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PROCESS FOR THE PREPARATION OF
2,3-PYRIDINEDICARBOXIMIDES

BACKGROUND OF THE INVENTION

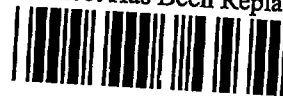
2,3-Pyridinedicarboximides are useful as
5 intermediates in the preparation of herbicidal 2-(2-
imidazolin-2-yl)nicotinic acids, esters and salts.
Methods for the preparation of 2,3-pyridinedicarboximides
are known in the art (see, e.g., U.S. 4,748,244; U.S.
4,754,033 and EP 308,084-A1). However, the methods
10 described in those patents and patent application are not
entirely satisfactory for the commercial manufacture of
2,3-pyridinedicarboximides.

It is, therefore, an object of the present invention
to provide an effective and efficient process for the
15 preparation of 2,3-pyridinedicarboximides.

It is also an object of the present invention to
provide a compound which is useful in the process of this
invention.

These and other objects and features of the present
20 invention will become more apparent from the detailed
description thereof set forth below.

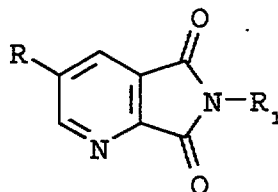
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SUMMARY OF THE INVENTION

The present invention provides an effective and efficient process for the preparation of a 2,3-pyridine-dicarboximide having the structural formula I



(I)

wherein

R is hydrogen, C₁-C₆alkyl or C₁-C₆alkoxymethyl;

R₁ is hydrogen, C₁-C₆alkyl, C(O)R₂,

phenyl optionally substituted with any combination

of from one to four halogen, C₁-C₄alkyl,

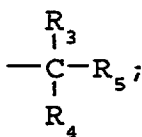
C₁-C₄alkoxy, nitro or cyano groups,

benzyl optionally substituted on the phenyl ring

with any combination of from one to four

halogen, C₁-C₄alkyl, C₁-C₄alkoxy, nitro or cyano

groups, or



R₂ is C₁-C₆alkyl, benzyl or

phenyl optionally substituted with any combination

of from one to four halogen, C₁-C₄alkyl,

C₁-C₄alkoxy, nitro or cyano groups;

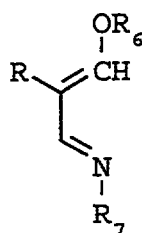
R₃ and R₄ are each independently C₁-C₄alkyl; and

R₅ is cyano or CONH₂,

which process comprises reacting an oxime or hydrazone having the structural formula II



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(II)

wherein

R is as described above;

R₆ is C₁-C₆alkyl;

5 R₇ is OR₈ or NR₉R₁₀;

R₈ is hydrogen, C₁-C₆alkyl, C(O)R₁₁,

phenyl optionally substituted with any combination
of from one to four halogen, C₁-C₄alkyl,
C₁-C₄alkoxy, nitro or cyano groups, or

10 benzyl optionally substituted on the phenyl ring
with any combination of from one to four
halogen, C₁-C₄alkyl, C₁-C₄alkoxy, nitro or cyano
groups;

R₁₁ is C₁-C₆alkyl, OR₁₂, NR₁₂R₁₃, benzyl or

15 phenyl optionally substituted with any combination
of from one to four halogen, C₁-C₄alkyl,
C₁-C₄alkoxy, nitro or cyano groups;

R₁₂ and R₁₃ are each independently hydrogen, C₁-C₆alkyl,
benzyl or

20 phenyl optionally substituted with any combination
of from one to four halogen, C₁-C₄alkyl,
C₁-C₄alkoxy, nitro or cyano groups; and

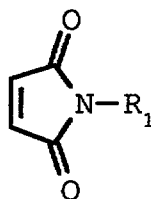
R₉ and R₁₀ are each independently hydrogen, C₁-C₆alkyl,
benzyl or

25 phenyl optionally substituted with any combination
of from one to four halogen, C₁-C₄alkyl,
C₁-C₄alkoxy, nitro or cyano groups,

with a maleimide having the structural formula III

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(III)

wherein R_1 is as described above.

This invention also relates to the formula II oximes described hereinabove.

5 In one preferred embodiment of the present invention, an oxime or hydrazone represented by formula II is reacted with a maleimide represented by formula III, preferably at a temperature above about 20°C e.g. in a temperature range of about 20° C to 160 °C, in the presence of a solvent.

10 Advantageously, it has now been found that 2,3-pyridinedicarboximides may be obtained in high yield and/or high purity by the effective and efficient process of the present invention.

The 2,3-pyridinedicarboximides may be isolated by
15 diluting the reaction mixture with water and filtering the formula I product from the aqueous mixture. The product formula I compounds may also be isolated by concentrating the reaction mixture *in vacuo* and filtering the formula I product from the concentrated mixture.

20 Alternatively, the reaction mixture may be integrated into the process used to prepare the final herbicidal agent without isolating the formula I compound.

Exemplary of halogen hereinabove are fluorine, chlorine, bromine and iodine. When used herein as a group or part of
25 a group the term alkyl includes straight or branched chain alkyl groups such as methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, s-butyl and t-butyl.

In another embodiment of the present invention, a Lewis acid is present. Preferably, the Lewis acid is

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present in an amount up to about one molar equivalent relative to the formula II compound when R_8 is hydrogen.

Lewis acids suitable for use in the present invention include
5 any conventional Lewis acids. Preferred Lewis acids include aluminum chloride and titanium(IV) chloride.

Solvents suitable for use in the process of the present invention preferably have a boiling point of at least about 60 °C and include aromatic hydrocarbons such as toluene,
10 xylenes, mesitylene and mixtures thereof; halogenated aromatic hydrocarbons such as mono- and dihalobenzenes and mixtures thereof; polynuclear aromatic hydrocarbons such as naphthalene, alkyl naphthalenes and mixtures thereof; ethers such as tetrahydrofuran and mixtures thereof; glycols such as
15 1,2-diethoxyethane and mixtures thereof; an alkanolic acid such as acetic acid, propionic acid and mixtures thereof; an alkanolic acid/water mixture such as an acetic acid/water mixture; acetonitrile; an acetonitrile/water mixture; and mixtures thereof. Preferred solvents include toluene,
20 xylenes, mesitylene, acetonitrile, an acetonitrile/water mixture, acetic acid and mixtures thereof with toluene and acetonitrile being more preferred.

In another preferred embodiment of the present invention, oximes of formula II wherein R_7 is OR_8 are reacted
25 with maleimides of formula III preferably at a temperature above about 60°C e.g. at a temperature range of about 60 °C to 160 °C, more preferably about 75 °C to 135 °C. And hydrazones of formula II wherein R_7 is NR_9R_{10} are reacted with maleimides of formula III preferably at a temperature above
30 about 20°C e.g. at a temperature range of about 20 °C to 160 °C, more preferably about 20 °C to 135 °C.

In a further preferred embodiment of the present invention, a base is present when R is C_1-C_6 alkoxymethyl. The base is used to reduce the amount of 5-methyl-2,3-

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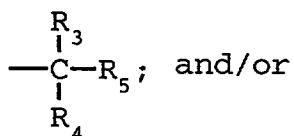
pyridinedicarboximides which are produced as undesirable by-products when R is C₁-C₆alkoxymethyl.

Bases suitable for use in the present invention include, but are not limited to, tri(C₂-C₄alkyl)amines such as triethylamine, N,N-diethylisopropylamine, N,N-diisopropylethylamine and the like, alkali metal acetates such as sodium acetate, potassium acetate and the like, and mixtures thereof. Preferred bases include triethylamine, sodium acetate and potassium acetate. The base is preferably present in an amount of at least about one molar equivalent relative to the formula II compound.

In a further embodiment of the present invention, a phase transfer catalyst is present when the base is present. Preferably, the phase transfer catalyst is present when the alkali metal acetate is present. Phase transfer catalysts suitable for use in the present invention include any conventional phase transfer catalysts. Preferred phase transfer catalysts include crown ethers such as 18-crown-6 and 15-crown-5.

In a preferred process of the present invention, R is hydrogen, C₁-C₄alkyl or C₁-C₄alkoxymethyl; R₁ is hydrogen, C₁-C₄alkyl,

phenyl optionally substituted with any combination of from one to four halogen, C₁-C₄alkyl, C₁-C₄alkoxy, nitro or cyano groups, or



R₃ and R₄ are each independently C₁-C₄alkyl; and/or

R₅ is cyano or CONH₂; and/or

R₆ is C₁-C₄alkyl;

R₇ is OR₈; and/or

R₈ is hydrogen or C₁-C₆alkyl.



In a more preferred process of the present invention,
R is hydrogen, methyl, ethyl or methoxymethyl; and/or

R₁ is methyl, phenyl or $\begin{array}{c} \text{CH}_3 \\ | \\ -\text{C}-\text{R}_5 \\ | \\ \text{CH}(\text{CH}_3)_2 \end{array}$; and/or

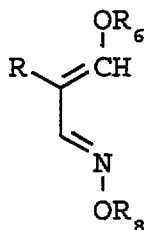
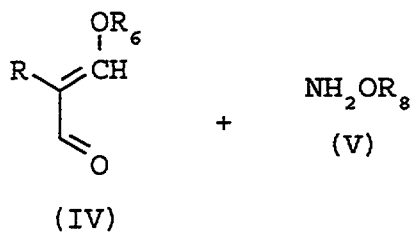
- 5 R₅ is cyano or CONH₂; and/or
R₆ is methyl or ethyl; and/or
R₇ is OR₈; and/or
R₈ is hydrogen or methyl.

Formula II oximes wherein

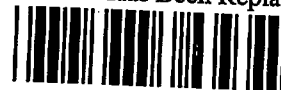
- 10 R₇ is OR₈; and/or
R₈ is hydrogen, C₁-C₆alkyl,
phenyl optionally substituted with any combination of
from one to four halogen, C₁-C₄alkyl, C₁-C₄alkoxy,
nitro or cyano groups, or
15 benzyl optionally substituted on the phenyl ring with
any combination of from one to four halogen,
C₁-C₄alkyl, C₁-C₄alkoxy, nitro or cyano groups,
may be prepared by reacting a 3-alkoxy-2-propenal of formula
IV with a substituted hydroxylamine of formula V optionally
20 in the presence of a base. The reaction scheme is shown
below in Flow Diagram I.



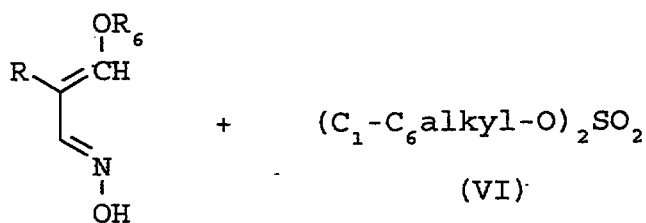
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FLOW DIAGRAM I

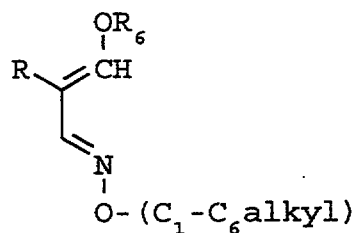
Alternatively, oximes of formula II wherein R_8 is $\text{C}_1\text{-C}_6$ alkyl may be prepared by reacting a formula II
 5 compound wherein R_8 is hydrogen with a dialkyl sulfate of formula VI in the presence of a base such as sodium hydroxide or an alkali metal alkoxide. The reaction scheme is shown in Flow Diagram II.



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FLOW DIAGRAM II

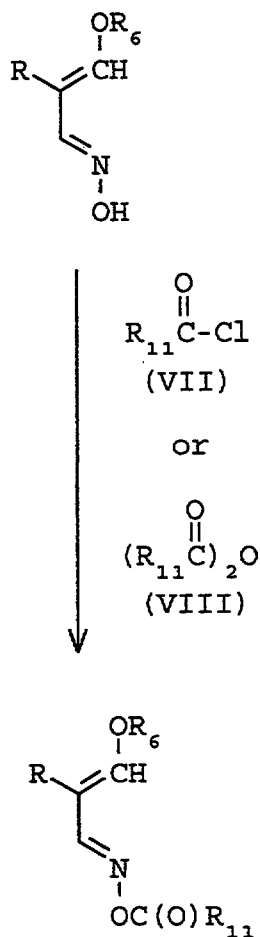
Base



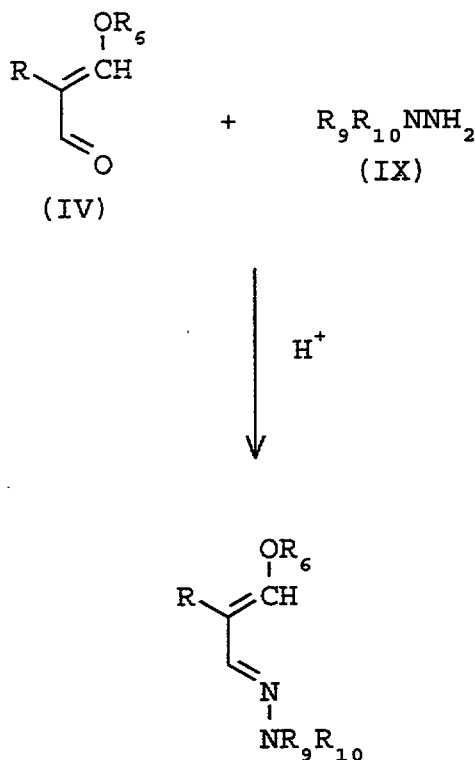
Formula II oximes wherein R_8 is $\text{C}(\text{O})\text{R}_{11}$ may be prepared by reacting a formula II compound wherein R_8 is hydrogen with an acid chloride of formula VII or an anhydride of formula VIII as shown in Flow Diagram III.



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FLOW DIAGRAM III

Formula II hydrazones may be prepared by reacting a
 3-alkoxy-2-propenal of formula IV with a hydrazine of
 5 formula IX optionally in the presence of an acid catalyst
 such as acetic acid. The reaction scheme is shown in
 Flow Diagram IV.

FLOW DIAGRAM IV

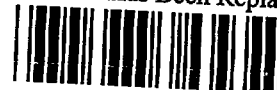
3-Alkoxy-2-propenal compounds of formula IV may be prepared according to the procedures described by E.

5 Breitmaier, et al in Synthesis, pages 1-9 (1987).

Maleimide compounds of formula III are known in the art and may be prepared according to the procedures described by M. Cava, et al in Organic Synthesis, 41, page 93 (1961).

10 Alternatively, formula IV compounds wherein R is methoxymethyl may be prepared by reacting a 3-(dialkyl-amino)-2-propenal of formula X with formaldehyde and methanol in the presence of a mineral acid such as sulfuric acid to form a 3-(dialkylamino)-2-(methoxy-

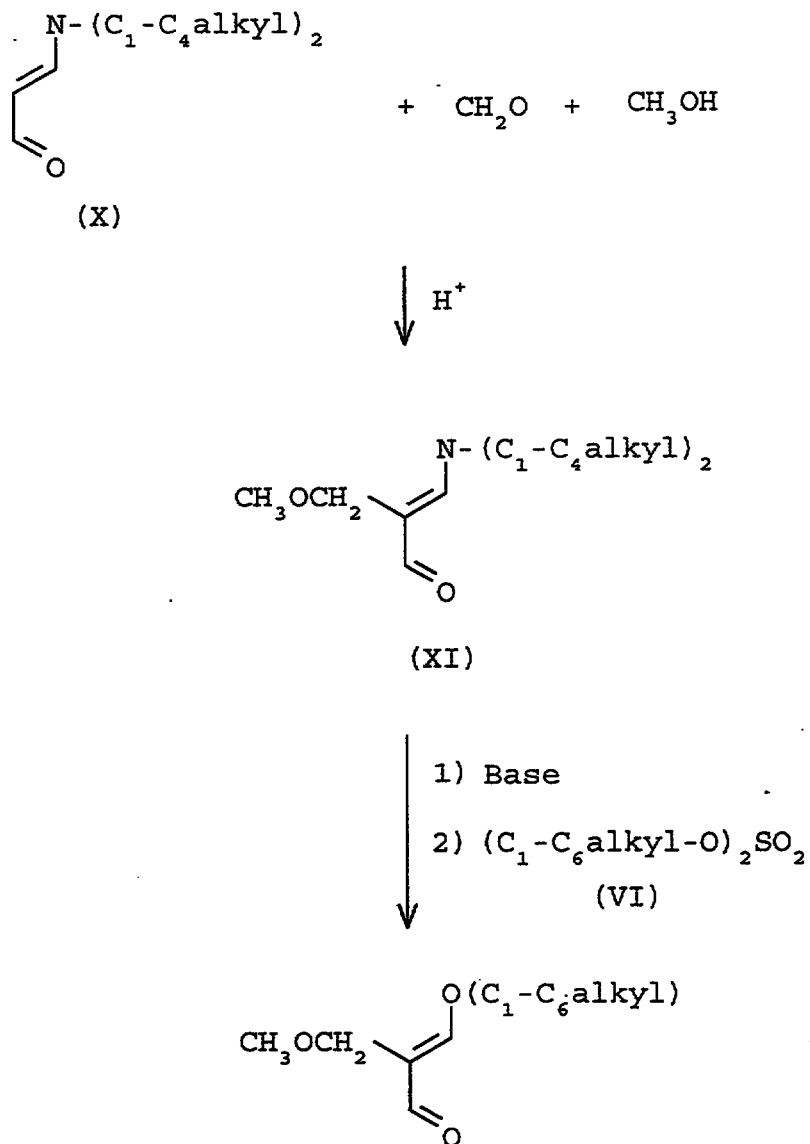
15 methyl)-2-propenal of formula XI, and reacting the formula XI compound with a base such as an alkali metal



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hydroxide and a dialkyl sulfate of formula VI. The reaction scheme is shown in Flow Diagram V.

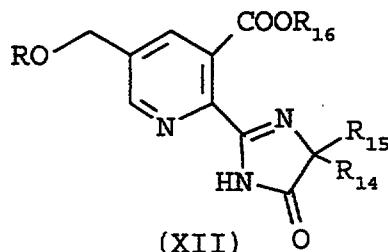
FLOW DIAGRAM V



- 5 The present invention also provides a process for the preparation of a herbicidal 5-(alkoxymethyl)-2-(2-imidazolin-2-yl)-nicotinic acid, ester and salt compound having the formula



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wherein

R is as defined above;

5 R_{14} is C_1 - C_4 alkyl;

R_{15} is C_1 - C_4 alkyl, C_3 - C_6 cycloalkyl or R_{14} and R_{15} when taken together with the atom to which they are attached, represent a C_3 - C_6 cycloalkyl group optionally substituted with methyl and

10 R_{16} is hydrogen, diloweralkylimino,

C_1 - C_{12} alkyl optionally substituted with one of the following groups: C_1 - C_3 alkoxy, halogen, hydroxy, C_3 - C_6 cycloalkyl, benzyloxy, furyl, phenyl, halophenyl, lower alkylphenyl, lower alkoxyphenyl, 15 nitrophenyl, carboxyl, loweralkoxycarbonyl, cyano or triloweralkylammonium;

C_3 - C_{12} alkenyl optionally substituted with one of the following groups: C_1 - C_3 alkoxy, phenyl, halogen or loweralkoxycarbonyl or with two C_1 - C_3 alkoxy groups 20 or two halogen groups;

C_3 - C_6 cycloalkyl optionally substituted with one or two C_1 - C_3 alkyl groups; or

a cation preferably selected from the group consisting of alkali metals, alkaline earth metals, manganese, copper,



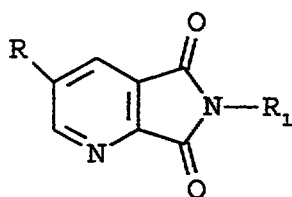
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iron, zinc, cobalt, lead, silver, nickel, ammonium and organic ammonium;

which process comprises:

(a) preparing a compound having the formula I

5



(I)

wherein R and R₁ are as defined above by a process as defined above; and

(b) converting the compound having formula I into the
10 compound having the formula XII.

The term "lower" as used above in relation to alkyl and alkoxy groups means that the alkyl or alkoxy group contains 1 to 6, preferably 1 to 4, carbon atoms.

The conversion of the compound having formula I into
15 the compound having formula XII may be carried out in a variety of ways. One may plan routes by combining reactions known for the conversion of one carboxylic acid derivative into another.

Methods that may be used to create the imidazolinone
20 herbicides are illustrated in the book "The Imidazolinone Herbicides" edited by D.L. Shaner and S.L. O'Connor, published 1991 by CRC Press, Boca Raton, Florida with particular reference to Chapter 2 entitled "Synthesis of the Imidazolinone Herbicides", pages 8-14 and the

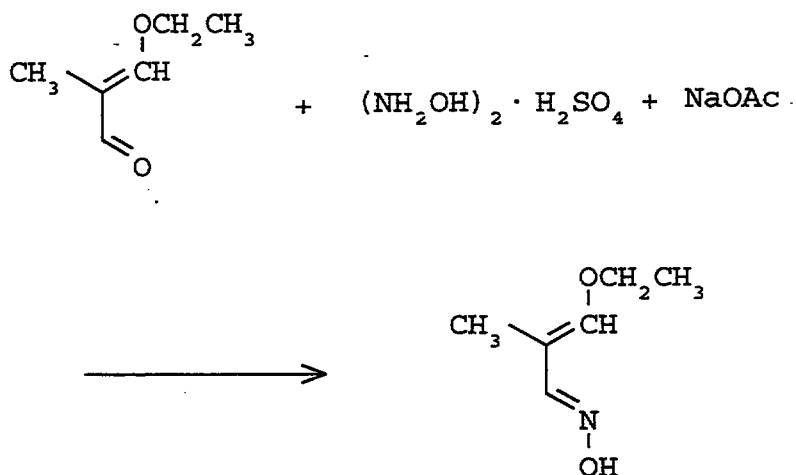


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references cited therein. The following patent literature references also illustrate the methods that may be used to convert the carboxylic acid derivatives into imidazolinone final products:

- 5 U.S. Patent Nos. 5,371,229; 5,334,576; 5,250,694;
5,276,157; 5,110,930; 5,122,608; 5,206,368;
4,925,944; 4,921,961; 4,959,476; 5,103,009;
4,816,588; 4,748,244; 4,754,033; 4,757,146;
4,798,619; 4,766,218; 5,001,254; 5,021,078;
10 4,723,011; 4,709,036; 4,658,030; 4,608,079;
4,719,303; 4,562,257; 4,518,780; 4,474,962;
4,623,726; 4,750,978; 4,638,068; 4,439,607;
4,459,408; 4,459,409; 4,460,776; 4,125,727 and
4,758,667, and European Patent Application Nos. EP-
15 A-0-041,623 and EP-A-0-308,084.

- In order to facilitate a further understanding of the invention, the following examples are presented primarily for the purpose of illustrating more specific details thereof. The invention should not be deemed
20 limited by the examples as the full scope of the invention is defined in the claims.

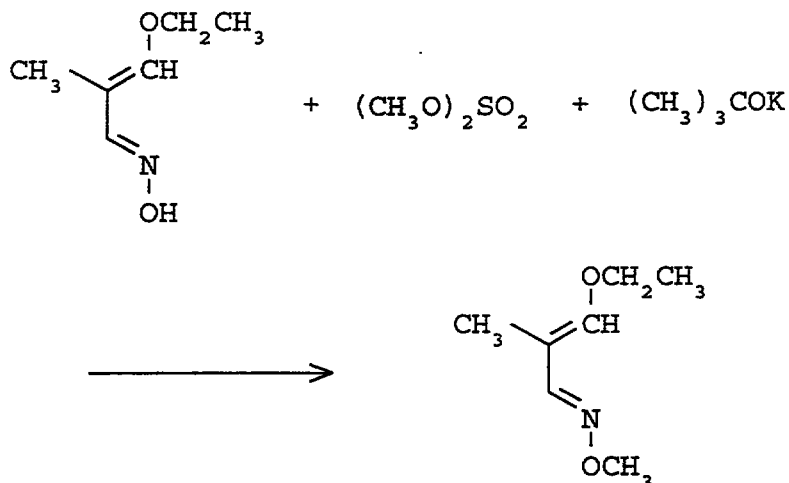
EXAMPLE 1Preparation of the Oxime of 3-ethoxy-2-methyl-2-propen-1-one, (E)- and (Z)-

5 3-Ethoxy-2-methyl-2-propenal, (E)- and (Z)- (30.0 g, 0.25 mol) is added dropwise to a mixture of hydroxylamine sulfate (33.0 g, 0.2 mol) and sodium acetate (33.4 g, 0.4 mol) in water (200 g). The resultant reaction mixture is stirred overnight and filtered to obtain a solid. The
10 solid is washed with water and dried to give the title product as a white solid (23.2 g, mp 78 °C, 71% yield).

Using essentially the same procedure, but substituting methoxylamine hydrochloride for hydroxylamine sulfate, the O-methyloxime of 3-ethoxy-2-methyl-2-
15 propen-1-one, (E)- and (Z)- is obtained as a yellow oil.



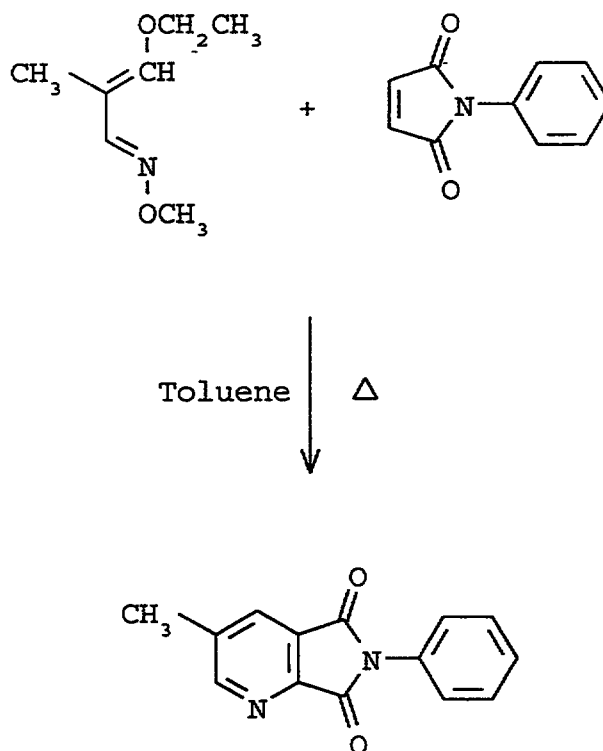
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EXAMPLE 2**Preparation of the O-methyloxime of 3-ethoxy-2-methyl-2-propen-1-one, (E)- and (Z)-**

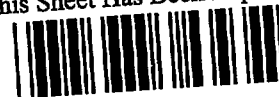
- 5 A mixture of the oxime of 3-ethoxy-2-methyl-2-propen-1-one, (E)- and (Z)- (0.5 g, 3.87 mmol) and potassium *tert*-butoxide (0.48 g, 4.2 mmol) in tetrahydrofuran is stirred for ten minutes at 10 °C, treated dropwise with dimethyl sulfate (0.59 g, 4.6
- 10 mmol), stirred for two hours and filtered. The resultant filtrate is concentrated in *vacuo* to give the title product as a yellow oil (0.74 g, 100% yield).



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EXAMPLE 3**Preparation of 5-Methyl-N-phenyl-2,3-pyridine-dicarboximide**

- 5 A solution of N-phenylmaleimide (1.69 g, 9.8 mmol) in toluene (16 g) is refluxed for 24 hours. During the reflux period, the O-methyloxime of 3-ethoxy-2-methyl-2-propen-1-one, (E)- and (Z)- (1.57 g, 11 mmol) is added portionwise to the reaction mixture. The final reaction
- 10 mixture is then concentrated *in vacuo* to give the title product as a orange solid (1.2 g, 52% yield).



EXAMPLES 4-7

Using essentially the same procedure as described in Example 3, but substituting the oxime of 3-ethoxy-2-methyl-2-propen-1-one, (E)- and (Z)- for the O-methyl-
5 oxime of 3-ethoxy-2-methyl-2-propen-1-one, (E)- and (Z)-, 5-methyl-N-phenyl-2,3-pyridinedicarboximide is produced in the yields shown in Table I.

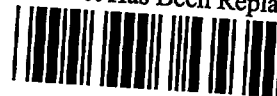
TABLE I

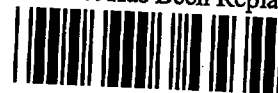
Preparation of 5-Methyl-N-phenyl-2,3-pyridinedicarboximide

<u>Example</u>	<u>Equivalents of N-phenylmaleimide</u>	<u>Lewis Acid/ Equivalents</u>	<u>Solvent</u>	<u>Hours Refluxed</u>	<u>% Yield</u>
4	0.3	AlCl ₃ /0.2	Toluene	27	20
5	0.3	TiCl ₄ /0.3	Toluene	10	10
6	0.2	-	H ₂ O/CH ₃ CN (1:1)	12	15
7	2.0	-	CH ₃ CO ₂ H	9	15

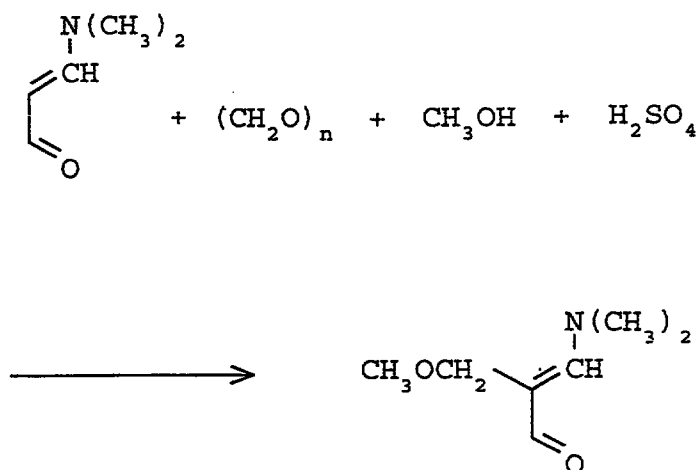
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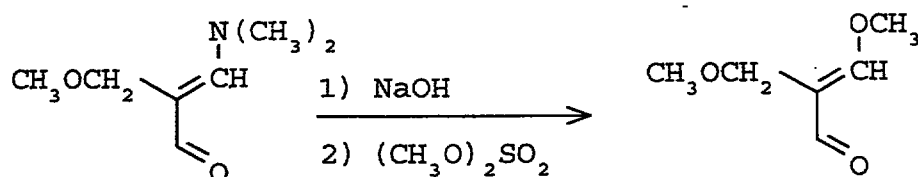
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EXAMPLE 8Preparation of 3-(Dimethylamino)-2-(methoxymethyl)-2-propenal, (E)- and (Z)-

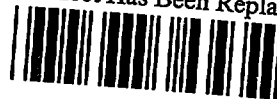
- 5 Concentrated sulfuric acid (1 mL) is slowly added to a solution of 3-(dimethylamino)-2-propenal (200 g, 2.01 mol) and paraformaldehyde (90 g, 3 mol) in methanol (1 L). The resultant solution is refluxed overnight, concentrated *in vacuo* to a volume of 200 mL, diluted with
- 10 toluene and distilled until the vapor temperature is 105 °C. The solution is then concentrated *in vacuo* to give the title product as an orange oil (251.4 g, 87% yield).



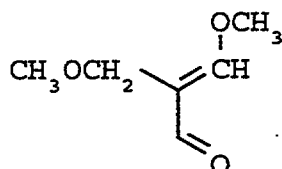
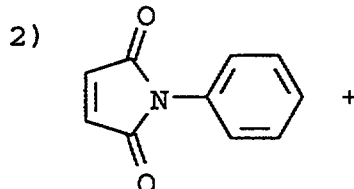
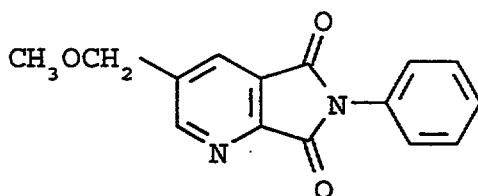
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EXAMPLE 9Preparation of 3-Methoxy-2-(methoxymethyl)-2-propenal, (E)- and (Z)-

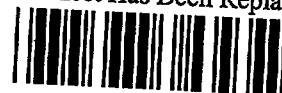
5 A solution of 3-(dimethylamino)-2-(methoxymethyl)-2-propenal, (E)- and (Z)- (53.06 g, 0.37 mol) and sodium hydroxide solution (29.7 g, 50%, 0.37 mol) in methanol (60 mL) is refluxed for 20 minutes and concentrated *in vacuo* to obtain a white solid. A solution of the solid
 10 in water (250 mL) is treated dropwise with dimethyl sulfate (46.75 g, 0.37 mol), stirred at room temperature for one hour and extracted with methylene chloride. The organic extract is dried over anhydrous sodium sulfate, concentrated *in vacuo* and distilled to give the title
 15 product as a colorless liquid (19.66 g, bp 80 °C/0.5 mm Hg, 41% yield).



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EXAMPLE 10**Preparation of 5-(Methoxymethyl)-N-phenyl-2,3-pyridinedicarboximide**1) $\text{NH}_2\text{OCH}_3 \cdot \text{HCl} + \text{NaOAc}$  $\text{C}_2\text{H}_5\text{N}[\text{CH}(\text{CH}_3)_2]_2$ 

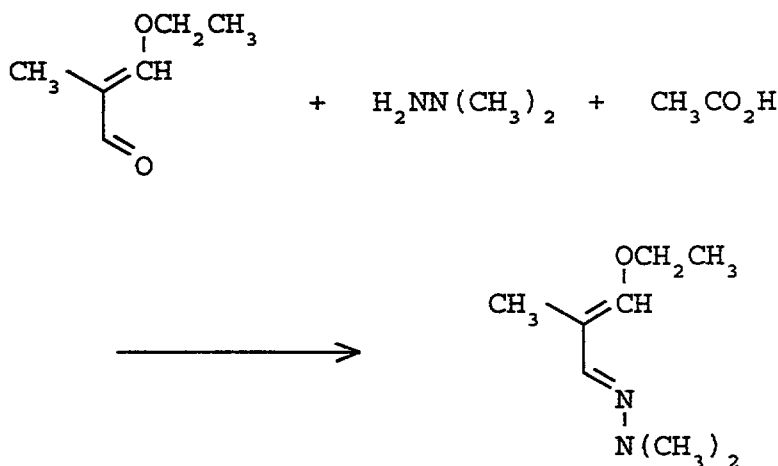
- 5 A solution of methoxyamine hydrochloride (1.7 g, 20 mmol) and sodium acetate (2.1 g, 25.6 mmol) in water (30 mL) is treated dropwise with 3-methoxy-2-(methoxymethyl)-2-propenal, (E)- and (Z)- (2.2 g, 16.9 mmol), stirred at room temperature for 30 minutes and extracted with
- 10 methylene chloride. The organic extract is dried over anhydrous sodium sulfate and concentrated *in vacuo* to obtain the O-methyloxime of 3-methoxy-2-(methoxymethyl)-2-propen-1-one. A mixture of the resultant O-methyloxime of 3-methoxy-2-(methoxymethyl)-2-propen-1-one, N-



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phenylmaleimide (2.9 g, 16.8 mmol) and diisopropylethyl-
 amine (2.2 g, 17.0 mmol) in toluene (50 mL) is refluxed
 for 23 hours. During the reflux period, additional
 N-phenylmaleimide (2.9 g, 16.8 mmol) is added to the
 5 reaction mixture. The final reaction mixture is
 concentrated in vacuo to give the title product as a
 solid (0.36 g, 8% yield) having a 5-(methoxymethyl)-N-
 phenyl-2,3-pyridinedicarboximide to 5-methyl-N-phenyl-
 2,3-pyridinedicarboximide ratio of 50:1.

10

EXAMPLE 11Preparation of 3-Ethoxy-2-methylacrolein dimethyl-
 hydrazone, (E)- and (Z)-

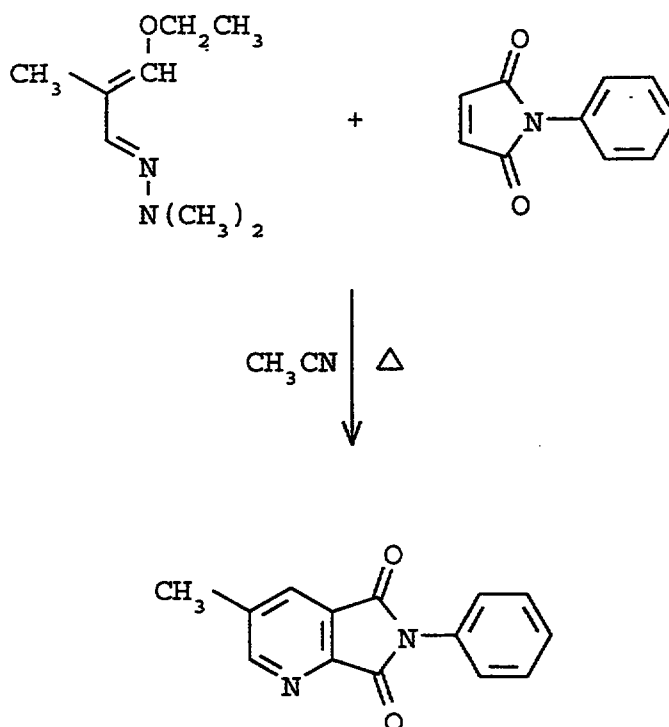
A mixture of 3-ethoxy-2-methyl-2-propenal, (E)- and
 15 (Z)- (4.0 g, 35 mmol), 1,1-dimethylhydrazine (2.73 g, 46
 mmol) and acetic acid (0.04 g, 0.7 mmol) in diethyl ether
 is refluxed for one hour, cooled, washed sequentially
 with water and brine, dried over anhydrous magnesium
 sulfate, and concentrated in vacuo to give the title
 20 product as a yellow oil.



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EXAMPLE 12

Preparation of 5-Methyl-N-phenyl-2,3-pyridine-
dicarboximide from N-phenylmaleimide and 3-ethoxy-2-
methylacrolein dimethylhydrazone, (E)- and (Z)-



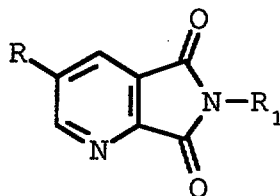
5

A solution of N-phenylmaleimide (1.1 g, 6.4 mmol) in acetonitrile is refluxed for 19 hours. During the reflux period, 3-ethoxy-2-methylacrolein dimethylhydrazone, (E)- and (Z)- (1.2 g, 7.6 mmol) is added portionwise to the reaction mixture. The final reaction mixture is then concentrated in vacuo to give the title product as a dark oil (0.23 g, 15% yield).

10

CLAIMS

1. A process for the preparation of a 2,3-pyridinedicarboximide having the structural formula I



(I)

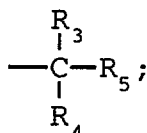
wherein

R is hydrogen, C₁-C₆alkyl or C₁-C₆alkoxymethyl;

R₁ is hydrogen, C₁-C₆alkyl, C(O)R₂,

phenyl optionally substituted with any combination of from one to four halogen, C₁-C₄alkyl, C₁-C₄alkoxy, nitro or cyano groups,

benzyl optionally substituted on the phenyl ring with any combination of from one to four halogen, C₁-C₄alkyl, C₁-C₄alkoxy, nitro or cyano groups, or



R₂ is C₁-C₆alkyl, benzyl or

phenyl optionally substituted with any combination of from one to four halogen, C₁-C₄alkyl, C₁-C₄alkoxy, nitro or cyano groups;

R₃ and R₄ are each independently C₁-C₄alkyl; and

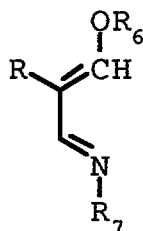
R₅ is cyano or CONH₂,

which process comprises reacting an oxime or hydrazone having the structural formula II

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(II)

wherein

R is as described above;

R₆ is C₁-C₆alkyl;

R₇ is OR₈ or NR₉R₁₀;

R₈ is hydrogen, C₁-C₆alkyl, C(O)R₁₁,

phenyl optionally substituted with any combination of
from one to four halogen, C₁-C₄alkyl, C₁-C₄alkoxy,
nitro or cyano groups, or

benzyl optionally substituted on the phenyl ring with
any combination of from one to four halogen,
C₁-C₄alkyl, C₁-C₄alkoxy, nitro or cyano groups;

R₁₁ is C₁-C₆alkyl, OR₁₂, NR₁₂R₁₃, benzyl or

phenyl optionally substituted with any combination of
from one to four halogen, C₁-C₄alkyl, C₁-C₄alkoxy,
nitro or cyano groups;

R₁₂ and R₁₃ are each independently hydrogen, C₁-C₆alkyl,
benzyl or

phenyl optionally substituted with any combination of
from one to four halogen, C₁-C₄alkyl, C₁-C₄alkoxy,
nitro or cyano groups; and

R₉ and R₁₀ are each independently hydrogen, C₁-C₆alkyl,
benzyl or

phenyl optionally substituted with any combination of
from one to four halogen, C₁-C₄alkyl, C₁-C₄alkoxy,
nitro or cyano groups,

with a maleimide having the structural formula III

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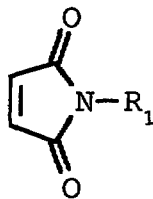


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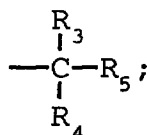
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(III)

wherein R_1 is as described above.

2. The process according to Claim 1 wherein R is hydrogen, C_1-C_4 alkyl or C_1-C_4 alkoxymethyl;
 R_1 is hydrogen, C_1-C_4 alkyl,
 phenyl optionally substituted with any combination of
 from one to four halogen, C_1-C_4 alkyl, C_1-C_4 alkoxy,
 nitro or cyano groups, or



- R_6 is C_1-C_4 alkyl;
 R_7 is OR_8 ; and
 R_8 is hydrogen or C_1-C_6 alkyl.

3. The process according to Claim 1 or Claim 2 wherein the formula II oxime or hydrazone is reacted with the formula III maleimide in the presence of a solvent selected from the group consisting of an aromatic hydrocarbon, a halogenated aromatic hydrocarbon, a polynuclear aromatic hydrocarbon, a glycol, an alkanolic acid, an alkanolic acid/water mixture, acetonitrile, an acetonitrile/water mixture, and mixtures thereof, and the boiling point of the solvent is at least about 60 °C.

4. The process according to any one of Claim 1 to 3 wherein the formula II oxime or hydrazone is reacted with the formula III maleimide at a temperature of above about 20 °C.

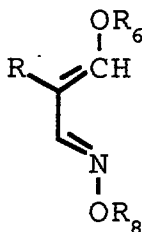
5. The process according to any one of Claim 1 to 4 further comprising a Lewis acid selected from the group consisting of aluminum chloride or titanium(IV) chloride.

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6. The process according to any one of Claim 1 to 5 further comprising a base selected from the group consisting of a tri(C₂-C₄alkyl)amine, an alkali metal acetate and mixtures thereof when R is C₁-C₆alkoxymethyl.

7. A compound having the structural formula



wherein

R is hydrogen, C₁-C₆alkyl or C₁-C₆alkoxymethyl;

R₆ is C₁-C₄alkyl;

R₈ is hydrogen, C₁-C₆alkyl, C(O)R₁₁,

phenyl optionally substituted with any combination of from one to four halogen, C₁-C₄alkyl, C₁-C₄alkoxy, nitro or cyano groups, or

benzyl optionally substituted on the phenyl ring with any combination of from one to four halogen, C₁-C₄alkyl, C₁-C₄alkoxy, nitro or cyano groups;

R₁₁ is C₁-C₆alkyl, OR₁₂, NR₁₂R₁₃, benzyl or

phenyl optionally substituted with any combination of from one to four halogen, C₁-C₄alkyl, C₁-C₄alkoxy, nitro or cyano groups; and

R₁₂ and R₁₃ are each independently hydrogen, C₁-C₆alkyl, benzyl or

phenyl optionally substituted with any combination of from one to four halogen, C₁-C₄alkyl, C₁-C₄alkoxy, nitro or cyano groups, and

the cis and trans isomers thereof.

8. The compound according to claim 7 wherein

R is hydrogen, C₁-C₄alkyl or C₁-C₄alkoxymethyl;

R₆ is C₁-C₄alkyl; and

R₈ is hydrogen or C₁-C₆alkyl.

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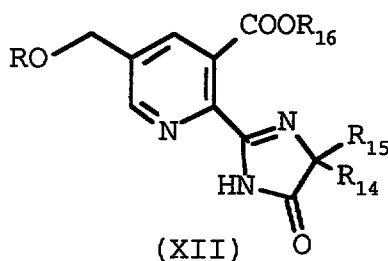


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9. The compound according to claim 7 selected from the group consisting of
the O-methyloxime of 3-ethoxy-2-methyl-2-propen-1-one;
the O-methyloxime of 3-methoxy-2-(methoxymethyl)-2-propen-1-one;
the oxime of 3-ethoxy-2-methyl-2-propen-1-one; and
the oxime of 3-methoxy-2-(methoxymethyl)-2-propen-1-one.

10. A process for the preparation of a herbicidal imidazolinone compound having the formula XII



wherein

R is as defined in claim 1;

R₁₄ is C₁-C₄ alkyl;

R₁₅ is C₁-C₄ alkyl, C₃-C₆ cycloalkyl or R₁₄ and R₁₅ when taken together with the atom to which they are attached, represent a C₃-C₆ cycloalkyl group optionally substituted with methyl and

R₁₆ is hydrogen, diloweralkylimino,

C₁-C₁₂ alkyl optionally substituted with one of the following groups: C₁-C₃ alkoxy, halogen, hydroxy, C₃-C₆ cycloalkyl, benzyloxy, furyl, phenyl, halophenyl, lower alkylphenyl, lower alkoxyphenyl, nitrophenyl, carboxyl, loweralkoxycarbonyl, cyano or triloweralkylammonium;

C₃-C₁₂ alkenyl optionally substituted with one of the following groups: C₁-C₃ alkoxy, phenyl, halogen or loweralkoxycarbonyl or with two C₁-C₃ alkoxy groups or two halogen groups;

C₃-C₆ cycloalkyl optionally substituted with one or two C₁-C₃ alkyl groups; or

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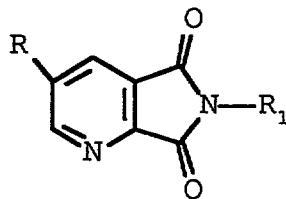
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a cation

which process comprises:

- (a) preparing a compound having the formula I



(I)

wherein R and R₁ are as defined in Claim 1 by a process as claimed in Claim 1; and

- (b) converting the compound having formula I into the compound having the formula XII.

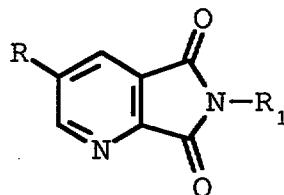
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ABSTRACT**PROCESS FOR THE PREPARATION OF
2,3-PYRIDINEDICARBOXIMIDES**

There is provided a process for the preparation of 2,3-pyridinedicarboximides having the structural formula I



(I).

The 2,3-pyridinedicarboximides are useful as intermediates in the preparation of herbicidal 2-(2-imidazolin-2-yl)nicotinic acids,

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PROCESS FOR THE PREPARATION OF
2,3-PYRIDINEDICARBOXIMIDES

BACKGROUND OF THE INVENTION

2,3-Pyridinedicarboximides are useful as
5 intermediates in the preparation of herbicidal 2-(2-
imidazolin-2-yl)nicotinic acids, esters and salts.
Methods for the preparation of 2,3-pyridinedicarboximides
are known in the art (see, e.g., U.S. 4,748,244; U.S.
4,754,033 and EP 308,084-A1). However, the methods
10 described in those patents and patent application are not
entirely satisfactory for the commercial manufacture of
2,3-pyridinedicarboximides.

It is, therefore, an object of the present invention
to provide an effective and efficient process for the
preparation of 2,3-pyridinedicarboximides.

It is also an object of the present invention to
provide a compound which is useful in the process of this
invention.

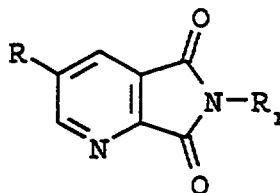
These and other objects and features of the present
20 invention will become more apparent from the detailed
description thereof set forth below.

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SUMMARY OF THE INVENTION

The present invention provides an effective and efficient process for the preparation of a 2,3-pyridine-dicarboximide having the structural formula I



(I)

wherein

R is hydrogen, C₁-C₆alkyl or C₁-C₆alkoxymethyl;

R₁ is hydrogen, C₁-C₆alkyl, C(O)R₂,

phenyl optionally substituted with any combination

of from one to four halogen, C₁-C₄alkyl,

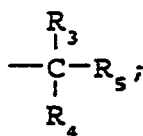
C₁-C₄alkoxy, nitro or cyano groups,

benzyl optionally substituted on the phenyl ring

with any combination of from one to four

halogen, C₁-C₄alkyl, C₁-C₄alkoxy, nitro or cyano

groups, or



R₂ is C₁-C₆alkyl, benzyl or

phenyl optionally substituted with any combination

of from one to four halogen, C₁-C₄alkyl,

C₁-C₄alkoxy, nitro or cyano groups;

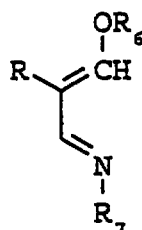
R₃ and R₄ are each independently C₁-C₄alkyl; and

R₅ is cyano or CONH₂,

which process comprises reacting an oxime or hydrazone having the structural formula II

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(II)

wherein

R is as described above;

R₆ is C₁-C₆alkyl;

5 R₇ is OR₈ or NR₉R₁₀;

R₈ is hydrogen, C₁-C₆alkyl, C(O)R₁₁,

phenyl optionally substituted with any combination
of from one to four halogen, C₁-C₄alkyl,
C₁-C₄alkoxy, nitro or cyano groups, or

10 benzyl optionally substituted on the phenyl ring
with any combination of from one to four
halogen, C₁-C₄alkyl, C₁-C₄alkoxy, nitro or cyano
groups;

R₁₁ is C₁-C₆alkyl, OR₁₂, NR₁₂R₁₃, benzyl or

15 phenyl optionally substituted with any combination
of from one to four halogen, C₁-C₄alkyl,
C₁-C₄alkoxy, nitro or cyano groups;

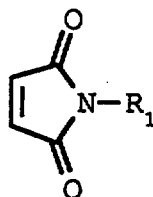
R₁₂ and R₁₃ are each independently hydrogen, C₁-C₆alkyl,
benzyl or

20 phenyl optionally substituted with any combination
of from one to four halogen, C₁-C₄alkyl,
C₁-C₄alkoxy, nitro or cyano groups; and

R₉ and R₁₀ are each independently hydrogen, C₁-C₆alkyl,
benzyl or

25 phenyl optionally substituted with any combination
of from one to four halogen, C₁-C₄alkyl,
C₁-C₄alkoxy, nitro or cyano groups,

with a maleimide having the structural formula III



(III)

wherein R_1 is as described above.

This invention also relates to the formula II oximes described hereinabove.

5 In one preferred embodiment of the present invention, an oxime or hydrazone represented by formula II is reacted with a maleimide represented by formula III, preferably at a temperature above about 20°C e.g. in a temperature range of about 20° C to 160 °C, in the presence of a solvent.

10 Advantageously, it has now been found that 2,3-pyridinedicarboximides may be obtained in high yield and/or high purity by the effective and efficient process of the present invention.

15 The 2,3-pyridinedicarboximides may be isolated by diluting the reaction mixture with water and filtering the formula I product from the aqueous mixture. The product formula I compounds may also be isolated by concentrating the reaction mixture *in vacuo* and filtering the formula I product from the concentrated mixture.

20 Alternatively, the reaction mixture may be integrated into the process used to prepare the final herbicidal agent without isolating the formula I compound.

25 Exemplary of halogen hereinabove are fluorine, chlorine, bromine and iodine. When used herein as a group or part of a group the term alkyl includes straight or branched chain alkyl groups such as methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, s-butyl and t-butyl.

In another embodiment of the present invention, a Lewis acid is present. Preferably, the Lewis acid is

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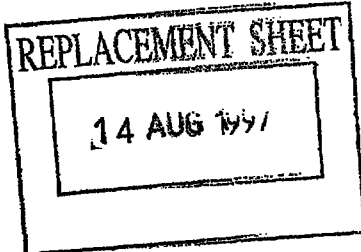
present in an amount up to about one molar equivalent relative to the formula II compound when R_8 is hydrogen.

Lewis acids suitable for use in the present invention include
5 any conventional Lewis acids. Preferred Lewis acids include aluminum chloride and titanium(IV) chloride.

Solvents suitable for use in the process of the present invention preferably have a boiling point of at least about 60 °C and include aromatic hydrocarbons such as toluene,
10 xylenes, mesitylene and mixtures thereof; halogenated aromatic hydrocarbons such as mono- and dihalobenzenes and mixtures thereof; polynuclear aromatic hydrocarbons such as naphthalene, alkyl naphthalenes and mixtures thereof; ethers such as tetrahydrofuran and mixtures thereof; glycols such as
15 1,2-diethoxyethane and mixtures thereof; an alkanolic acid such as acetic acid, propionic acid and mixtures thereof; an alkanolic acid/water mixture such as an acetic acid/water mixture; acetonitrile; an acetonitrile/water mixture; and mixtures thereof. Preferred solvents include toluene,
20 xylenes, mesitylene, acetonitrile, an acetonitrile/water mixture, acetic acid and mixtures thereof with toluene and acetonitrile being more preferred.

In another preferred embodiment of the present invention, oximes of formula II wherein R_7 is OR_8 are reacted
25 with maleimides of formula III preferably at a temperature above about 60°C e.g. at a temperature range of about 60 °C to 160 °C, more preferably about 75 °C to 135 °C. And hydrazones of formula II wherein R_7 is NR_9R_{10} are reacted with maleimides of formula III preferably at a temperature above
30 about 20°C e.g. at a temperature range of about 20 °C to 160 °C, more preferably about 20 °C to 135 °C.

In a further preferred embodiment of the present invention, a base is present when R is C_1-C_6 alkoxymethyl. The base is used to reduce the amount of 5-methyl-2,3-



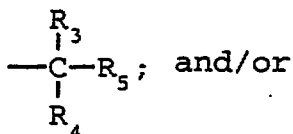
pyridinedicarboximides which are produced as undesirable by-products when R is C₁-C₆alkoxymethyl.

Bases suitable for use in the present invention include, but are not limited to, tri(C₂-C₄alkyl)amines such as triethylamine, N,N-diethylisopropylamine, N,N-diisopropylethylamine and the like, alkali metal acetates such as sodium acetate, potassium acetate and the like, and mixtures thereof. Preferred bases include triethylamine, sodium acetate and potassium acetate. The base is preferably present in an amount of at least about one molar equivalent relative to the formula II compound.

In a further embodiment of the present invention, a phase transfer catalyst is present when the base is present. Preferably, the phase transfer catalyst is present when the alkali metal acetate is present. Phase transfer catalysts suitable for use in the present invention include any conventional phase transfer catalysts. Preferred phase transfer catalysts include crown ethers such as 18-crown-6 and 15-crown-5.

In a preferred process of the present invention, R is hydrogen, C₁-C₄alkyl or C₁-C₄alkoxymethyl; R₁ is hydrogen, C₁-C₄alkyl,

phenyl optionally substituted with any combination of from one to four halogen, C₁-C₄alkyl, C₁-C₄alkoxy, nitro or cyano groups, or



R₃ and R₄ are each independently C₁-C₄alkyl; and/or R₅ is cyano or CONH₂; and/or R₆ is C₁-C₄alkyl; R₇ is OR₈; and/or R₈ is hydrogen or C₁-C₆alkyl.

In a more preferred process of the present invention,
R is hydrogen, methyl, ethyl or methoxymethyl; and/or

R₁ is methyl, phenyl or $\begin{array}{c} \text{CH}_3 \\ | \\ -\text{C}-\text{R}_5 \\ | \\ \text{CH}(\text{CH}_3)_2 \end{array}$; and/or

- 5 R₅ is cyano or CONH₂; and/or
R₆ is methyl or ethyl; and/or
R₇ is OR₈; and/or
R₈ is hydrogen or methyl.

Formula II oximes wherein

- 10 R₇ is OR₈; and/or

R₈ is hydrogen, C₁-C₆alkyl,

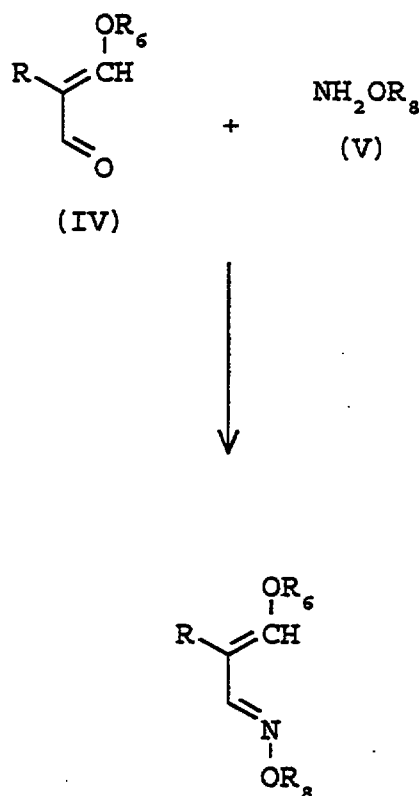
phenyl optionally substituted with any combination of
from one to four halogen, C₁-C₄alkyl, C₁-C₄alkoxy,
nitro or cyano groups, or

- 15 benzyl optionally substituted on the phenyl ring with
any combination of from one to four halogen,
C₁-C₄alkyl, C₁-C₄alkoxy, nitro or cyano groups,

may be prepared by reacting a 3-alkoxy-2-propenal of formula
IV with a substituted hydroxylamine of formula V optionally
20 in the presence of a base. The reaction scheme is shown
below in Flow Diagram I.

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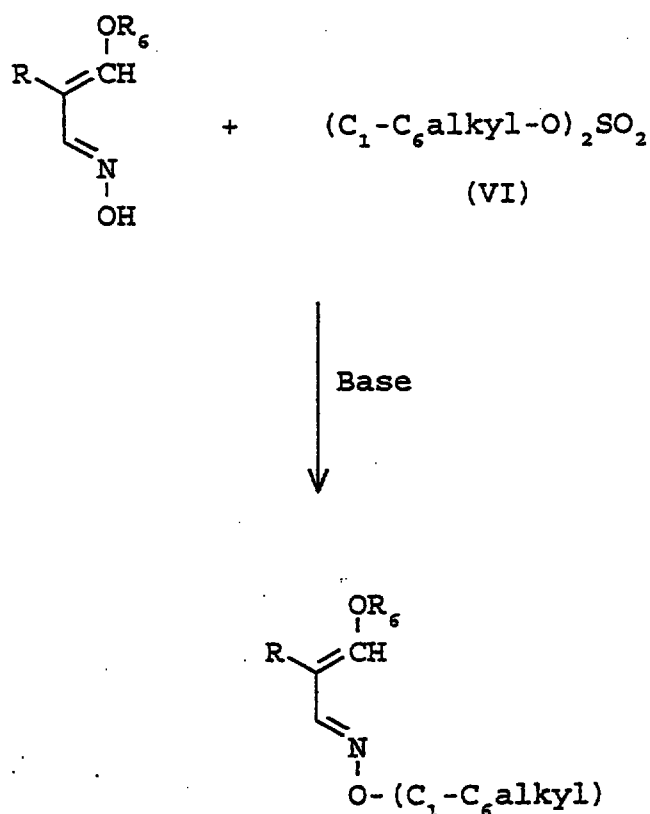
FLOW DIAGRAM I



Alternatively, oximes of formula II wherein R₈ is C₁-C₆alkyl may be prepared by reacting a formula II
5 compound wherein R₈ is hydrogen with a dialkyl sulfate of formula VI in the presence of a base such as sodium hydroxide or an alkali metal alkoxide. The reaction scheme is shown in Flow Diagram II.

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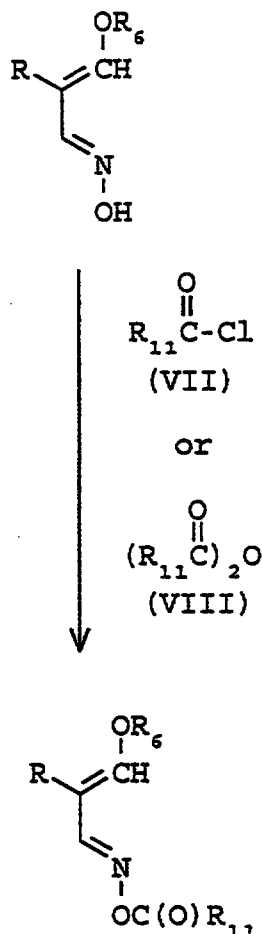
FLOW DIAGRAM II



Formula II oximes wherein R_8 is $\text{C}(\text{O})\text{R}_{11}$ may be prepared by reacting a formula II compound wherein R_8 is hydrogen with an acid chloride of formula VII or an anhydride of formula VIII as shown in Flow Diagram III.

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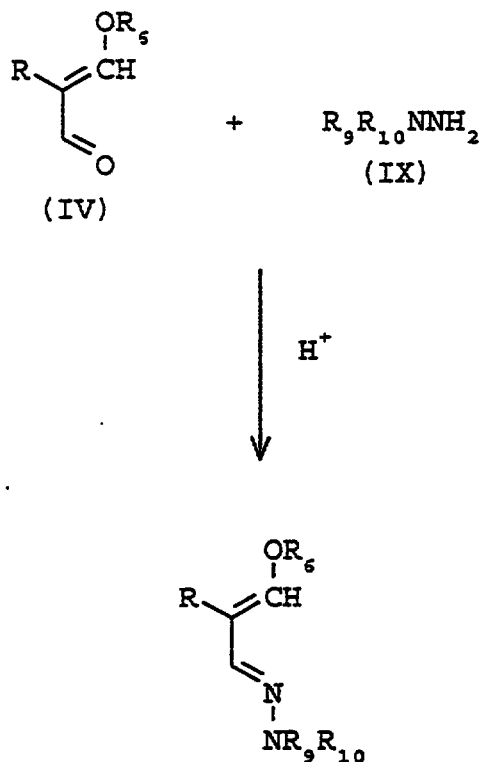
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FLOW DIAGRAM III

Formula II hydrazones may be prepared by reacting a
3-alkoxy-2-propenal of formula IV with a hydrazine of
5 formula IX optionally in the presence of an acid catalyst
such as acetic acid. The reaction scheme is shown in
Flow Diagram IV.

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FLOW DIAGRAM IV



3-Alkoxy-2-propenal compounds of formula IV may be prepared according to the procedures described by E.

5 Breitmaier, et al in Synthesis, pages 1-9 (1987).

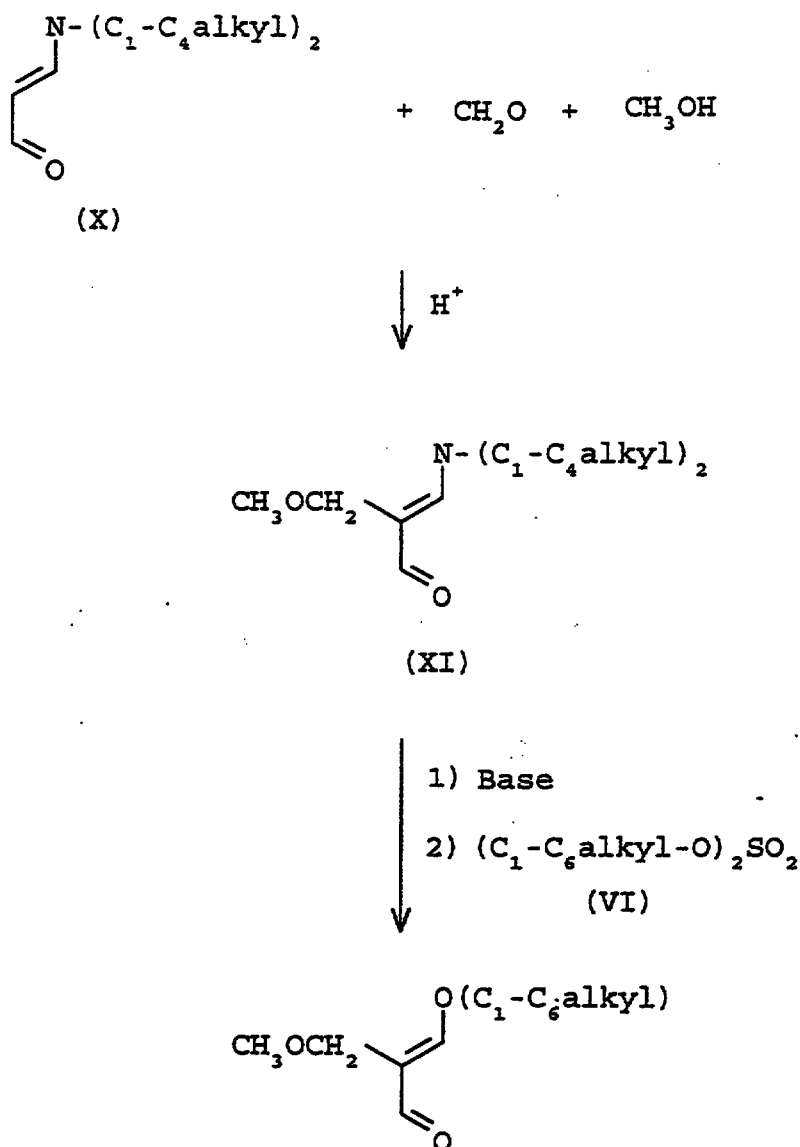
Maleimide compounds of formula III are known in the art and may be prepared according to the procedures described by M. Cava, et al in Organic Synthesis, 41, page 93 (1961).

10 Alternatively, formula IV compounds wherein R is methoxymethyl may be prepared by reacting a 3-(dialkyl-amino)-2-propenal of formula X with formaldehyde and methanol in the presence of a mineral acid such as sulfuric acid to form a 3-(dialkylamino)-2-(methoxy-
15 methyl)-2-propenal of formula XI, and reacting the formula XI compound with a base such as an alkali metal

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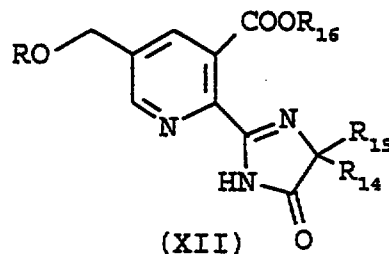
hydroxide and a dialkyl sulfate of formula VI. The reaction scheme is shown in Flow Diagram V.

FLOW DIAGRAM V

5 The present invention also provides a process for the preparation of a herbicidal 5-(alkoxymethyl)-2-(2-imidazolin-2-yl)-nicotinic acid, ester and salt compound having the formula

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wherein

R is as defined above;

5 R_{14} is C_1 - C_4 alkyl;

R_{15} is C_1 - C_4 alkyl, C_3 - C_6 cycloalkyl or R_{14} and R_{15} when taken together with the atom to which they are attached, represent a C_3 - C_6 cycloalkyl group optionally substituted with methyl and

10 R_{16} is hydrogen, diloweralkylimino,

C_1 - C_{12} alkyl optionally substituted with one of the following groups: C_1 - C_3 alkoxy, halogen, hydroxy, C_3 - C_6 cycloalkyl, benzyloxy, furyl, phenyl, halophenyl, lower alkylphenyl, lower alkoxyphenyl, nitrophenyl, carboxyl, loweralkoxycarbonyl, cyano or
15 triloweralkylammonium;

C_3 - C_{12} alkenyl optionally substituted with one of the following groups: C_1 - C_3 alkoxy, phenyl, halogen or loweralkoxycarbonyl or with two C_1 - C_3 alkoxy groups
20 or two halogen groups;

C_3 - C_6 cycloalkyl optionally substituted with one or two C_1 - C_3 alkyl groups; or

a cation preferably selected from the group consisting of alkali metals, alkaline earth metals, manganese, copper,

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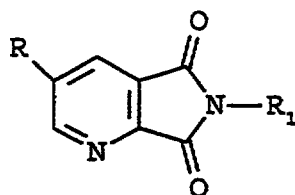
-14-

iron, zinc, cobalt, lead, silver, nickel, ammonium and organic ammonium;

which process comprises:

(a) preparing a compound having the formula I

5



(I)

wherein R and R₁ are as defined above by a process as defined above; and

(b) converting the compound having formula I into the compound having the formula XII.

10

The term "lower" as used above in relation to alkyl and alkoxy groups means that the alkyl or alkoxy group contains 1 to 6, preferably 1 to 4, carbon atoms.

The conversion of the compound having formula I into the compound having formula XII may be carried out in a variety of ways. One may plan routes by combining reactions known for the conversion of one carboxylic acid derivative into another.

15

Methods that may be used to create the imidazolinone herbicides are illustrated in the book "The Imidazolinone Herbicides" edited by D.L. Shaner and S.L. O'Connor, published 1991 by CRC Press, Boca Raton, Florida with particular reference to Chapter 2 entitled "Synthesis of the Imidazolinone Herbicides", pages 8-14 and the

20

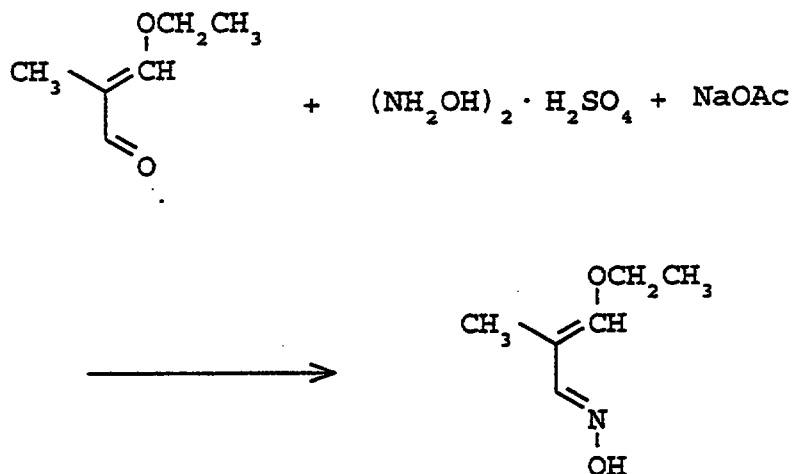
references cited therein. The following patent literature references also illustrate the methods that may be used to convert the carboxylic acid derivatives into imidazolinone final products:

- 5 U.S. Patent Nos. 5,371,229; 5,334,576; 5,250,694;
5,276,157; 5,110,930; 5,122,608; 5,206,368;
4,925,944; 4,921,961; 4,959,476; 5,103,009;
4,816,588; 4,748,244; 4,754,033; 4,757,146;
4,798,619; 4,766,218; 5,001,254; 5,021,078;
10 4,723,011; 4,709,036; 4,658,030; 4,608,079;
4,719,303; 4,562,257; 4,518,780; 4,474,962;
4,623,726; 4,750,978; 4,638,068; 4,439,607;
4,459,408; 4,459,409; 4,460,776; 4,125,727 and
4,758,667, and European Patent Application Nos. EP-
15 A-0-041,623 and EP-A-0-308,084.

- In order to facilitate a further understanding of the invention, the following examples are presented primarily for the purpose of illustrating more specific details thereof. The invention should not be deemed
20 limited by the examples as the full scope of the invention is defined in the claims.

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EXAMPLE 1Preparation of the Oxime of 3-ethoxy-2-methyl-2-propen-1-one, (E)- and (Z)-

5 3-Ethoxy-2-methyl-2-propenal, (E)- and (Z)- (30.0 g, 0.25 mol) is added dropwise to a mixture of hydroxylamine sulfate (33.0 g, 0.2 mol) and sodium acetate (33.4 g, 0.4 mol) in water (200 g). The resultant reaction mixture is stirred overnight and filtered to obtain a solid. The

10 solid is washed with water and dried to give the title product as a white solid (23.2 g, mp 78 °C, 71% yield).

Using essentially the same procedure, but substituting methoxylamine hydrochloride for hydroxylamine sulfate, the O-methyloxime of 3-ethoxy-2-methyl-2-

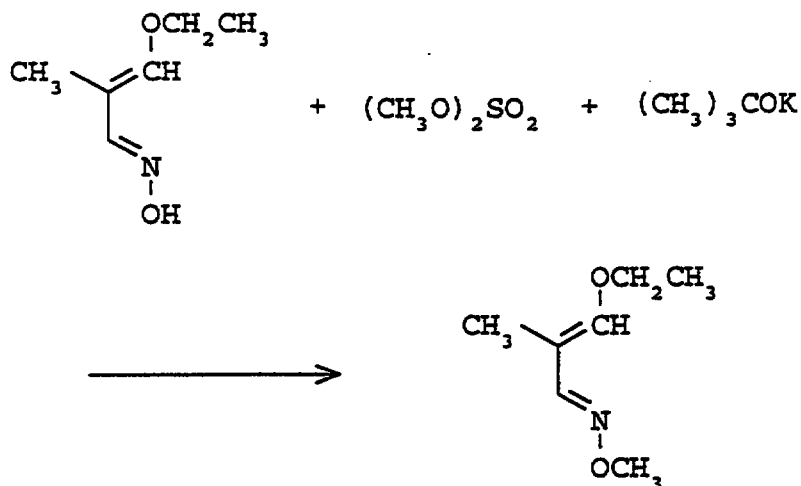
15 propen-1-one, (E)- and (Z)- is obtained as a yellow oil.

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EXAMPLE 2

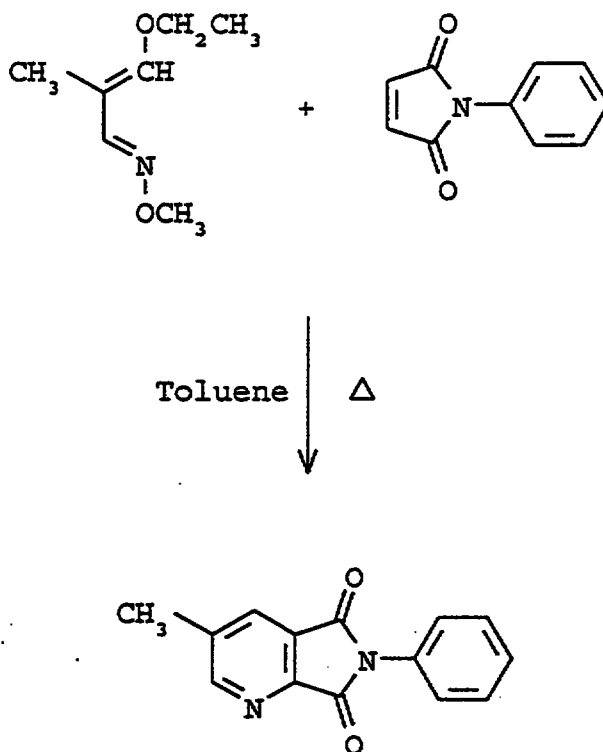
Preparation of the O-methyloxime of 3-ethoxy-2-methyl-2-propen-1-one, (E)- and (Z)-



- 5 A mixture of the oxime of 3-ethoxy-2-methyl-2-propen-1-one, (E)- and (Z)- (0.5 g, 3.87 mmol) and potassium tert-butoxide (0.48 g, 4.2 mmol) in tetrahydrofuran is stirred for ten minutes at 10 °C, treated dropwise with dimethyl sulfate (0.59 g, 4.6
- 10 mmol), stirred for two hours and filtered. The resultant filtrate is concentrated in vacuo to give the title product as a yellow oil (0.74 g, 100% yield).

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EXAMPLE 3Preparation of 5-Methyl-N-phenyl-2,3-pyridine-dicarboximide

- 5 A solution of N-phenylmaleimide (1.69 g, 9.8 mmol) in toluene (16 g) is refluxed for 24 hours. During the reflux period, the O-methyloxime of 3-ethoxy-2-methyl-2-propen-1-one, (E)- and (Z)- (1.57 g, 11 mmol) is added portionwise to the reaction mixture. The final reaction
- 10 mixture is then concentrated in vacuo to give the title product as a orange solid (1.2 g, 52% yield).

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EXAMPLES 4-7

Using essentially the same procedure as described in Example 3, but substituting the oxime of 3-ethoxy-2-methyl-2-propen-1-one, (E)- and (Z)- for the O-methyl-
5 oxime of 3-ethoxy-2-methyl-2-propen-1-one, (E)- and (Z)-, 5-methyl-N-phenyl-2,3-pyridinedicarboximide is produced in the yields shown in Table I.

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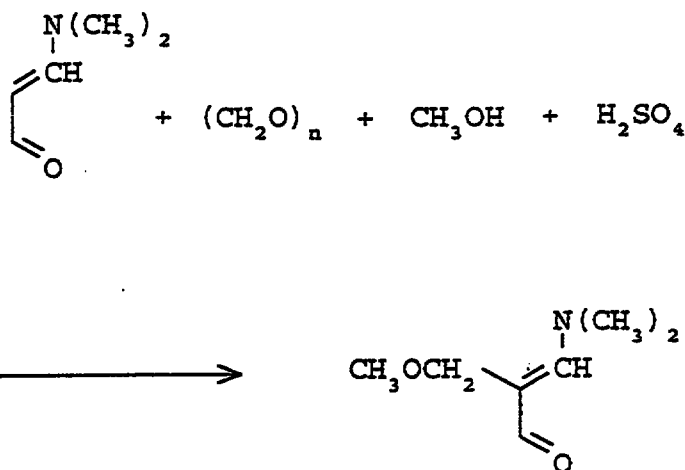
TABLE I

Preparation of 5-Methyl-N-phenyl-2,3-pyridinedicarboximide

<u>Example</u>	<u>Equivalents of N-phenylmaleimide</u>	<u>Lewis Acid/ Equivalents</u>	<u>Solvent</u>	<u>Hours Refluxed</u>	<u>% Yield</u>
4	0.3	AlCl ₃ /0.2	Toluene	27	20
5	0.3	TiCl ₄ /0.3	Toluene	10	10
6	0.2	-	H ₂ O/CH ₃ CN (1:1)	12	15
7	2.0	-	CH ₃ CO ₂ H	9	15

EXAMPLE 8

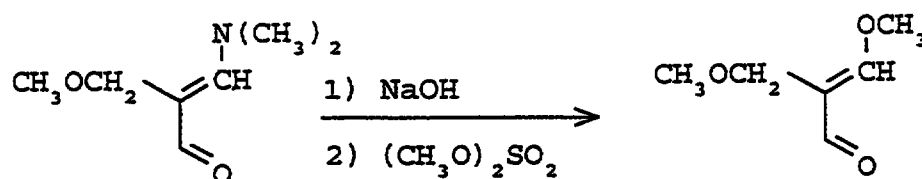
Preparation of 3-(Dimethylamino)-2-(methoxymethyl)-
2-propenal, (E)- and (Z)-



- 5 Concentrated sulfuric acid (1 mL) is slowly added to a solution of 3-(dimethylamino)-2-propenal (200 g, 2.01 mol) and paraformaldehyde (90 g, 3 mol) in methanol (1 L). The resultant solution is refluxed overnight, concentrated in vacuo to a volume of 200 mL, diluted with
- 10 toluene and distilled until the vapor temperature is 105 °C. The solution is then concentrated in vacuo to give the title product as an orange oil (251.4 g, 87% yield).

EXAMPLE 9

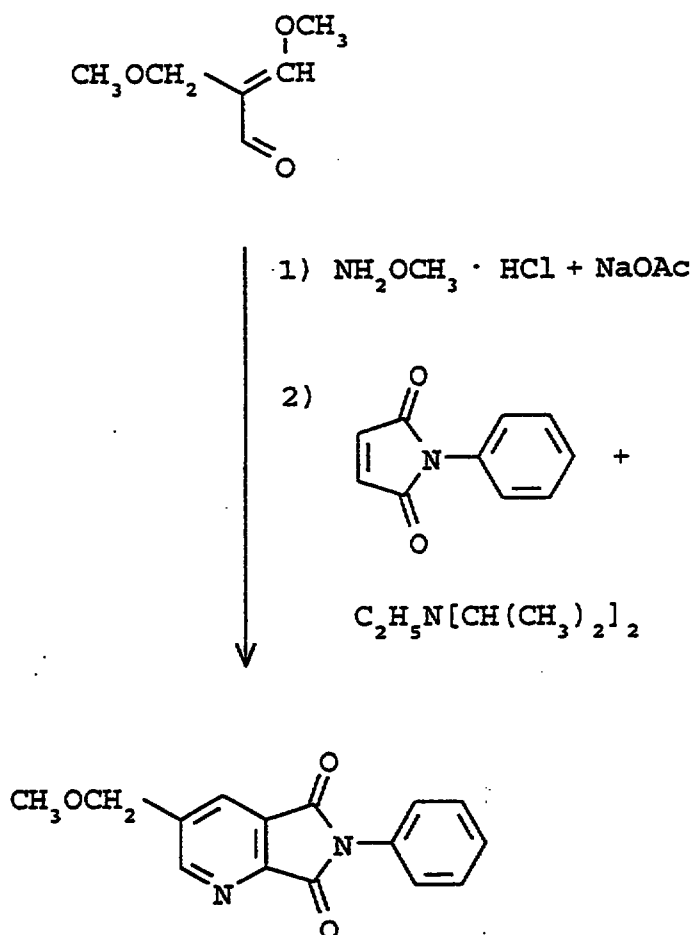
Preparation of 3-Methoxy-2-(methoxymethyl)-2-propenal, (E)- and (Z)-



- 5 A solution of 3-(dimethylamino)-2-(methoxymethyl)-2-propenal, (E)- and (Z)- (53.06 g, 0.37 mol) and sodium hydroxide solution (29.7 g, 50%, 0.37 mol) in methanol (60 mL) is refluxed for 20 minutes and concentrated in vacuo to obtain a white solid. A solution of the solid
- 10 in water (250 mL) is treated dropwise with dimethyl sulfate (46.75 g, 0.37 mol), stirred at room temperature for one hour and extracted with methylene chloride. The organic extract is dried over anhydrous sodium sulfate, concentrated in vacuo and distilled to give the title
- 15 product as a colorless liquid (19.66 g, bp 80 °C/0.5 mm Hg, 41% yield).

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EXAMPLE 10**Preparation of 5-(Methoxymethyl)-N-phenyl-2,3-pyridinedicarboximide**

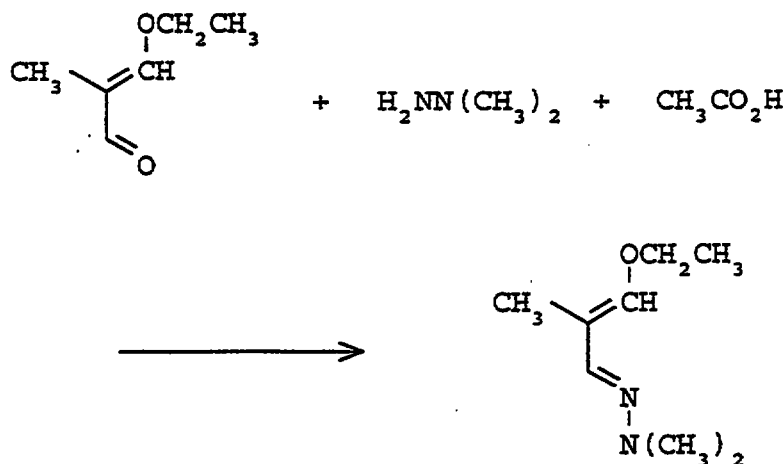
- 5 A solution of methoxyamine hydrochloride (1.7 g, 20 mmol) and sodium acetate (2.1 g, 25.6 mmol) in water (30 mL) is treated dropwise with 3-methoxy-2-(methoxymethyl)-2-propenal, (E)- and (Z)- (2.2 g, 16.9 mmol), stirred at room temperature for 30 minutes and extracted with
- 10 methylene chloride. The organic extract is dried over anhydrous sodium sulfate and concentrated in vacuo to obtain the O-methyloxime of 3-methoxy-2-(methoxymethyl)-2-propen-1-one. A mixture of the resultant O-methyloxime of 3-methoxy-2-(methoxymethyl)-2-propen-1-one, N-

phenylmaleimide (2.9 g, 16.8 mmol) and diisopropylethyl-amine (2.2 g, 17.0 mmol) in toluene (50 mL) is refluxed for 23 hours. During the reflux period, additional N-phenylmaleimide (2.9 g, 16.8 mmol) is added to the
5 reaction mixture. The final reaction mixture is concentrated in vacuo to give the title product as a solid (0.36 g, 8% yield) having a 5-(methoxymethyl)-N-phenyl-2,3-pyridinedicarboximide to 5-methyl-N-phenyl-2,3-pyridinedicarboximide ratio of 50:1.

10

EXAMPLE 11

Preparation of 3-Ethoxy-2-methylacrolein dimethyl-hydrazone, (E)- and (Z)-



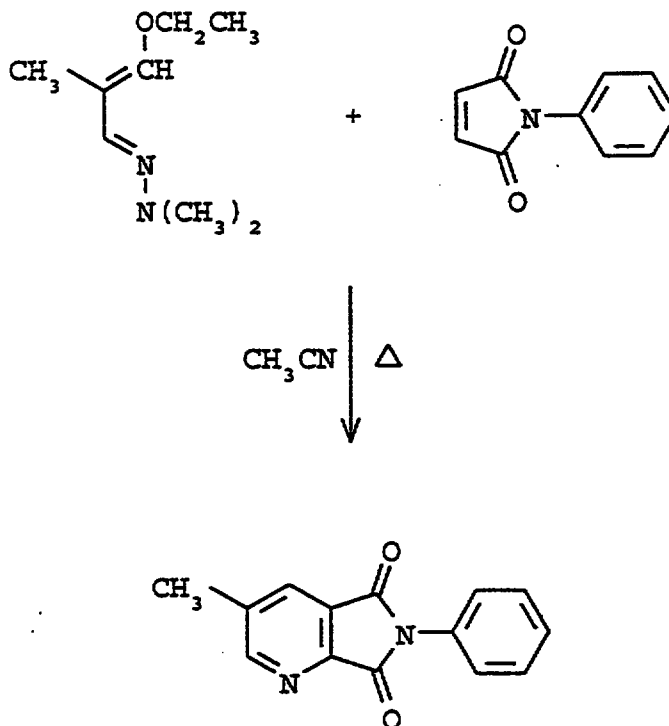
A mixture of 3-ethoxy-2-methyl-2-propenal, (E)- and
15 (Z)- (4.0 g, 35 mmol), 1,1-dimethylhydrazine (2.73 g, 46 mmol) and acetic acid (0.04 g, 0.7 mmol) in diethyl ether is refluxed for one hour, cooled, washed sequentially with water and brine, dried over anhydrous magnesium sulfate, and concentrated in vacuo to give the title
20 product as a yellow oil.

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EXAMPLE 12

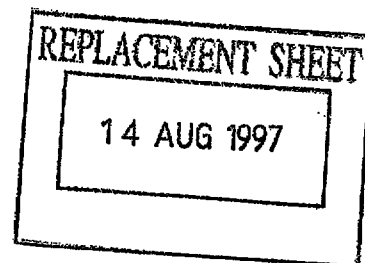
Preparation of 5-Methyl-N-phenyl-2,3-pyridine-
dicarboximide from N-phenylmaleimide and 3-ethoxy-2-
methylacrolein dimethylhydrazone, (E)- and (Z)-



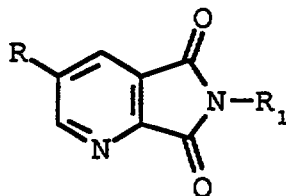
5

A solution of N-phenylmaleimide (1.1 g, 6.4 mmol) in acetonitrile is refluxed for 19 hours. During the reflux period, 3-ethoxy-2-methylacrolein dimethylhydrazone, (E)- and (Z)- (1.2 g, 7.6 mmol) is added portionwise to the reaction mixture. The final reaction mixture is then concentrated in vacuo to give the title product as a dark oil (0.23 g, 15% yield).

10

CLAIMS

1. A process for the preparation of a 2,3-pyridinedicarboximide having the structural formula I



(I)

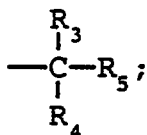
wherein

R is hydrogen, C₁-C₆alkyl or C₁-C₆alkoxymethyl;

R₁ is hydrogen, C₁-C₆alkyl, C(O)R₂,

phenyl optionally substituted with any combination of
from one to four halogen, C₁-C₄alkyl, C₁-C₄alkoxy,
nitro or cyano groups,

benzyl optionally substituted on the phenyl ring with
any combination of from one to four halogen,
C₁-C₄alkyl, C₁-C₄alkoxy, nitro or cyano groups, or



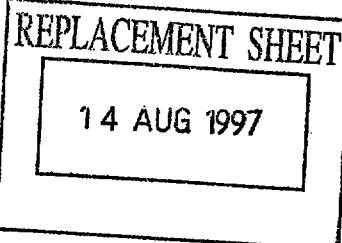
R₂ is C₁-C₆alkyl, benzyl or

phenyl optionally substituted with any combination of
from one to four halogen, C₁-C₄alkyl, C₁-C₄alkoxy,
nitro or cyano groups;

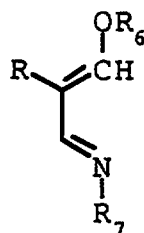
R₃ and R₄ are each independently C₁-C₄alkyl; and

R₅ is cyano or CONH₂,

which process comprises reacting an oxime or hydrazone having
the structural formula II



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(II)

wherein

R is as described above;

R₆ is C₁-C₆alkyl;

R₇ is OR₈ or NR₉R₁₀;

R₈ is hydrogen, C₁-C₆alkyl, C(O)R₁₁,

phenyl optionally substituted with any combination of
from one to four halogen, C₁-C₄alkyl, C₁-C₄alkoxy,
nitro or cyano groups, or

benzyl optionally substituted on the phenyl ring with
any combination of from one to four halogen,
C₁-C₄alkyl, C₁-C₄alkoxy, nitro or cyano groups;

R₁₁ is C₁-C₆alkyl, OR₁₂, NR₁₂R₁₃, benzyl or

phenyl optionally substituted with any combination of
from one to four halogen, C₁-C₄alkyl, C₁-C₄alkoxy,
nitro or cyano groups;

R₁₂ and R₁₃ are each independently hydrogen, C₁-C₆alkyl,
benzyl or

phenyl optionally substituted with any combination of
from one to four halogen, C₁-C₄alkyl, C₁-C₄alkoxy,
nitro or cyano groups; and

R₉ and R₁₀ are each independently hydrogen, C₁-C₆alkyl,
benzyl or

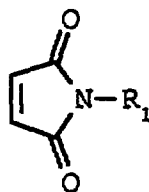
phenyl optionally substituted with any combination of
from one to four halogen, C₁-C₄alkyl, C₁-C₄alkoxy,
nitro or cyano groups,

with a maleimide having the structural formula III



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(III)

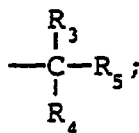
wherein R_1 is as described above.

2. The process according to Claim 1 wherein

R is hydrogen, C_1 - C_4 alkyl or C_1 - C_4 alkoxymethyl;

R_1 is hydrogen, C_1 - C_4 alkyl,

phenyl optionally substituted with any combination of
from one to four halogen, C_1 - C_4 alkyl, C_1 - C_4 alkoxy,
nitro or cyano groups, or



R_6 is C_1 - C_4 alkyl;

R_7 is OR_8 ; and

R_8 is hydrogen or C_1 - C_6 alkyl.

3. The process according to Claim 1 or Claim 2 wherein the formula II oxime or hydrazone is reacted with the formula III maleimide in the presence of a solvent selected from the group consisting of an aromatic hydrocarbon, a halogenated aromatic hydrocarbon, a polynuclear aromatic hydrocarbon, a glycol, an alkanolic acid, an alkanolic acid/water mixture, acetonitrile, an acetonitrile/water mixture, and mixtures thereof, and the boiling point of the solvent is at least about 60 °C.

4. The process according to any one of Claim 1 to 3 wherein the formula II oxime or hydrazone is reacted with the formula III maleimide at a temperature of above about 20 °C.

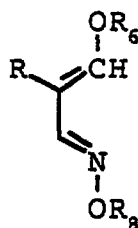
5. The process according to any one of Claim 1 to 4 further comprising a Lewis acid selected from the group consisting of aluminum chloride or titanium(IV) chloride.



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6. The process according to any one of Claim 1 to 5 further comprising a base selected from the group consisting of a tri(C₁-C₄alkyl)amine, an alkali metal acetate and mixtures thereof when R is C₁-C₆alkoxymethyl.

7. A compound having the structural formula



wherein

R is hydrogen, C₁-C₆alkyl or C₁-C₆alkoxymethyl;

R₆ is C₁-C₄alkyl;

R₈ is hydrogen, C₁-C₆alkyl, C(O)R₁₁,

phenyl optionally substituted with any combination of from one to four halogen, C₁-C₄alkyl, C₁-C₄alkoxy, nitro or cyano groups, or

benzyl optionally substituted on the phenyl ring with any combination of from one to four halogen, C₁-C₄alkyl, C₁-C₄alkoxy, nitro or cyano groups;

R₁₁ is C₁-C₆alkyl, OR₁₂, NR₁₂R₁₃, benzyl or

phenyl optionally substituted with any combination of from one to four halogen, C₁-C₄alkyl, C₁-C₄alkoxy, nitro or cyano groups; and

R₁₂ and R₁₃ are each independently hydrogen, C₁-C₆alkyl, benzyl or

phenyl optionally substituted with any combination of from one to four halogen, C₁-C₄alkyl, C₁-C₄alkoxy, nitro or cyano groups, and

the cis and trans isomers thereof.

8. The compound according to claim 7 wherein

R is hydrogen, C₁-C₄alkyl or C₁-C₄alkoxymethyl;

R₆ is C₁-C₄alkyl; and

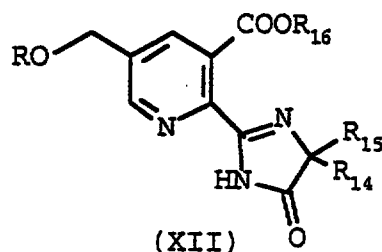
R₈ is hydrogen or C₁-C₆alkyl.



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9. The compound according to claim 7 selected from the group consisting of
the O-methyloxime of 3-ethoxy-2-methyl-2-propen-1-one;
the O-methyloxime of 3-methoxy-2-(methoxymethyl)-2-propen-1-one;
the oxime of 3-ethoxy-2-methyl-2-propen-1-one; and
the oxime of 3-methoxy-2-(methoxymethyl)-2-propen-1-one.

10. A process for the preparation of a herbicidal imidazolinone compound having the formula XII



wherein

R is as defined in claim 1;

R₁₄ is C₁-C₄ alkyl;

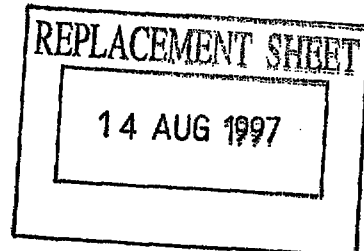
R₁₅ is C₁-C₄ alkyl, C₃-C₆ cycloalkyl or R₁₄ and R₁₅ when taken together with the atom to which they are attached, represent a C₃-C₆ cycloalkyl group optionally substituted with methyl and

R₁₆ is hydrogen, diloweralkylimino,

C₁-C₁₂ alkyl optionally substituted with one of the following groups: C₁-C₃ alkoxy, halogen, hydroxy, C₃-C₆ cycloalkyl; benzyloxy, furyl, phenyl, halophenyl, lower alkylphenyl, lower alkoxyphenyl, nitrophenyl, carboxyl, loweralkoxycarbonyl, cyano or triloweralkylammonium;

C₃-C₁₂ alkenyl optionally substituted with one of the following groups: C₁-C₃ alkoxy, phenyl, halogen or loweralkoxycarbonyl or with two C₁-C₃ alkoxy groups or two halogen groups;

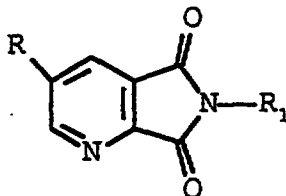
C₃-C₆ cycloalkyl optionally substituted with one or two C₁-C₃ alkyl groups; or



a cation

which process comprises:

(a) preparing a compound having the formula I



(I)

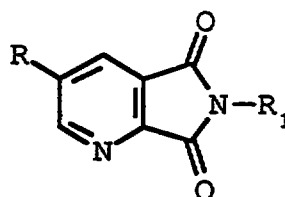
wherein R and R₁ are as defined in Claim 1 by a process as claimed in Claim 1; and

(b) converting the compound having formula I into the compound having the formula XII.

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ABSTRACT**PROCESS FOR THE PREPARATION OF
2,3-PYRIDINEDICARBOXIMIDES**

There is provided a process for the preparation of 2,3-pyridinedicarboximides having the structural formula I



(I).

The 2,3-pyridinedicarboximides are useful as intermediates in the preparation of herbicidal 2-(2-imidazolin-2-yl)nicotinic acids,