating agent, such as NBS, in a suitable solvent, to afford Compound 2 of the formula



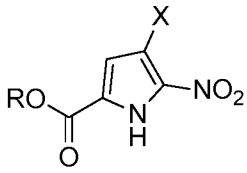
Compound 2

b) reacting Compound 2 with base and an alcohol to afford Compound 3 of the formula



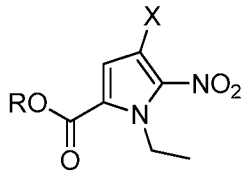
Compound 3

c) reacting Compound 3 with a nitrating agent to afford Compound 4 of the formula



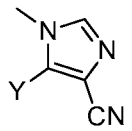
Compound 4

d) reacting Compound 4, first, with an ethylating agent to afford Compound 5 of the formula



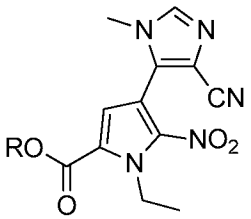
Compound 5

And, subsequently with Compound 33 of the formula,



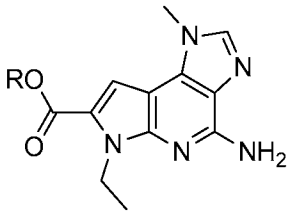
Compound 33

in the presence of an appropriate ligand and an appropriate base to afford Compound 6



Compound 6

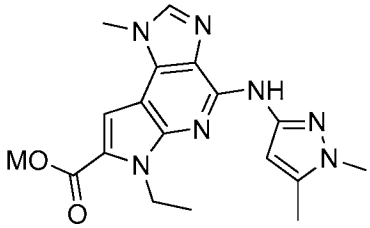
e) and, reacting Compound 6 with hydrogen, a metal catalyst and optionally a base, to afford Compound 7



Compound 7

wherein R, X and Y are as previously defined.

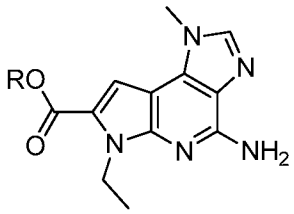
In a fourth aspect, there is provided a process for the preparation of Compound 26 of the formula



Compound 26

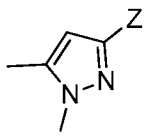
which comprises:

a) reacting Compound 7 of the formula



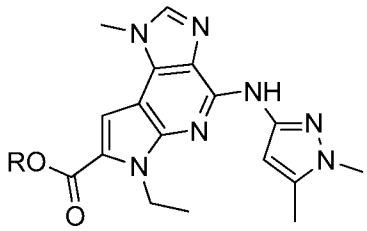
Compound 7

with Compound 24 of the formula



Compound 24

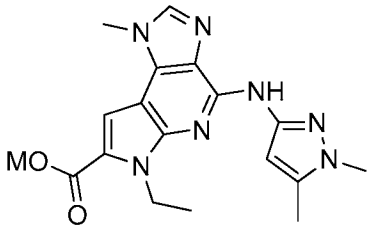
to provide Compound 25,



and,

Compound 25

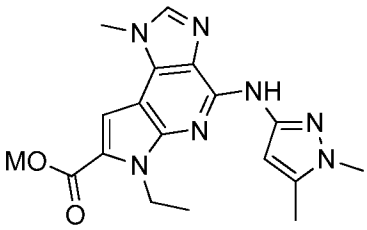
b) reacting Compound 25 with an aqueous inorganic base in a suitable solvent to prepare Compound 26



Compound 26

wherein R and M are as previously defined; and Z is Cl, Br, I, -OP(O)(OR')$_2$ or -OS(O)CF_3.

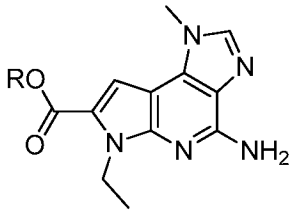
In a fifth aspect, there is provided a process for the preparation of Compound 26



Compound 26

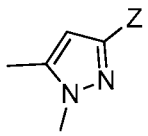
which comprises

a) reacting Compound 7 of the formula



Compound 7

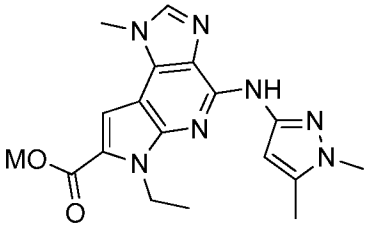
with a suitable strong base in water, a metal catalyst, a ligand and Compound 24 (or salt forms thereof) of the formula



Compound 24

and subsequently treating the solution with a metal salt to provide Compound 26, wherein R, Z and M are as previously defined.

A further aspect of the invention provides a compound of formula I by reacting Compound 26

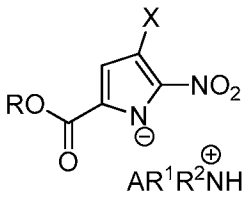


Compound 26

where M is as defined above,

with an activator, optionally a catalyst, in the presence of base and dicyclopropylamine (optionally as its hydrochloride salt) to prepare Compound I.

A further aspect of the invention provides basic salt forms of the pyrrole derivative with amine derivatives



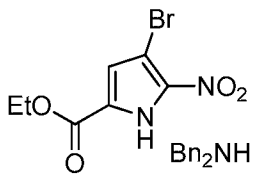
wherein

R and X are as previously defined, A is H, NH_2, OH or R^1;

R^1 and R^2 are independently C_1-C_5 alkyl, benzyl, allyl, $-(CH_2CH_2)_2O$, $-(CH_2CH_2)_3N$, and other simple amine bases such as, TEA, DBU, DIPEA, DABCO, DCHA, tetramethyl guanidine, ammonia, hydrazine, morpholine, DMAP, tetramethyl piperidine and dibenzylamine.

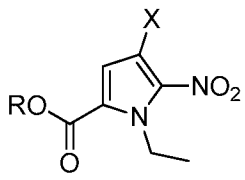
In a preferred embodiment, R is Et, A is H, X is Br and R^1 and R^2 are both benzyl.

Another aspect of the invention provides Compound 10a of the formula



Compound 10a

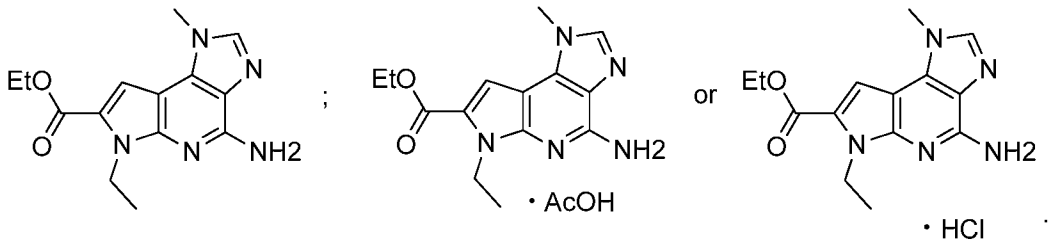
Another aspect of the invention provides Compound 5 of the formula



Compound 5

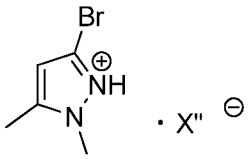
wherein R and X are as previously defined.

Another aspect of the invention provides Compound 13 of the formula as its free base, or acidic salt which is



Compound 13 Compound 13a Compound 13b

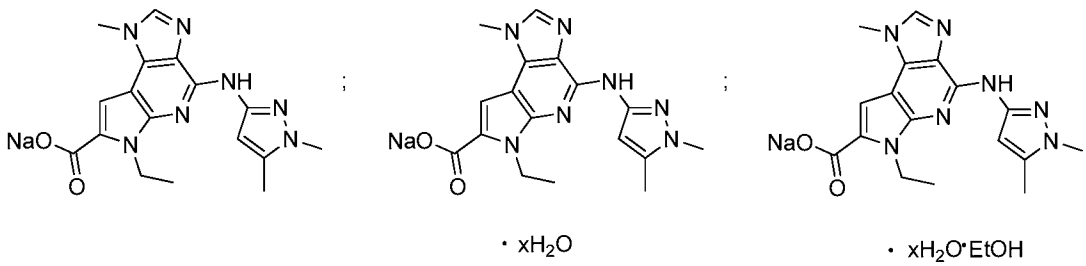
Another aspect of the invention provides acidic salt forms of Compound 29



Compound 29

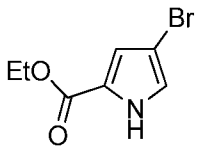
where X" is Cl, Br or CF_3SO_3.

Another aspect of the invention provides compound 31 of the formula as its free form, hydrate or hydrated ethanol solvate



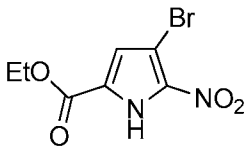
Compound 31 Compound 31a Compound 31b

Another aspect of the invention provides a method for nitrating Compound 9 of the formula



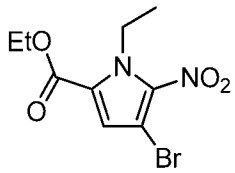
Compound 9

which comprises combining a metal salt of nitric acid selected from $NaNO_3$, KNO_3 or $LiNO_3$, with SO_3.pyridine complex, in the presence of the respective metal sulfate salt selected from Na_2SO_4, Li_2SO_4 or K_2SO_4, and metal bisulfate salt selected from $NaHSO_4$, $LiHSO_4$ or $KHSO_4$, in a suitable solvent, such as MeCN, to afford Compound 10 of the formula



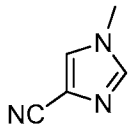
Compound 10

Another aspect of the invention provides a method for coupling Compound 11



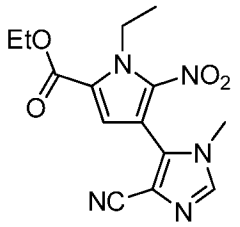
Compound 11

to Compound 28 of the formula



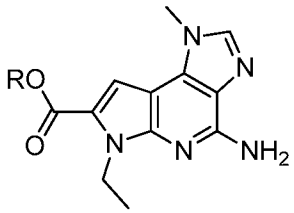
Compound 28

which comprises treating Compound 11 with a suitable palladium source such as $PdCl_2$ (or a pre-ligated version), a phosphine ligand such as Xantphos and a suitable potassium source such as potassium pivalate (PivOK) and optionally an organic base such as Hunig's base, to afford Compound 12 of the formula



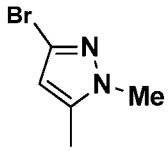
Compound 12

Another aspect of the invention provides a method for coupling amine derivative Compound 7 of the formula



Compound 7

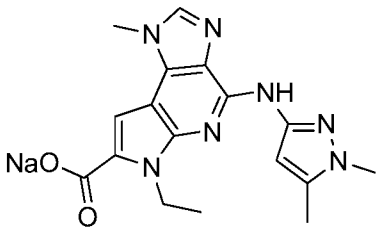
to Compound 29 of the formula



Compound 29

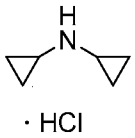
in the presence of a suitable palladium source, a ligand and a base in a suitable solvent (such as tAmylOH).

Another aspect of the invention provides a method of coupling Compound 31 of the formula



Compound 31

to Compound 27 of the formula



27

which comprises treating Compound 31 with DPPCl in the presence of base, then reacting Compound 27 in the presence of DMAP to afford Compound I.

Another aspect of the invention provides a method of coupling Compound 31 to Compound 27 of the formula by treating Compound 31 with DMC, followed by treatment with Compound 27 in the presence of base DMAP, to afford Compound I.

Another aspect of the invention provides Compound I prepared by the processes described herein.

A final aspect of the invention provides a method for treating a myeloproliferative disorder, comprising administering to a mammalian species, preferably a human, in need thereof, a therapeutically effective amount of Compound I, wherein Compound I is prepared utilizing the novel process steps of the invention.

The processes of the invention have several important advantages over prior syntheses of Compound I. In particular, due to the short sequence of chemical steps, high yields and process improvement, the throughput, cycle-time and overall yield have been dramatically improved. Additionally, the process consistently provides Compound I in high quality for use as a pharmaceutical API.

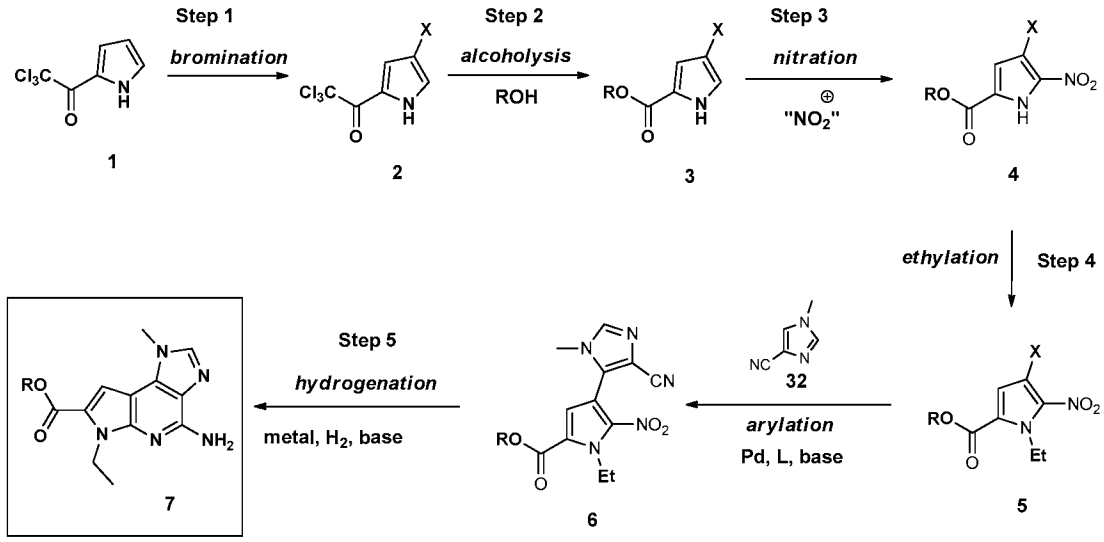
What is now needed in the art are new methods of making the pyrrolopyridine compound, which is useful against myeloproliferative diseases, both in terms of overall yield and material throughput.

DETAILED DESCRIPTION OF THE INVENTION

The following schemes illustrate the improved synthetic steps of the invention. These Schemes are illustrative and are not meant to limit the possible techniques one skilled in the art may use to manufacture compounds disclosed herein.

As shown below in Scheme 1, the general preparation of compound 7 is described. Trichloroacetyl pyrrole (Compound 1) is reacted with a halogenating agent to give the C4-bromo pyrrole (Compound 2). Alcoholysis occurs in the presence of an alcohol and base to generate ester (Compound 3), which can be selectively nitrated through contact with an appropriate nitrating agent (defined as a species that generates NO_2^+), yielding C5-nitro pyrrole (Compound 4). Compound 4 can be isolated as its free form, or optionally as a salt with an appropriate base. Ethylation with an appropriate alkylating agent generates the N-ethyl pyrrole (Compound 5), which in the presence of an imidazole, base, palladium and an appropriate phosphine ligand, will undergo a coupling process to form Compound 6. Reduction of the nitro-group of Compound 6 in the presence of hydrogen, a metal catalyst and optionally a base will produce Compound 7.

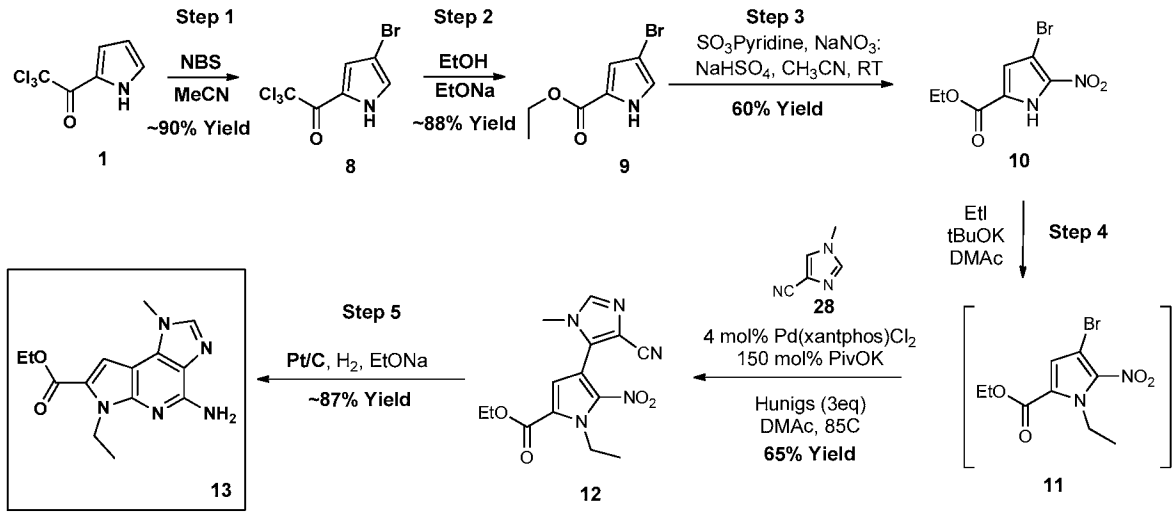
Scheme 1



As shown below in Scheme 2, the preparation of Compound 13 is described. Trichloroacetyl pyrrole is treated with NBS in acetonitrile to produce Compound 8. Treatment with sodium ethoxide in EtOH yields the ethyl ester Compound 9. This may be treated with a range of nitrating systems, in this example, $NaNO_3/SO_3$·Py, to generate nitro-pyrrole Compound 10, which can be isolated directly or as a salt form with an appropriate base, preferably dibenzylamine. Ethylation with ethyl iodide generates Compound 11 which may be isolated, or optionally telescoped directly into the arylation

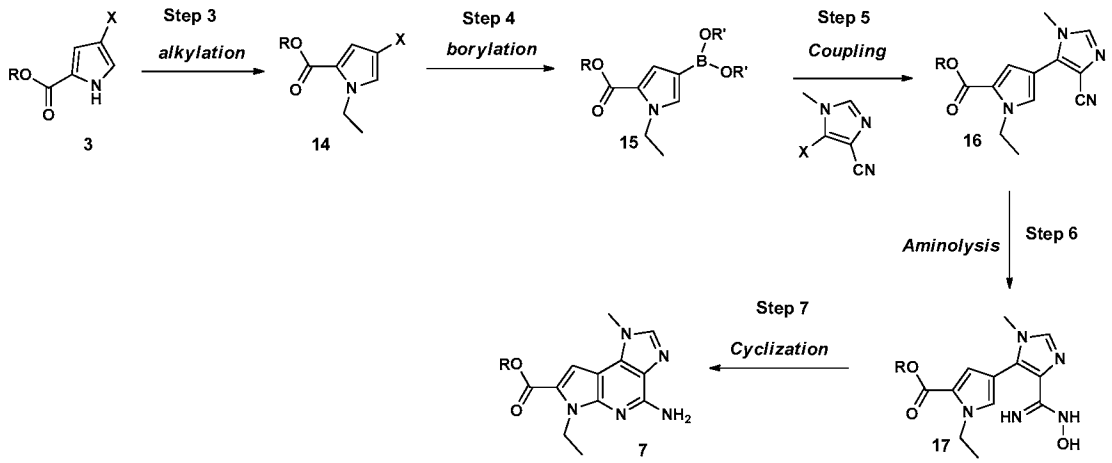
with Compound 32. Arylation proceeds in the presence of palladium, Xantphos, potassium pivylate and Hunig's base to generate Compound 12. Hydrogenation in the presence of Pt/C followed by cyclization with NaOEt yields Compound 13.

Scheme 2



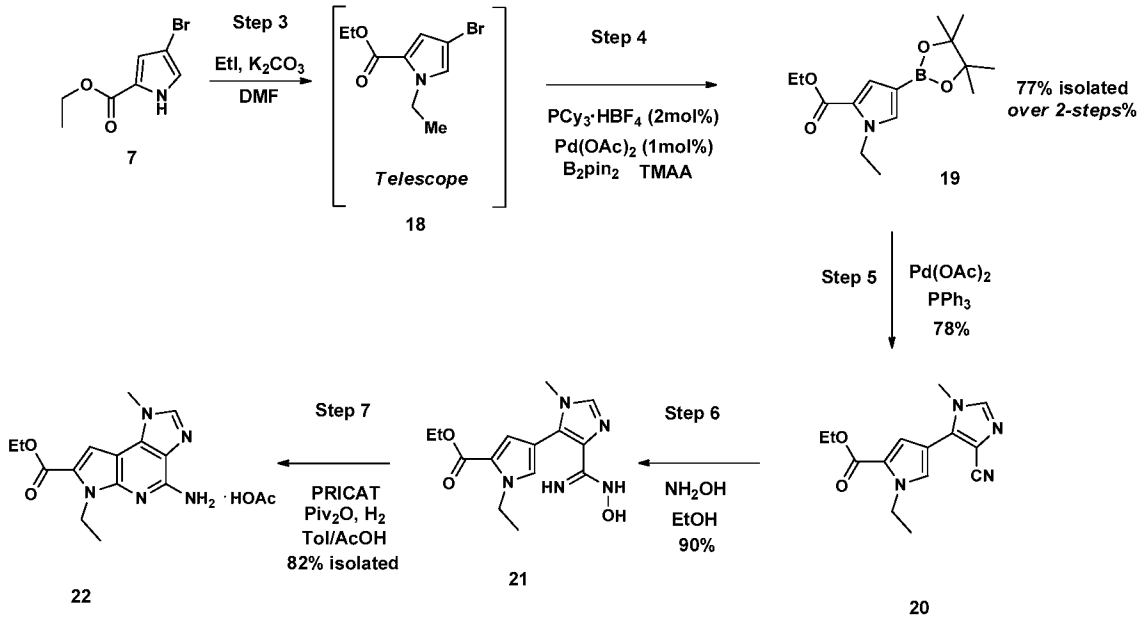
Another process of the invention is disclosed in Scheme 3 shown below. Compound 14 is prepared from Compound 3 in the presence of an alkylating agent. Treatment with a suitable diboron reagent produces Compound 15, which can then be coupled with a suitably functionalized imidazole derivative to yield Compound 16. Aminolysis with a suitable nitrogen donor produces Compound 17, which can cyclize under appropriate conditions to produce Compound 7.

Scheme 3



As shown below in Scheme 4, ethylation of Compound 9 with ethyl iodide produces Compound 18. This may be directly reacted with dipinacol-diboron in the presence of $Pd(OAc)_2$ and tricyclohexylphosphin hexafluorophosphate and tetramethylammonium acetate to yield Compound 19. Subsequent coupling with 5-Br-imidazole derivative yields Compound 20. Treatment with hydroxylamine hydrochloride in the presence of triethylamine yields the Compound 21. Subsequent cyclization with Piv_2O in the presence of PRICAT™ and hydrogen yields Compound 13.

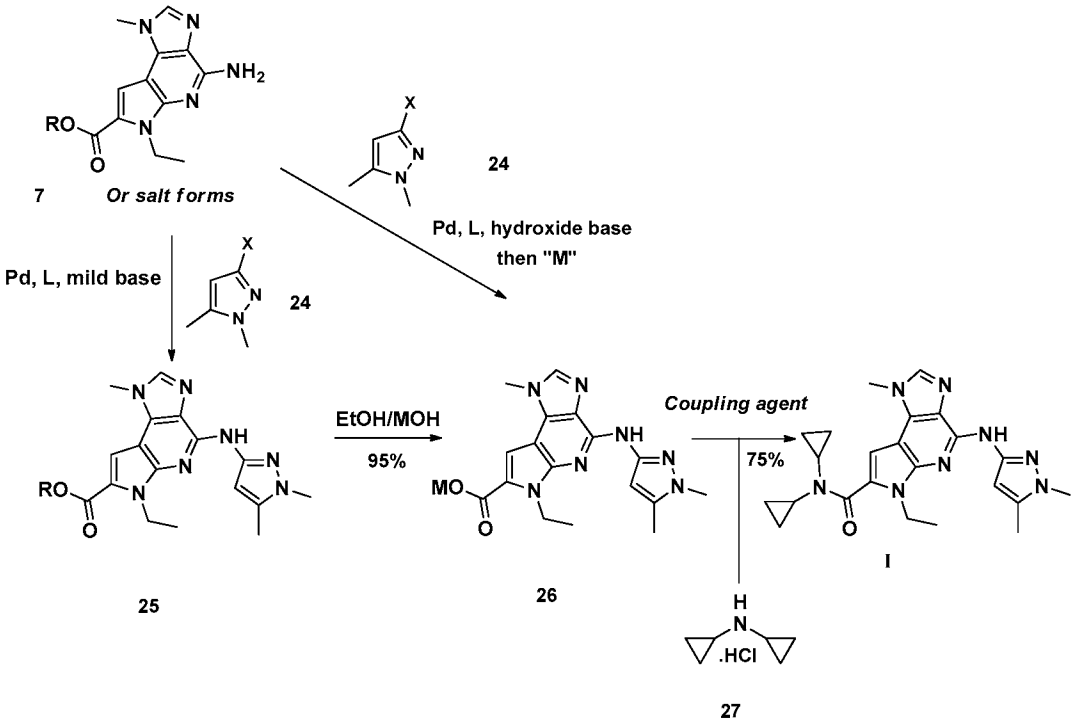
Scheme 4



As shown below in Scheme 5, Compound 23 may be converted to Compound 26 by two pathways. In one option, Compound 23 can be treated with palladium, ligand and a mild base to prepare Compound 25. Reaction of Compound 25 with a metal hydroxide produces Compound 26.

Alternately, Compound 23 can be treated with palladium and ligand in the presence of a soluble hydroxide base, followed by treatment with the metal counter-ion to prepare Compound 26 directly. Once Compound 26 is formed, it can be coupled to Compound 27 to form compound I.

Scheme 5



Examples

The invention will now be further described by the following working example(s), which are preferred embodiments of the invention. All temperatures are in degrees Celsius (°C) unless otherwise indicated. These examples are illustrative rather than limiting and it is to be understood that there may be other embodiments that fall within the spirit and scope of the invention as defined by the claims appended hereto.

For ease of reference, the following abbreviations may be used herein.

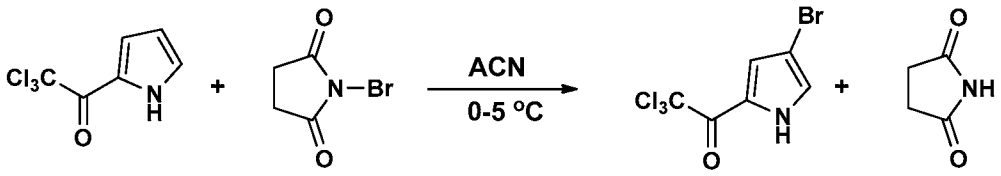
Abbreviations

ACN	acetonitrile
AcOH	acetic acid
Ac_2O	acetic anhydride
ADDP	1,1′-(azodicarbonyl)dipiperidine
aq.	aqueous
Bn	benzyl
Boc	*t*-butyl carbamate
Boc_2O	di-*t*-butyl dicarbonate
Bu	butyl
Cbz	benzyl carbamate
conc.	concentrated
DCE	dichloroethane
DCM	dichloromethane
DIAD	diisopropyl azodicarboxylate
DIEA	diisopropylethylamine
DIPEA	N,N-diisopropylethylamine
DMAP	4-N,N-dimethylaminopyridine
DMF	dimethyl formamide
DMSO	dimethyl sulfoxide
DMT-MM	4-(4,6-dimethoxy-1,3,5-triazin-2-yl)-4-methylmorpholinium chloride
EDC	1-(dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride
eq.	equivalents
Et	ethyl
EtOAc	ethyl acetate
EtOH	ethanol
Et_2O	diethyl ether
Et_3N	triethylamine
Fmoc	9-fluorenylmethyl carbamate
h	hour(s)

HATU	*O*-(7-azabenzotriazol-1-yl)-N,N,N′,N′-tetramethyluronium hexafluorophosphate
HOAt	1-hydroxy-7-azabenzotriazole
HPLC	high pressure liquid chromatography
i-PrOH	isopropanol
KOAc	potassium acetate
LAH	Lithium aluminum hydride
LR	Limiting reagent
min	minute(s)
Me	methyl
MeCN	acetonitrile
MeOH	methanol
Me_2NH	dimethyl amine
NaHMDS	sodium bis(trimethylsilyl)amide
$Na(OAc)_3BH$	sodium triacetoxyborohydride
n-BuLi	*n*-butyl lithium
NCS	*N*-chlorosuccinimide
NMM	*N*-methylmorpholine
NMP	*n*-methylpyrrolidinone
NMR	nuclear magnetic resonance
OTf	trifluoromethylsulfonyloxy
Pd/C	palladium on carbon
$Pd(dppf)_2Cl_2$	[1,1′-*bis*(diphenylphosphino)ferrocene] dichloropalladium(II)
$Pd(OAc)_2$	palladium acetate
$Pd(PPh_3)_4$	tetrakis(triphenylphosphine)palladium
$Pd_2(dba)_3$	tris(dibenzylideneacetone)dipalladium(0)
Ph	phenyl
PhMe	toluene
Ph_2TfN	1,1,1-trifluoro-N-phenyl-N-(trifluoromethyl)sulfonyl methanesulfonamide
PPh_3	triphenyl phosphorus

rt/RT	room temperature
sat.	saturated
t-Bu	tertiary butyl
t-BuOH	tertiary butanol
TFA	trifluoroacetic acid
Tf_2O	trifluoromethylsulfonic anhydride
THF	tetrahydrofuran
TMAA	tetra-methyl ammonium acetate
TMS	trimethylsilyl
TsO	*p*-toluenesulfonyl
Xantphos	4,5-bis(diphenylphosphino)-9,9-dimethylxanthane

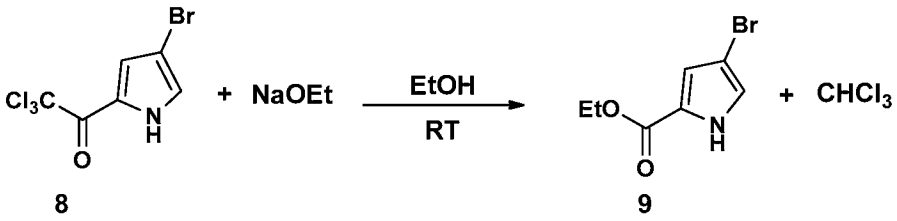
Example 1



1 8

A solution of Compound **1** in acetonitrile (1238.0 kg, 264.9 kg after correction) was charged into a 5000 L glass-lined reactor at a temperature of 20-30 °C. The mixture was added with stirring over about 2 h and then cooled to 0 °C. NBS (221.8 kg) was charged into the mixture at intervals of 20-30 min at 0-20 °C. The mixture was cooled to 0-5 °C and reacted until the content of Compound 8was ≤ 1.0%. Additional NBS (4.0 kg) was charged into the mixture at 0-20 °C. The mixture was reacted over 3 h until the content of Compound 8 was ≤ 1.0%. Purified water (2650.0 kg) was added over about 1.5 – 2.5 h at 0-20 °C. The mixture was cooled to 0-5 °C and then stirred for about 1 h for crystallization. The mixture was filtered and the filter cake was rinsed with water.

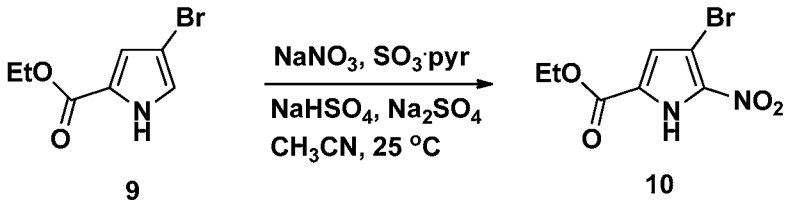
Example 2



8 9

While maintaining the temperature at 20-30 °C, anhydrous ethanol (950.0 kg) was charged into a 3000 L glass-lined reactor followed by Compound 8 (342.7 kg). The mixture was cooled to 0-5 °C over about 2 h. Sodium alcoholate solution in ethanol (21%, 36.4 kg) was added dropwise over about 1-1.5 h at 0-5 °C. The reaction mixture was then heated to about 25-30 °C and tested until the content of Compounds **8/9** was ≤ 1.0%. The reaction mixture was concentrated at a temperature ≤ 50 °C until about 1.3-1.4 volume of Compound 8 was left. The concentrated mixture was cooled at 25-30 °C. The mixture was quenched into cooled water (3427.0 kg) over about 2 h. After addition, the mixture was stirred at 0-5 °C over about 2 h for crystallization. The mixture was filtered and the filter cake was rinsed. The solid was dried at 30-40 °C over 40-45 h to afford 234.3 kg of Compound 9 , 99.9% purity and 91.3% yield.

Example 3

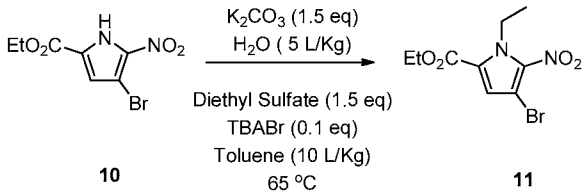


9 10

A mixture of $NaNO_3$, $NaHSO_4$, and Na_2SO_4 in CH_3CN is wet-milled to constant particle size of ~50 micron. To the slurry of inorganic salts is added SO_3·pyridine and Compound 9. The reaction mixture is agitated at 25 °C until 90-95% conversion is achieved. The reaction is quenched with aqueous sodium hydroxide and the spent inorganic salts are removed by filtration. The filtrate is passed through a carbon pad and distilled under constant volume distillation and diluted with water to a target 15

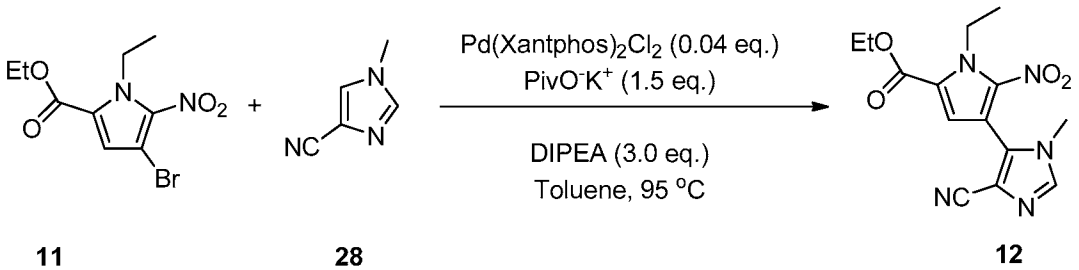
volumes/kg of Compound 9 and a target ratio 1.0:2.0 vol/vol MeCN to water. The resulting solids are deliquored, washed, and dried to afford Compound 10.

Example 4



Compound 10 (1.0 eq) and TBABr (1.0 eq) were added to a biphasic mixture of toluene (8 L/kg **10**) and potassium carbonate (1.5 eq) in water (5 L/kg **10**). The batch temperature was held at 25 °C. The resulting triphasic slurry was heated to 60-65 °C and diethylsulfate (1.5 eq, in a solution of toluene 2 L/kg **10**) was slowly added over ~ 1 h. The reaction was aged until less than 1 RAP of Compound 10 (**10:11**) remained. The resulting homogeneous biphasic mixture was cooled to 20 °C and the lean aq. phase was removed. The rich organic phase was washed with water (2x7 L/kg **10**) and concentrated to 6 mL/g **10**. The concentrated stream was dried via azeotropic, constant volume distillation with toluene until the water content of the stream was <0.1 wt %. The resulting stream was telescoped into the subsequent direct arylation reaction.

Example 5

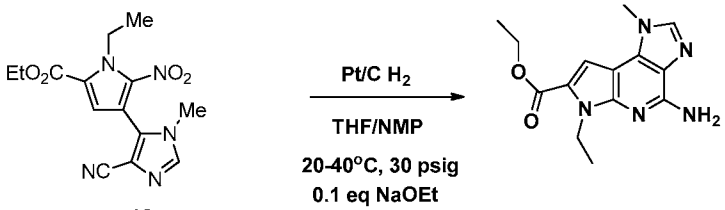


11 **28** **12**

To the toluene stream of Compound 11, with potassium pivalate (1.5 equiv.) was charged, followed by DIPEA (3 eq.), Compound 28 (3 eq.) and Pd(Xantphos)Cl_2 (0.04 eq.). The vessel was evacuated to < 200 torr and backfilled with nitrogen (3 X) followed

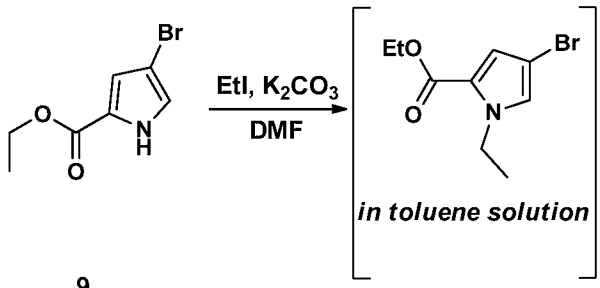
by heating to 95 °C until residual Compound 11 was less than 1 RAP (**11:12**). The reaction mixture was cooled to 25 °C and diluted with ethyl acetate (15 mL/g vs input pyrrole) and aq. N-acetylcysteine (0.2 eq., 5 wt % solution, 1.8 mL/g vs. input pyrrole) and heated to 50 °C for 1 h. The biphasic mixture was cooled to 25 °C. The lower aqueous layer was removed. The ethyl acetate stream was washed with water (2x7 mL/g vs. input pyrrole). The rich organic phase was polish filtered followed by a vessel/polish filter rinse with ethyl acetate (2 mL/g vs. input pyrrole). The rich organic stream was concentrated to 4 mL/g vs. input pyrrole via vacuum distillation, while maintaining the batch temperature above 50 °C. If spontaneous nucleation did not occur, Compound 12 seeds (1 wt %) were charged, followed by aging for 30 min at temperature. MTBE (5 mL/g vs. 11) was charged to the slurry over 1 hour while maintaining the batch temperature above 40 °C, followed by aging at 40 °C for 1 h. The slurry was cooled to 0 °C over 6 h and aged at 0°C for 6 h. The slurry was filtered and washed with EtOAc:Toluene:MTBE (1.5:1.0:1.5, 2 mL/g vs. input 11). The wet cake was dried (50 °C, 100 torr) until LOD was < 1 wt %.

Example 6



Compound 12 (1 eq., limiting reagent (LR)) is dissolved in THF/NMP (20 Vol wrt LR, 9/1 ratio) and submitted to hydrogenation using 10 wt% (wrt LR) Pt/C (5 wt%) at 25 to 40° C for 5-10 h. The reaction containing the corresponding amine is filtered. The rich organic stream is concentrated to Compound 12 Vol (wrt LR) and subjected to 0.1 eq of 21 wt% NaOEt/EtOH for 5 h at 20-25 °C, upon which Compound 13 forms. The stream is cooled to 0-10 °C, and water (5L/Kg, wrt to LR) is added and then filtered to isolate Compound 13. The product is dried at 50 °C under vacuum.

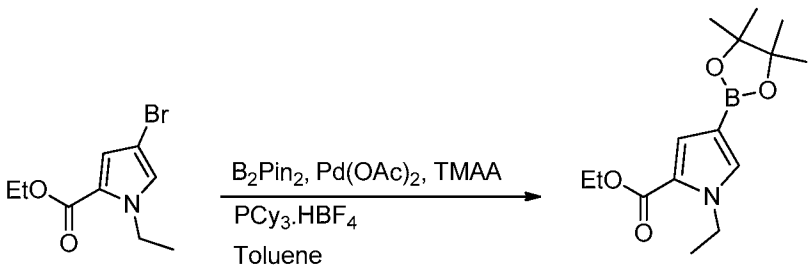
Example 7



9 18

Compound 18 was prepared by treating the pyrrole with ethyl iodide and pulverized potassium carbonate in DMF at 25-30°C under inert atmosphere. After the reaction was completed, the batch mass was cooled to 15°C to 20°C and quenched by slow addition of water then MTBE. The MTBE layer was separated and washed with water. The MTBE layer was distilled to 4 Vol and solvent swapped with toluene. The toluene stream was then taken into the next step.

Example 8

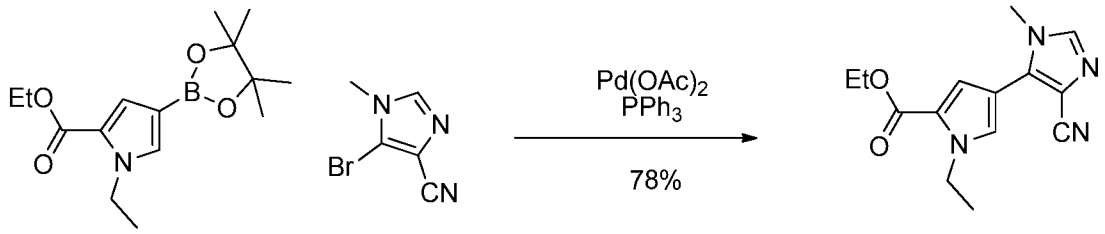


18 19

Tetra-methyl ammonium acetate in toluene slurry was heated to 75-80°C to get a clear solution. The mass was cooled to below 30°C and pyrrole in toluene and bis (pinacolato) diborane were added. The reactor was inerted by nitrogen purging then the reaction was heated to 75-80°C. A freshly prepared catalyst/ligand complex (0.01eq of palladium acetate, 0.025eq of tricyclohexyl phosphino hexafluoroborate and 0.2eq of tetra methyl ammonium acetate in toluene) was charged under nitrogen atmosphere at RT and stirred for 2h. The mass was then stirred at 75-80°C under nitrogen atmosphere. After the reaction was completed, the mixture was cooled below 30°C and quenched with aq. sodium bisulphate solution. The organic layer was polish filtered through a Celite bed and the filtrate was washed with water. The solvent swapped to ethanol until the toluene

content became less than 0.5 %. The solution was cooled to 0-5°C and water was added for crystallization. The product was then isolated by filtration.

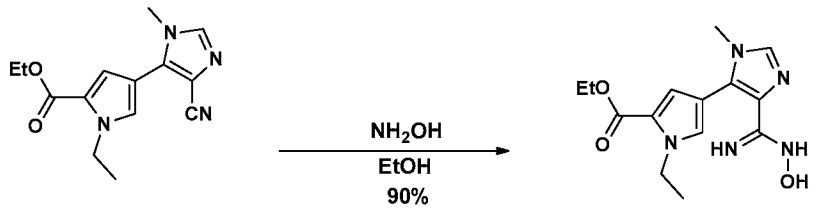
Example 9



19 34 20

Compound 20 was prepared by treating Compound 19 with Compound 34 in the presence of palladium acetate, triphenyl phosphine and potassium carbonate in dimethyl acetamide with the water mixture as the solvent. Dimethyl acetamide, water, potassium carbonate and the two starting materials were charged into the reactor. The mixture was made inert with nitrogen for 30 min and then charged with freshly prepared catalyst mixture (palladium acetate, triphenyl phosphine and potassium carbonate in dimethyl acetamide). The temperature was raised to 78-83 °C then the mass was stirred at this temperature. After the reaction was completed, the reaction mass was cooled to ambient temperature and purified water was added slowly into the mass for product crystallization. The mass was stirred for a period of 3 h and filtered. The wet cake was washed with purified water and dried in VTD at 50-55 °C under vacuum.

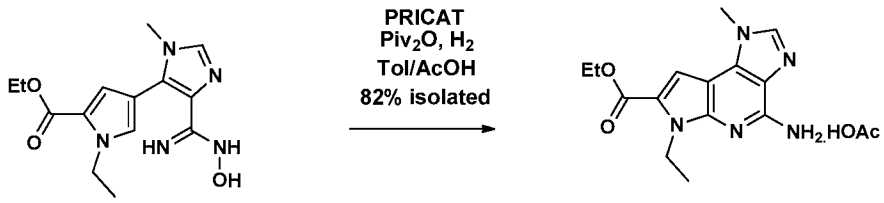
Example 10



20 21

Compound 21 was prepared by treating Compound 20 with hydroxylamine hydrochloride and triethyl amine using ethanol as the solvent. Compound 20 was added into ethanol (15 Vol) and the reaction mass was heated to 38-40 °C. Hydroxylamine hydrochloride was charged and stirred for 10 min, then triethyl amine was added slowly at 38-40 °C over a period of 1h. The above mass was stirred at 38-40 °C until Compound 20 becomes less than 5.0%, typically in about 15 h. After the reaction was completed, the above reaction mass was cooled to ambient temperature (below 30 °C) and filtered. The wet cake was washed with purified water (4 Vol) and dried under vacuum in VTD at 55-60 °C.

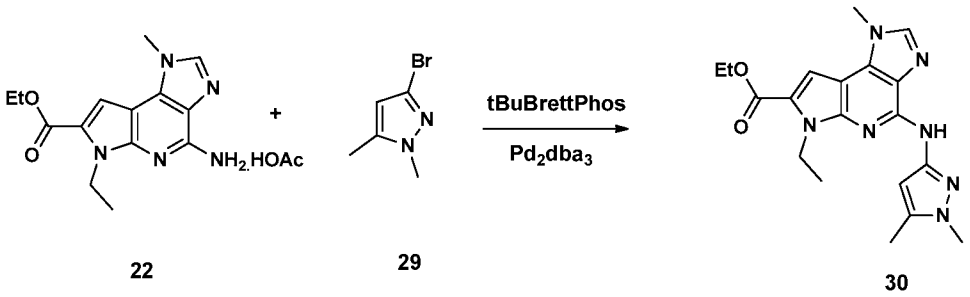
Example 11



21 22

Initially Compound 21 was treated with pivalic anhydride using toluene and acetic acid mixture as solvent under inert atmosphere until Compound 21 becomes less than 3.0% with respect to Compound 21, typically in about 30 min. PRICAT Nickel was then added under nitrogen atmosphere. The reaction mass was inerted with nitrogen for three cycle times and then degassed with hydrogen gas for three cycle times. Following this, 3.0 kg/cm^2 hydrogen pressure was applied to the reaction mass which was stirred for about 12h. After the reaction was completed, the reaction mixture was filtered through a sparkler filter. The filtrate was distilled and the solvent exchanged with toluene until the ratio of acetic acid & toluene reaches 1:20. At this time, n-Heptane was charged and cooled to 15°C. Then the product was filtered and the wet cake was dried in VTD at 50-55°C under vacuum.

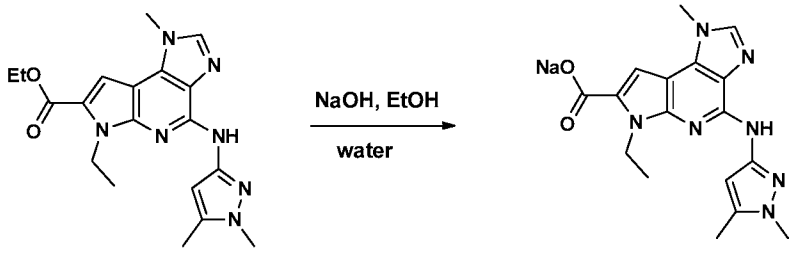
Example 12



22 29 30

Compound 30 was prepared by the coupling of Compound 22 with Compound 29, 3-bromo-1,5-dimethyl-1H-pyrazole in the presence of Tris(dibenzylideneacetone)dipalladium chloroform adduct, t-Brettphos and potassium phosphate in tert-amyl alcohol at 98-103 °C under inert atmosphere. After completion of the reaction (typical level of Int.9 -5% & typical reaction hrs 20 h), the mass was cooled to ambient temperature and t-amyl alcohol (4 Vol) and 20 Vol of water were charged into the reaction mass. The reaction mass was stirred for 15 min. and then phase split. The organic layer was diluted with 10 Vol of MTBE and product was extracted with 20 Vol of 1M methane sulphonic acid. The MSA stream was treated with 15 wt % charcoal to reduce the residual palladium numbers. The filtrate was cooled to below 20 °C and the pH was adjusted to 1.7-1.9 using 1N NaOH for product crystallization and then iltered. The wet cake was washed with purified water (3 x 5 Vol), followed by methanol (5 Vol). The cake was vacuum dried for 3 h. then the wet cake and dimethyl sulfoxide (20 Vol) were charged into a reactor. The mass was heated to 120-125 °C to get clear solution then the mass was cooled to ambient temperature and stirred for 2 h, then filtered. The wet cake was washed with methanol (3x 4.0 Vol) and vacuum dried for 2 h. The wet cake was dried in VTD at below 55°C under vacuum.

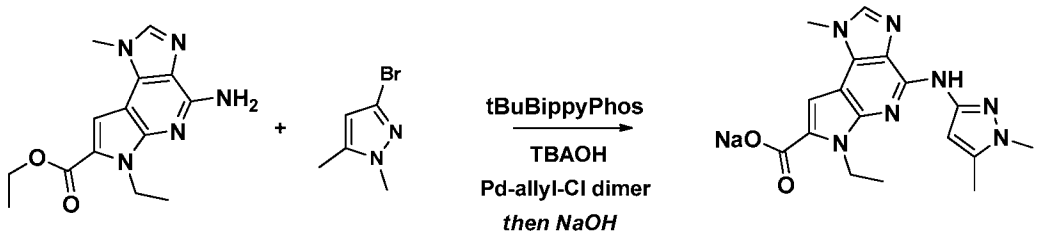
Example 13



30 31

Compound 30 , ethanol (16.5 Vol), water and aq sodium hydroxide solution were charged into a reactor then the mass was heated to 70-75 °C and stirred until Compound 30 becomes less than 1.0%. After the reaction was completed, the mass was diluted with ethanol for complete product precipitation at 65-75 °C. Then the mass was cooled to 50 °C for a period of 1h and stirred for 1h at 50 °C. The mass was further cooled to 20 °C and stirred for 1h at 20 °C and then filtered. The wet cake was washed with 5 Vol of 15% aqueous ethanolic solution followed by THF. The wet cake was dried under vacuum at 70-75 °C till LOD comes to less than 5.0 %, typically in about 40 h.

Example 14



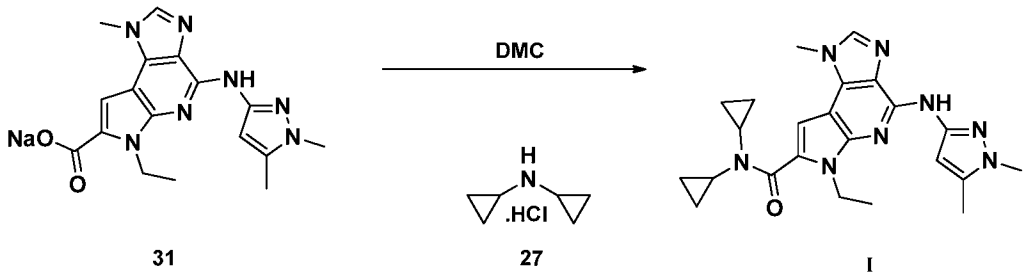
13 29 31

In a vessel 36.5 mmol (~42.6 mL) of Compound 29 solution in 2-methyl-2-butanol was combined with 30.7g (65.1 mmol) tetrabutylammonium hydroxide (55 wt% in water), 8.01g (27.0 mmol) Compound 13 , and 10 mL 2-methyl-2-butanol. The mixture was heated at 70 °C until hydrolysis of Compound 13 was complete (full dissolution, <15 min). The solution was cooled to 60 °C and 1.12g (2.22 mmol) of tBu-BippyPhos followed by 384 mg (1.028 mmol) allylpalladium chloride dimer (L:Pd = 1:1) was added. The mixture was heated to 80 °C and was aged at this temperature for 20h before cooling to 22 °C.

Water was added and the mixture concentrated, a constant volume distillation was then performed to swap to ethanol (40-55 °C, 150 mbar). The resulting solution was passed through a 5 micron filter to remove any particulates. The solution was heated to 55 °C and 8.10 mL (40.52 mmol, 1.5 equiv) 5N NaOH (aq) was added dropwise over a 3 h period. Crystals of Compound 31 began to form, and after aging for an additional 1h, the mixture was cooled to 20 °C over 3 h. After an additional 6h of aging, crystals were collected on a frit and the cake was washed with 40 mL of 90:10 ethanol: water, followed

by 48 mL acetone. After drying at 80 °C in a vacu-oven for 16 h, Compound 31 was collected as an off-white solid (8.89g, 85%).

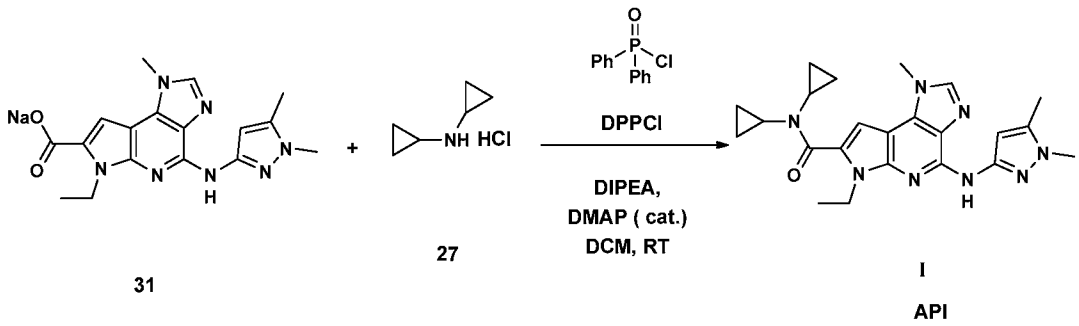
Example 15



31 27 I

Compound 31 was added into dichloromethane (20 Vol) and cooled to 15-20 °C. The reaction mass was charged with DMC in DCM solution (1.4 eq of DMC in 5.0 Vol of DCM). The mixture was stirred until Compound 31becomes less than 2.0% with respect to the corresponding acid chloride, typically in about 1h. After completion of the reaction, Compound 27 (1.4 eq) and N,N-diisopropylethyleneamine (3.0 eq) were charged and the mixture was stirred. After completion of the reaction, the mass was quenched with 12 Vol of water then the layers were separated. The organic layer was washed with water and filtered through a celite bed. The filtrate was concentrated to ~6.0 vol and then the mass was cooled to 35 °C. To the resulting solution was added THF, followed by seeds of product, then stirred for 3 h. The solvent was swapped with THF until dichloromethane becomes less than 2 wt% (wrt THF). The mass was cooled to -5 to 0 °C over a period of 2 h and stirred for 2 h. The reaction mass was then filtered under a nitrogen atmosphere. The material was slurried with pre-cooled THF (2*2 Vol) and filtered. The wet cake was dried in VTD at 60 °C under vacuum till LOD becomes < 1%, typically in about 20 h.

Example 16



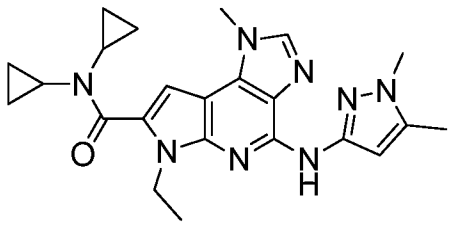
31 27 I

API

To a slurry of Compound 31 (15.00 g, 40.0 mmol) in dichloromethane (300 ml) was added diphenylphosphinic chloride (12.29 g, 51.9 mmol). The mixture was stirred at room temperature for 2 h and N,N-diisopropylethylamine (16.53 g, 127.9 mmol) was then added and stirred for another 30 min. Compound 27 (6.94 g, 51.9 mmol) and 4-dimethylaminopyridine (0.49 g, 4.0 mmol) were subsequently added and stirred for 16 h until the reaction was completed. The reaction mixture was treated with N-acetyl-L-cysteine (3.26 g, 20.0 mmol) and citric acid (10.10 g, 48.0 mmol) in deionized water (180 ml) for 2 h. After phase split, the dichloromethane phase was washed once with 0.42 N NaOH solution (180 ml) and washed twice with deionized water (180 ml each). The final dichloromethane phase was concentrated (to 90 ml) and acetone (30 ml) was added. The solution was cooled to 35 °C and N-2 form seed of Compound I (150 mg) was added and aged for 1 h. The resulting slurry was solvent-swapped to acetone (DCM < 10% v/v), and cooled to 0 °C. The solid was filtered and washed with cold acetone and dried to afford 14.69 g (85%) of Compound I (HPLC AP 99.8) as off-white crystals.

What is claimed is:

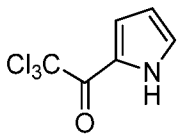
1. A process for the preparation of Compound I of the formula



(I)

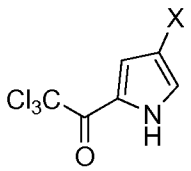
comprising the steps of

a) reacting Compound 1 of the formula



Compound 1

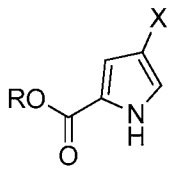
with a halogenating agent, such as NBS, in a suitable solvent to afford Compound 2 of the formula



Compound 2

wherein X is Cl, Br or I;

b) reacting Compound 2 with an alcohol to afford Compound 3 of the formula



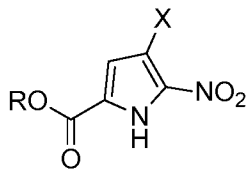
Compound 3

wherein

R is Me, Et, iPr, nPr, nBu, sec-Bu or tBu; and

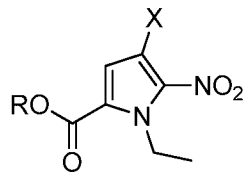
X is as defined above;

c) subsequently reacting Compound 3 with a nitrating agent to afford Compound 4 of the formula



Compound 4

d) reacting Compound 4, first, with an ethylating agent to afford Compound 5 of the formula

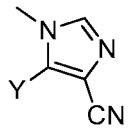


Compound 5

wherein

R and X are as defined above;

and subsequently with a suitably substituted imidazole of the formula,



Compound 33

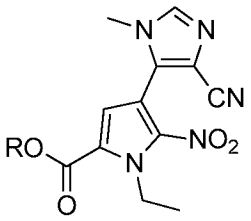
wherein

Y is H, Cl, Br, I or $B(OR')_2$; and

R' is Me, Et, i-Pr, n-Pr, n-Bu, sec-Bu, t-Bu, $-(CH_2)_n$ or $-C(Me)_2C(Me)_2-$; and

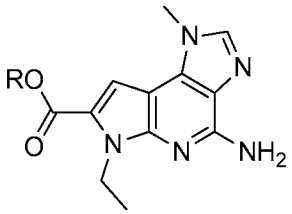
n is 2, 3, 4 or 5;

in the presence of a suitable catalytic metal, a ligand, an inorganic salt and optionally an organic base, to afford Compound 6 of the formula



Compound 6

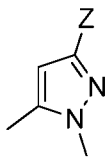
e) which is then reacted with hydrogen in the presence of a suitable catalytic metal and optionally a base, to afford Compound 7 of the formula



Compound 7

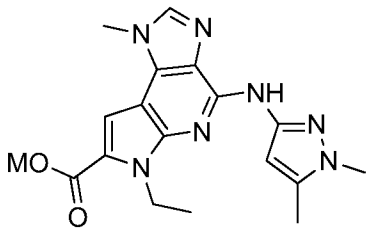
wherein R is as defined above;

f) which is reacted with Compound 24of the formula



Compound 24

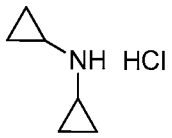
wherein Z is Cl, Br, I, -OP(O)(OR'')$_2$ or -OS(O)CF_3;
in the presence of a suitable metal, a ligand, and base, to afford Compound 26 of the formula



Compound 26

wherein R'' is Ph or t-Bu and M is Li, Na, K, Cs, Rb, Mg or Ca;

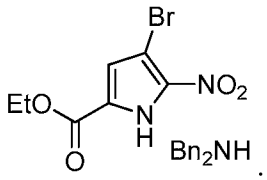
g) which is reacted with Compound 27 of the formula



Compound 27

in a the presence of a suitable activator, a suitable solvent, such as DCM, and optionally a base, to afford Compound I.

2. A compound of the formula



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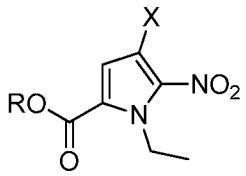
3. A compound of the formula



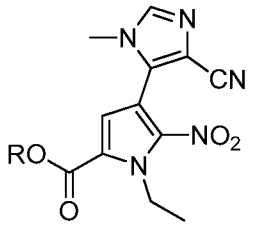
wherein

R is Me, Et, i-Pr, n-Pr, n-Bu, sec-Bu or t-Bu; and

X is Cl, Br or I.

4. The compound according to claim 3 wherein R is Et and X is Br.

5. A compound of the formula

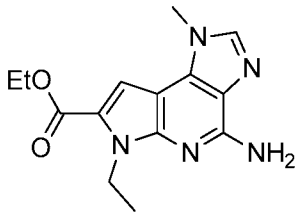


Compound 6

wherein R is Me, Et, i-Pr, n-Pr, n-Bu, sec-Bu or t-Bu.

6. The compound according to claim 5 wherein R is Et.

7. A compound of the formula as its free base, or acidic salt which is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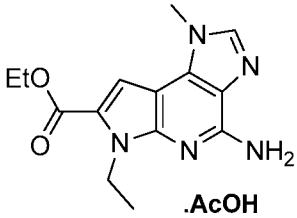
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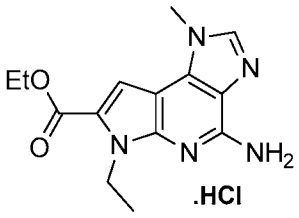
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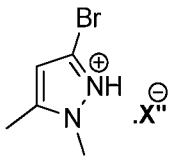
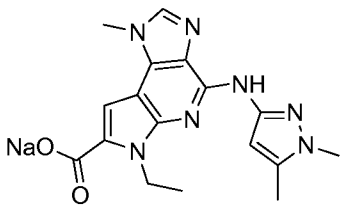
8. Acidic salt forms of the compound



Compound 29

wherein X" is Cl, Br or CF_3SO_3.

9. A compound of the formula as its free form, hydrate or hydrated ethanol solvate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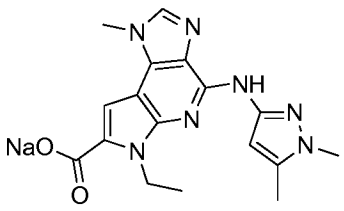
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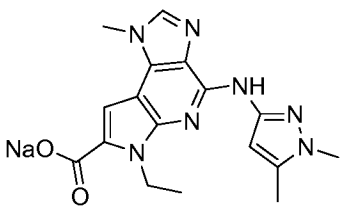
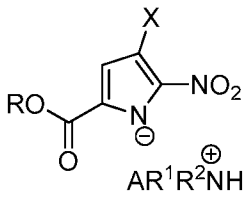


10. A compound of the formula



wherein

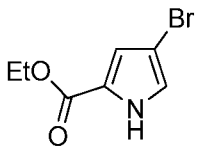
R is Me, Et, i-Pr, n-Pr, n-Bu, sec-Bu or t-Bu; and

X is Cl, Br or I;

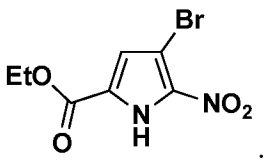
A is H, NH_2, OH or R^1;

R^1 and R^2 are independently C_1-C_5 alkyl, benzyl, allyl, $-(CH_2CH_2)_2O$, $-(CH_2CH_2)_3N$, and other simple amine bases such as, TEA, DBU, DIPEA, DABCO, DCHA, tetramethyl guanidine, ammonia, hydrazine, morpholine, DMAP, tetramethyl piperidine and dibenzylamine.

11. A method for nitrating Compound 9 of the formula



which comprises combining a metal salt of nitric acid selected from $NaNO_3$, KNO_3 or $LiNO_3$, with SO_3.pyridine complex, in the presence of the respective metal sulfate salt selected from Na_2SO_4, Li_2SO_4 or K_2SO_4, and metal bisulfate salt selected from $NaHSO_4$, $LiHSO_4$ or $KHSO_4$, in a suitable solvent to afford Compound 10 of the formula



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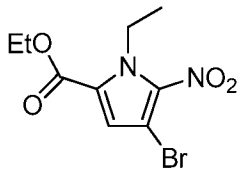
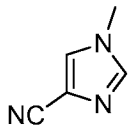
12. The method of claim 11 where the suitable solvent is MeCN.

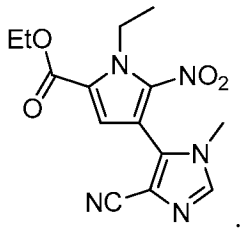
13. A method for coupling Compound 11 of the formula



to Compound 28 of the formula



which comprises treating Compound 28 with a suitable palladium source, a phosphine ligand and a suitable potassium source and optionally an organic base to afford Compound 12 of the formula



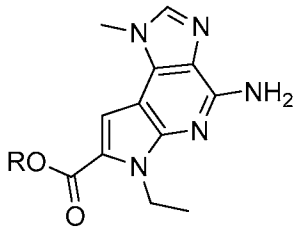
14. The method of claim 13 wherein the suitable palladium source is a $PdCl_2$ source, or $Pd(OAc)_2$.

15. The method of claim 14 where the suitable potassium source is KOPiv.

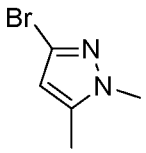
16. The method of claim 13 where the suitable phosphine ligand is Xantphos.

17. The method of claim 13 where the optional organic base is Hunig's base.

18. A method for coupling Compound 7 of the formula



to Compound 29 of the formula

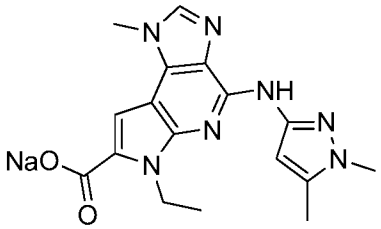


which comprises reacting the compounds in the presence of a suitable palladium source, a ligand and a base in a suitable solvent.

19. The method of claim 18 where the palladium-source is Pd-allyl chloride dimer, the base is tetra-butyl ammonium hydroxide, the phosphine ligand is tBuBippyPhos or Adamantyl-BippyPhos and the solvent is an alcohol.

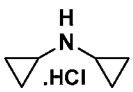
20. The method of claim 19 where the solvent is t-Amyl alcohol.

21. A method for coupling Compound 31 of the formula



31

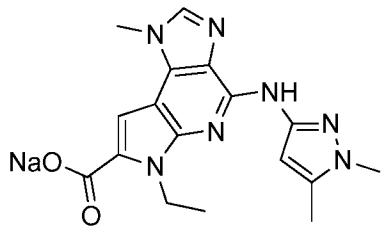
to Compound 27 of the formula



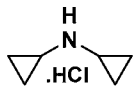
27

which comprises treating Compound 31 with DPPCl in the presence of base, and subsequently reacting Compound 27 in the presence of DMAP to afford Compound I.

22. A method of coupling Compound 31 of the formula



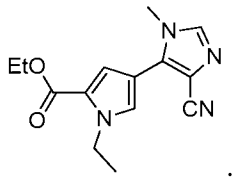
to Compound 27 of the formula



27

which comprises treating Compound 31 with DMC, followed by treatment with Compound 27 in the presence of a base to afford Compound I.

23. A compound of the formula



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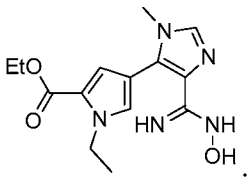
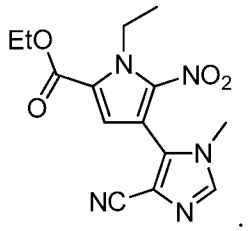
24. A compound of the formula



.

25. A compound of the formula



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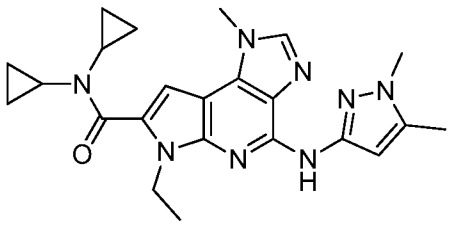
26. Compound I of the formula



(I)

prepared by the process of Claim 1.

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/053054

A. CLASSIFICATION OF SUBJECT MATTER
INV. C07D231/16 C07D403/04 C07D471/14 C07D207/42 A61K31/437 A61P35/00
ADD.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C07D A61K A61P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2011/059943 A1 (PURANDARE ET. AL.) 10 March 2011 (2011-03-10) cited in the application claims; example 73	1-26
A	US 2010/210629 A1 (PITTS ET. AL.) 19 August 2010 (2010-08-19) example A168	7,9
A	WO 2008/112695 A2 (IRM LLC) 18 September 2008 (2008-09-18) page 30, paragraph [0100]	7,9

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 October 2014	03/12/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Helps, Ian

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Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	G. D. CUNY ET. AL.: "Strucutre-activity relationship study of bone morphogenic protein (BMP) signalling inhibitors.", BIOORGANIC AND MEDICINAL CHEMISTRY LETTERS, vol. 18, 27 June 2008 (2008-06-27), pages 4388-4392, XP002731905, page 4390, Scheme 4, compound 22 -----	2,3

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2014/053054

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WO 2008112695 A2	18-09-2008	NONE	