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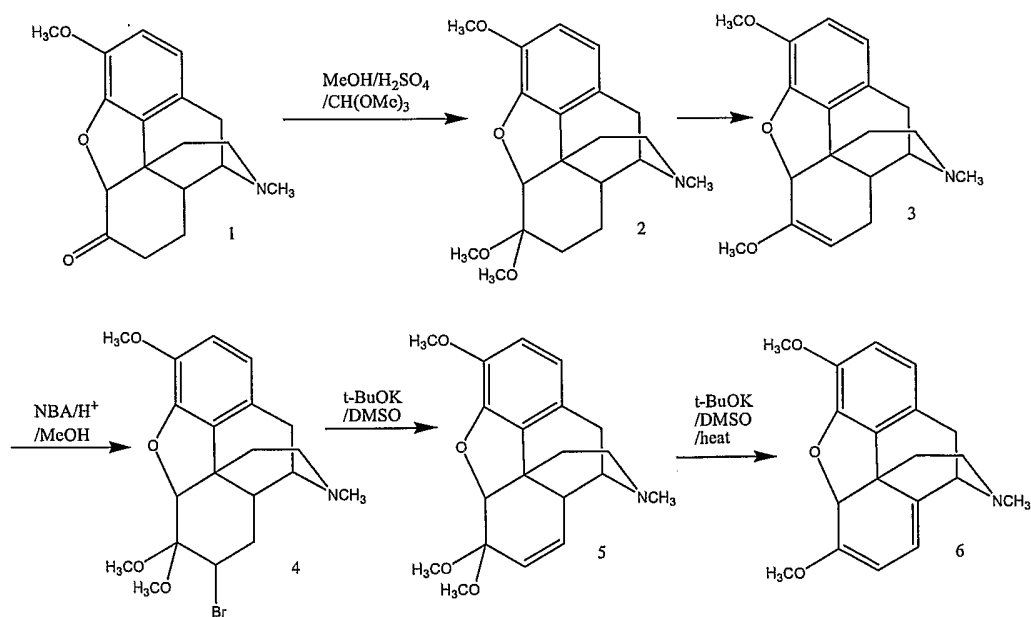
(54) Title: A NEW SYNTHETIC ROUTE TO 14-HYDROXYL OPIATES THROUGH 1-HALO-THEBAINE OR ANALOGS

(57) Abstract: Novel methods of synthesis of known and novel 14-hydroxyl opiates through 1-halothebaine and derivatives are described.

A NEW SYNTHETIC ROUTE TO 14-HYDROXYL OPIATES THROUGH 1-HALO-THEBAINE OR ANALOGS

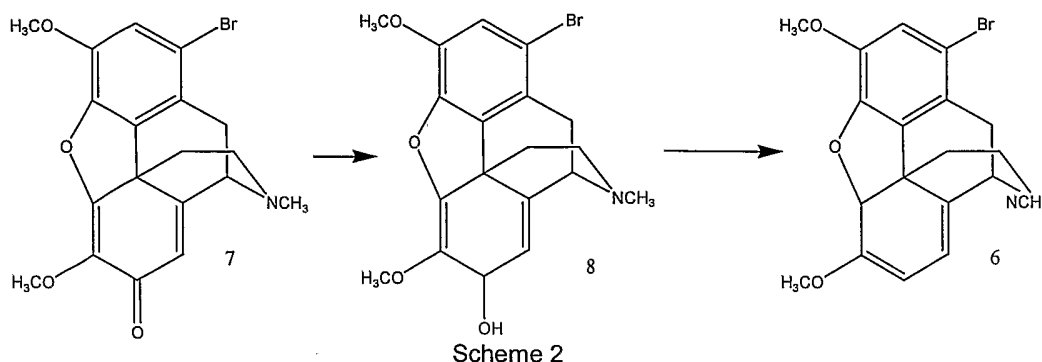
BACKGROUND OF THE INVENTION

- [0001]** The present invention relates to a method for the production of 14 hydroxyl-opiates, and more particularly to a method of producing 14-hydroxyl-opiates through 1-halo-northebaine derivatives.
- [0002]** An example of a 14-hydroxyl-opiate is oxycodone. Oxycodone is a semi-synthetic opioid agonist that is used as an alternative to morphine in controlling severe acute postoperative or posttraumatic pain or cancer pain. Oxycodone is currently commercially produced in two steps from thebaine which is extracted from a natural source or synthetically derived from a natural product. The synthetic thebaine is made in at least three steps from hydrocodone that is generated in two steps from codeine.
- [0003]** In more general terms, conventional methods for producing 14-hydroxyl-opiates typically involve multi-step synthetic methods that are expensive and inefficient. Attempts to improve efficiency have included the use of transition metal oxidants such as ruthenium tetroxide, manganese(IV)oxide, and catalytic cobalt compounds with oxygen or air on codeine or derivatives of morphine followed by reduction of the resultant 14-hydroxyl-codeinone. Overall, these oxidative methods result in low yield due in part to difficult isolations from complex mixtures of byproducts in remaining inorganic salts, and suffer from poor reproducibility.
- [0004]** Enzymatic methods of conversion have also been attempted, but these methods, because of the low concentrations of opiate substrate in the reaction medium and slow kinetics, are costly and difficult to scale up.
- [0005]** The conventional route to preparing thebaine is disclosed in the literature as follows:



Conventional Route for making thebaine  
Scheme 1

[0006] Similarly, 1-bromothebaine has reportedly been synthesized from Formula 7 as follows:



[0007] There is therefore a need for an improved method of conversion that is easily scaled up and economical for manufacturing purposes.

#### SUMMARY OF THE INVENTION

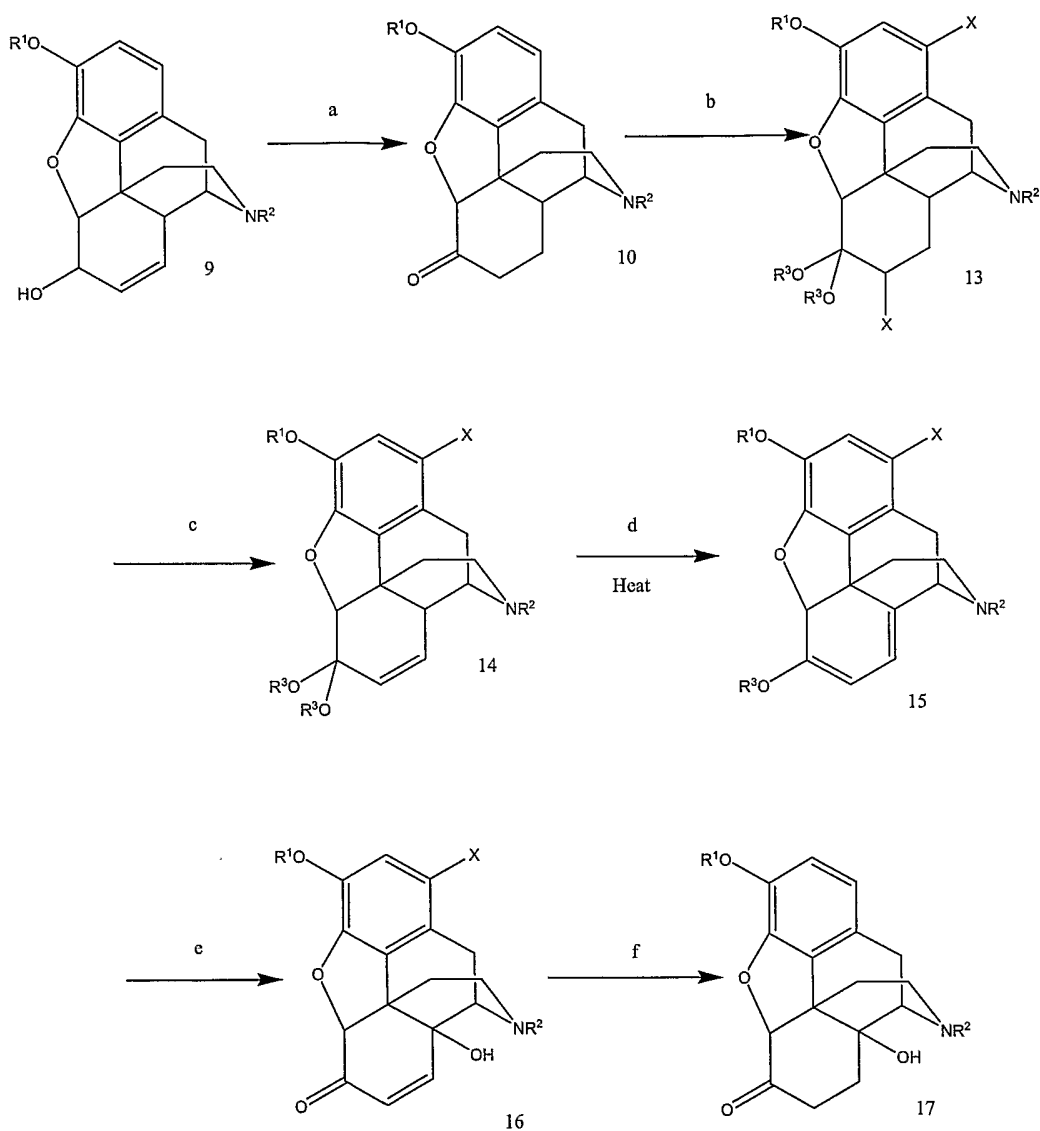
[0008] One aspect of the present invention is to provide a totally synthetic option to the use of naturally derived thebaine and more efficient pathways for the preparation of 14-hydroxylated opiate products including but not limited to oxycodone, oxymorphone, naloxone, nalmeferne, nalbuphine, naltrexone and the useful product intermediate noroxymorphone.

[0009] An aspect of the present invention utilizes a transition metal complex of the formula  $[M(PR^4R^5R^6)_nX_m]_p$ ; wherein M is a Group VIII transition metal;  $R^4$ ,  $R^5$  and  $R^6$  are selected from the group consisting of alkyl, aryl, alkoxy, phenoxy and combinations thereof; X is a halide or an anion; n is 1, 2, 3 or 4; m is 1 or 2; and p is at least 1.

[0010] These are merely illustrative aspects of the present invention and should not be deemed an all-inclusive listing of the innumerable aspects associated with the present invention. These and other aspects will become apparent to those skilled in the art in light of the following disclosure.

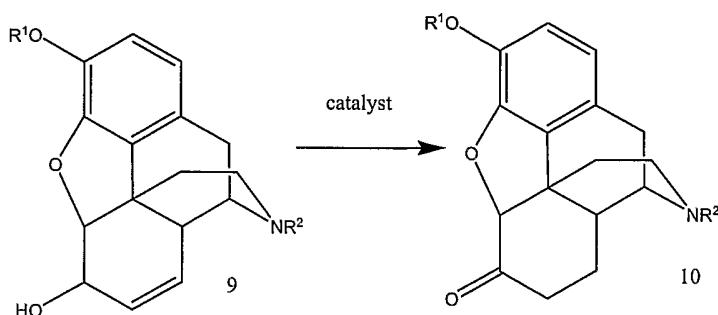
## "DETAILED DESCRIPTION"

[00011] In an illustrative embodiment of the present invention there is provided a method for the conversion of 14- hydroxyl-opiates through 1-halo-thebaine derivatives, as shown in Scheme 3, below.



Scheme 3

**[00012]** Step a is the preparation of a composition according to Formula 10 in a "one-pot" synthesis from a composition according to Formula 9,



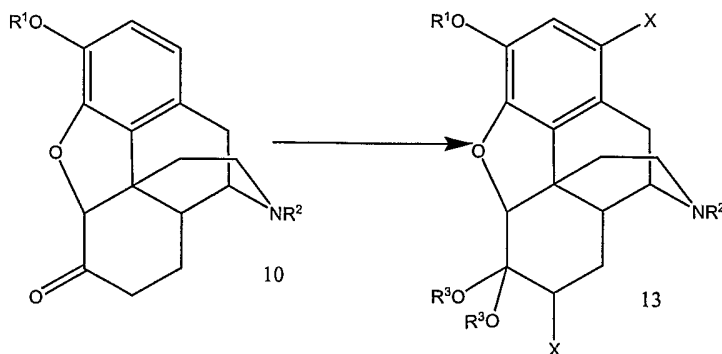
wherein R<sup>1</sup> is a member of but not limited to H, a benzyl, a substituted benzyl, an alkyl, an aryl, an acyl, an alkoxy carbonyl, an aminocarbonyl, trialkylsilyl, tetrahydropyranyl or tetrahydrofuranyl group;

R<sup>2</sup> is H, a benzyl group, an aryl group, an acyl group, a formyl group, an alkoxy carbonyl or an aminocarbonyl group; and

R<sup>3</sup> is an alkyl group, including but not limited to C1-C6 alkyl group derived from an alcohol including but not limited to methanol, ethanol, n-propanol, and n-butanol, or two R<sup>3</sup> groups taken together can form a cyclic bridging group derived from diols including but not limited to ethylene glycol and propylene glycol; an aryl group or an acyl group.

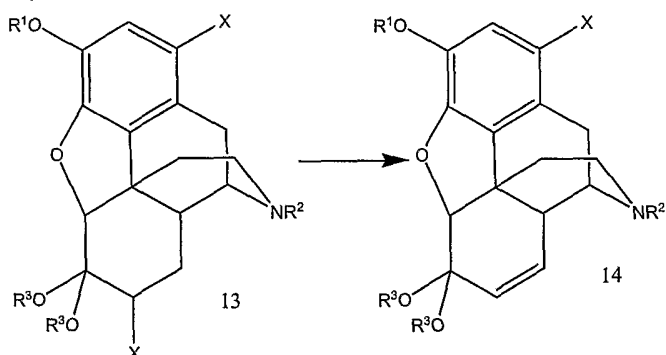
**[00013]** In this embodiment of the present invention a composition of Formula 9 is catalytically converted to a composition of Formula 10 in the presence of at least one transition metal complex of the formula  $[M(PR^4R^5R^6)_nX_m]_p$ ; wherein M is a Group VIII transition metal; R<sup>4</sup>, R<sup>5</sup> and R<sup>6</sup> are selected from the group consisting of alkyl, aryl, alkoxy, phenoxy and combinations thereof; X is a halide or an anion; n is 1, 2, 3 or 4; m is 1 or 2; and p is at least 1. The catalysts of the present invention are the subject matter of pending U.S. Patent Application 10/495,503, filed November 5, 2003, and incorporated herein in its entirety.

**[00014]** Step b) of the overall Scheme 3 is the only known example of the conversion of a composition according to Formula 9 into a composition according to Formula 13 in a "single pot" reaction. Step b) comprises the execution of step a) followed by halogenating the resulting composition according to Formula 10 with at least one halogenating reagent in at least one protic solvent in the presence of R<sup>7</sup>C(OMe)<sub>3</sub> and at least one acid to form a composition according to Formula 13;



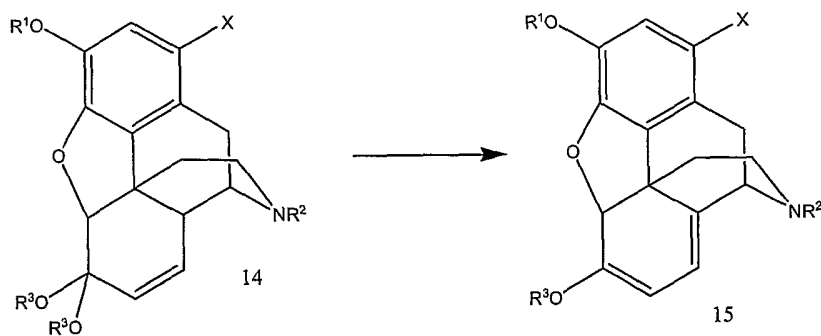
'R' may be selected from H, alkyl or alkoxy and the acid is any mild or strong acid capable of resulting in the desired conversion. Suitable acids or Lewis acids include but are not limited to sulfuric acid (H<sub>2</sub>SO<sub>4</sub>), phosphoric acid (H<sub>3</sub>PO<sub>4</sub>), methanesulfonic acid (MeSO<sub>3</sub>H), p-toluenesulfonic acid, trifluoroacetic acid, trifluoromethanesulfonic acid, hydrogen chloride (HCl), hydrogen bromide (HBr), tetrafluoroboric acid (HBF<sub>4</sub>) and mixtures thereof or Lewis acids, BF<sub>3</sub>, PCl<sub>5</sub> or POCl<sub>3</sub>. Any suitable halogenation reagent as are known in the art may be used. Suitable halogenation reagents include but are not limited to chlorine (Cl<sub>2</sub>), bromine (Br<sub>2</sub>), N-bromoacetamide (NBA), N-bromosuccinimide (NBS), 1,3-dibromo-5,5-methylhydantoin (DBDMH,) 1,3-dichloro-5,5-methylhydantoin (DCDMH,) N-chlorosuccinimide (NCS), pyridinium tribromide. The halogenations are carried out in a suitable solvent or mixture of solvents. Suitable solvents include but are not limited to chloroform, dichloromethane, acetonitrile, methanol, chlorobenzene and mixtures thereof.

**[00015]** Step c) comprises reacting the composition according to Formula 13 with less than about two equivalents of at least one base to form a composition according to Formula 14;



**[00016]** Suitable bases include but are not limited to salts of alkoxides, hydroxides, amides, anhydrous fluoride and carbonate. In some preferred embodiments, a phase transfer agent may be used to facilitate the transport of the inorganic base into the reaction media and to magnify the basicity of the anion. Such a phase transfer agent includes but is not limited to 18-crown-6, tetraalkylammonium salts, pyridinium salts, imidazolium salts, N,N-dialkylaminopyridinium salts, and substituted analogs.

**[00017]** Step d) involves heating the composition according to formula 14 in the presence of at least one acid to form a composition according to Formula 15;

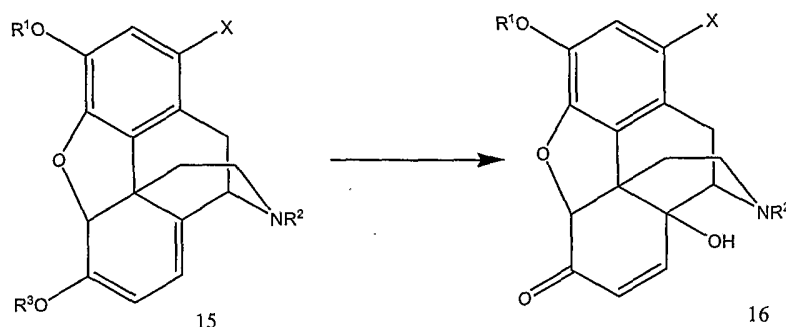


**[00018]** The conversion of Formula 14 into formula 15 occurs in the presence of an acid or a Lewis acid selected from the group including but is not limited to glacial acetic acid (HOAc), formic acid (HCO<sub>2</sub>H), n-propanoic acid, RCO<sub>2</sub>H, wherein R is alkyl, or aryl, methanesulfonic (MeSO<sub>3</sub>H), p-toluenesulfonic

acid, trifluoroacetic acid ( $\text{CF}_3\text{CO}_2\text{H}$ ), phosphoric acid, sulfuric acid,  $\text{PCl}_5$  and  $\text{POCl}_3$ . Combinations of an acid with a protic solvent should be avoided at this step so that hydrolysis to the codeinone-type by-product is minimized or prevented. It is noted that in the presence of a base in addition to prolonged heating, significant losses of Formula 15 have been observed.

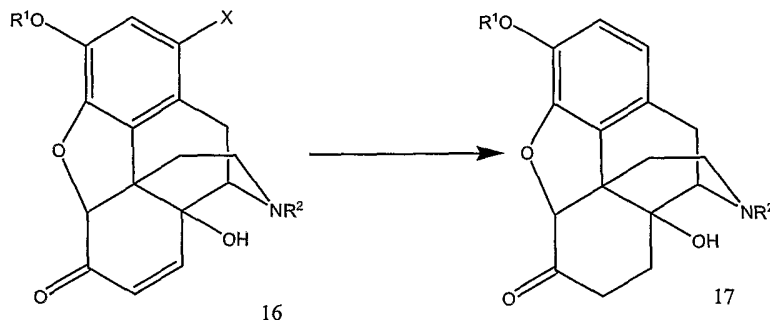
**[00019]** As illustrative of another aspect of the enablement of these inventions, a composition of Formula 15 is prepared in "one-pot" from a composition of Formula 13. Herein, "one-pot" is meant to refer to more than one chemical transformation performed within a single manufacturing vessel before isolation of an intermediate or product.

**[00020]** Step e) of reaction Scheme 1 comprises oxidizing a composition according to Formula 15 with at least one oxidizing agent to form a composition according to Formula 16;



**[00021]** Suitable oxidizing agents include but are not limited to hydrogen peroxide solution, peroxyacetic acid, 3-chloroperoxybenzoic acid,  $\text{RCO}_3\text{H}$  (R is H, an alkyl, or an aryl) or optionally the *in situ* peroxyacid preparation using a carboxylic acid and hydrogen peroxide.

**[00022]** Step f) of Scheme 3 discloses reducing the composition according to Formula 16 with at least one reductive agent to form the composition according to Formula 17;



**[00023]** Suitable reductive reagents includes but not are not limited to a combination of pressurized hydrogen or formic and a metal supported catalyst such as  $\text{M/C}$ , wherein M is Pd, Pt, Ru, or Rh and C is carbon, as well as other conventional reductive reagents as are well known in the art.

**[00024]** These inventions, as illustrated in Scheme 3 and described above provide a totally synthetic option to the use of naturally derived thebaine and more efficient pathways for the preparation of a host of 14-hydroxylated opiate products; for example, oxycodone oxymorphone, naloxone and naltrexone.

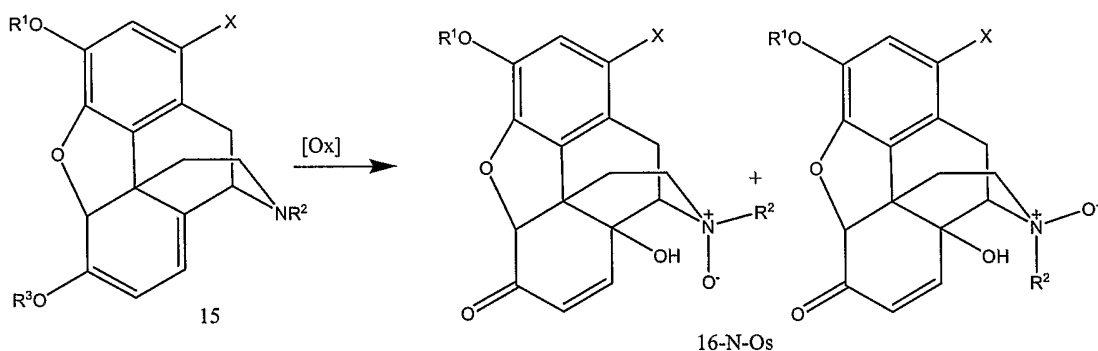
[00025] In another embodiment of the present invention, there is provided a "one-pot" method for the conversion of a composition according to Formula 9 into a composition according to Formula 13, as described in detail above.

[00026] In a further embodiment of the present invention, there is provided a "one-pot" method for the conversion of a composition according to Formula 13 into a composition according to Formula 15.

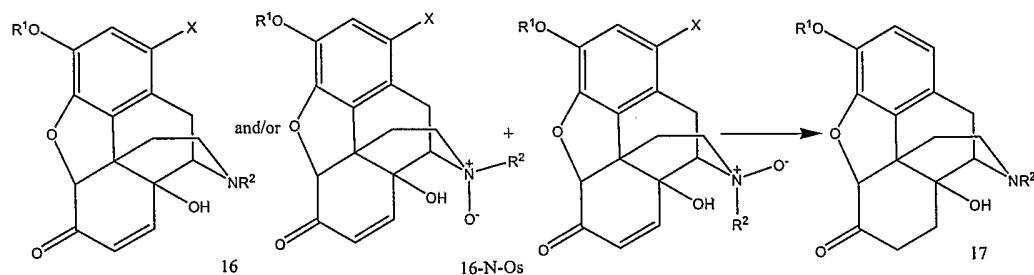
[00027] In yet another embodiment of the present invention, there is provided a "one-pot" method for the conversion of a composition according to Formula 13 into a composition according to Formula 16.

[00028] In yet another embodiment of the present invention, there is provided a "one-pot" method for the conversion of a composition according to Formula 14 into a composition according to Formula 17.

[00029] In another embodiment of the present invention, a composition according to Formula 15 is oxidized to form N-oxides according to Formula 16-N-Os;



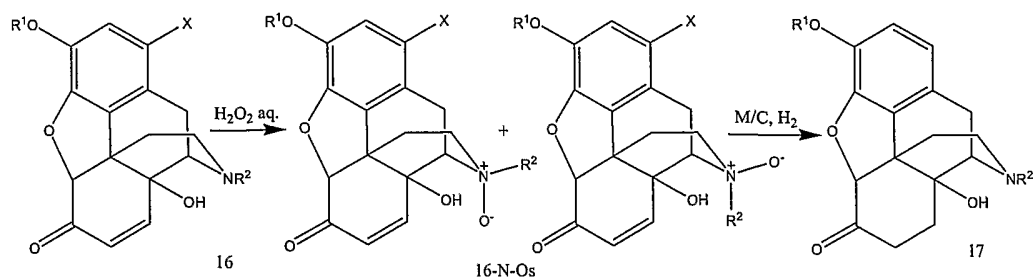
[00030] In another embodiment, a composition according Formula 16 or a composition according to Formula 16-N-Os is converted into a composition according to Formula 17, by reducing the composition according to Formula 16 or Formula 16-N-Os or salts thereof with at least one reductive agent to form the composition according to Formula 17;



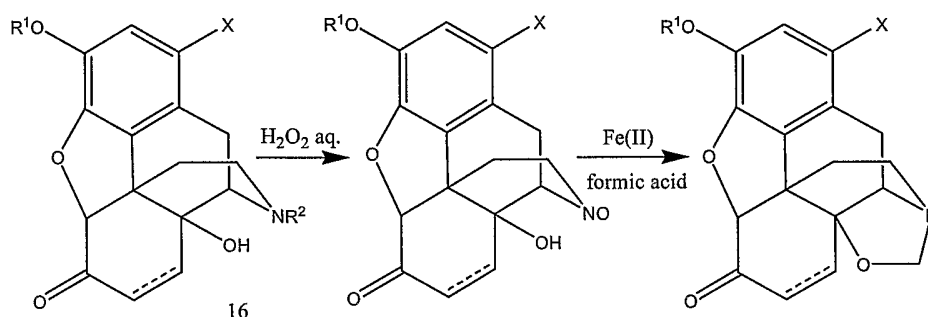
wherein  $R^1$  is H, a benzyl group, an aryl group, an acyl group, an alkoxy carbonyl group or tetrahydropyranyl group and  $R^2$  is H, a benzyl group, an aryl group, and an acyl group.

[00031] It is note depending on the conditions, when  $R^1$  is a benzyl group, reduction can lead to elimination of benzyl to H. If the N-oxides are treated with certain metal ions like Fe(II/III) when  $R^2$  is a methyl, a Modified NonClassical Polonovski Reaction occurs giving the NH group norhalothebaine analog(for N-demethylations), as referred to in JOC Vol.68, No. 25 (2003) 9847. Under neutral pH, the oxidation of the 1-halothebaines analogs will give the corresponding N-oxides in high yield. Over oxidation with peracid provides the 14-hydroxycodeinone N-oxide derivatives where  $R^2$  may come from the recited list. Alternatively, the 14-hydroxycodeinone may be oxidized separately using

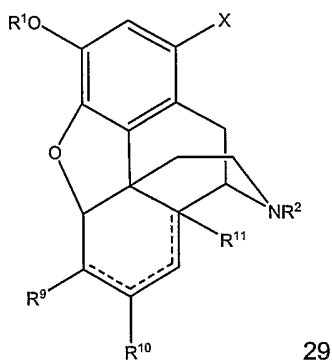
hydrogen peroxide to its corresponding N-oxides, in this instance, 1-halo-14-hydroxycodeinone derivatives with R's from the recited lists.



**[00032]** It has been reported in the art that nor-N-oxides when treated with Fe(II) in formic acid affords the oxazolidine compound. The oxazolidine may be hydrolyzed back to the nor-compound so could act a nitrogen protecting group. Some of the compositions of the present invention would react similarly where  $R^2$  is a hydrogen (H). A non-limiting illustrative reaction is as follows:



**[00033]** The novel intermediates of Formulas 10 through 16 are given in the general Formula 29, below:

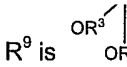




wherein  $R^1$  is H,  $CH_3$ ,  $PhCH_2$ ,  $R^8CO$ ,  $R^8OCO$  or THP;

$R^2$  is H,  $CH_3$ ,  $PhCH_2$ , CHO,  $R^8CO$ ,  $R^8OCO$ ;

$R^3$  is C1-4 alkyl, aryl or acetate;

$R^8$  is C1-6 alkyl;

$R^9$  is  as part of a ketal;  as a part of an enol ether or acetate; or  as part of a ketone;

$R^{10}$  is H, Cl or Br; and

$R^{11}$  is H or OH.

**[00034]** An illustrative embodiment of the inventions herein described is the preparation of oxycodone from 1-bromo-thebaine. The 1-bromothebaine is made in a "one pot" reaction from 1,7-dibromohydrocodone dimethyl ketal, that in turn is generated in "one pot" by sequential reactions from codeine. The details of this illustrative synthesis are given in the examples, below. It is noted that the preparation of 1-bromothebaine in a "one-pot" reaction from codeine avoids the inherent difficulties of preparing and isolating the very moisture sensitive enol ether intermediate of Formula 3, wherein  $R^1$  and  $R^2$  are methyl groups, as illustrated in the conventional reaction Scheme 1.

**[00035]** Similarly, oxymorphone, noroxymorphone and derivatives can be synthesized as shown in Scheme 3. Oxymorphone is prepared from morphine as shown in scheme 3. The phenol group of morphine is protected using a benzyl ( $\text{PhCH}_2$ ) group or acyl (RCO) group. In the case of  $\text{PhCH}_2$  as protecting group, oxymorphone is made directly after hydrogenation of Formula 16 ( $R^1 = \text{PhCH}_2$ ). Alternatively, the O-acylated oxymorphone (Formula 17,  $R^1 = \text{RCO}$  and  $R^2 = \text{Me}$ ) provides O-acylated oxymorphone that is easily hydrolyzed to oxymorphone. If noroxymorphone is the target product, then the  $\text{PhCH}_2$  protected morphine derivative (Formula 9,  $R^1 = R^2 = \text{PhCH}_2$  or  $R^1 = \text{RCO}$  and  $R^2 = \text{PhCH}_2$ ) is used as the starting material.

**[00036]** Many process designs, as are well known in the art, could be utilized with the process of the present invention.

**[00037]** Examples:

**[00038]** Example 1

**[00039]** To a 1000 mL three-necked flask, MeOH (250 mL) was added. Codeine (62.5 g, 0.209 mol) was added and stirred until completely dissolved. The solution was flushed with nitrogen over a 10 minute period. Wilkenson's catalyst,  $\text{Rh}(\text{PPh}_3)_3\text{Cl}$ , (0.625 g) was added under nitrogen. The solution was refluxed for 3 h to give a suspension. MeOH (125 mL) was removed by distillation. The suspension was cooled to 50°C.  $\text{CH}(\text{OMe})_3$  (125 mL) and  $\text{H}_2\text{SO}_4$  (14.2 mL) were added. The temperature was maintained under 62°C during the addition of  $\text{H}_2\text{SO}_4$ . After refluxing for 30 min., the solution was cooled to 50°C. A solution of  $\text{Br}_2$  (23.63 mL, 0.46 mol) in  $\text{CHCl}_3$  (125 mL) was added over 45 min. and the temperature was maintained at or around 50°C for 30 min after this addition was complete. The solution was filtered. The filtrate and  $\text{CHCl}_3$  (125 mL) was added to a stirred solution of 29%  $\text{NH}_4\text{OH}$  (188 mL) and water (188 mL) held at 0 ~ 5°C for about 10 min until two layers formed. The aqueous layer was extracted with  $\text{CHCl}_3$  (125 mL). The organic layers were washed with water (3 X 313 mL) and taken to dryness under reduced pressure to give 115 g of a sticky solid. The solid was dissolved in MeOH (188 mL) and taken to dryness under reduced pressure to provide 104 g of the crude product 13 as a foam (yield of crude product >99%, purity >92% area/area by HPLC).

**[00040]** Example 2

**[00041]** The 1,7-dibromohydrocodone dimethyl ketal (13, 80.0 g, 0.159 mmol) was dissolved in 1-methyl-2-pyrrolidinone (NMP, 120 mL), flushed with nitrogen for 10 min and cooled to 5~10°C. KOBu-t (26.8 g, 0.24 mol) was added in three portions. Since the reaction was exothermic, the temperature was maintained under 45°C by controlling the addition rate. The mixture was stirred at 40 ~ 45°C for 1 h after the addition and then cooled to rt. Glacial acetic acid (HOAc, 180 mL) was then added. The solution was heated to 100°C for 6 h. HOAc (~100 mL) was removed by distillation. The solution was poured into a iced water (480 mL), followed by a toluene (120 mL) wash. Toluene (480 mL) was added to the aqueous layer. NaOH (50%) was added until the pH = 12.3. The organic layer was washed with water (5 X 480 mL). The product in the organic layer was assayed to contain 41.5 g (purity 88%area/area by HPLC). The crude product of 21 was isolated as a brown solid (45 g).

**[00042]** Example 3

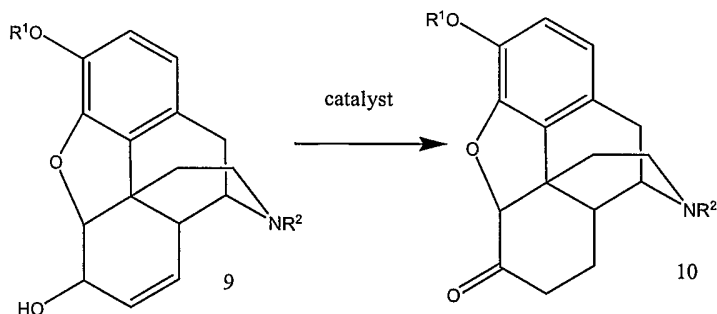
**[00043]** Compound 15 (5.00 g, 12.8 mmol) was dissolved in HOAc (15 mL). Peroxyacetic acid (CH<sub>3</sub>CO<sub>3</sub>H~ 20%, freshly made from HOAc/H<sub>2</sub>O, 7.2 mL, ~ 19 mmol) was added dropwise at 25-30°C. Stirring at rt was continued for another 50 min after the complete addition. 5% Pd/C (0.25 g) was added and stirred at rt for 2 h followed by another addition of 5% Pd/C (0.75 g). The reactor was flushed with nitrogen three times and then hydrogen three times. The reactor was heated to 60°C under hydrogen 60 psi for 12 h. The suspension was filtered. The solid was washed with MeOH (2 X 5 mL). The combined filtrates were taken almost dryness under reduced pressure. Ethyl acetate (20 mL)/5% NH<sub>4</sub>OH (20 mL, final pH > 10) was added. The aqueous layer was extracted with ethyl acetate (20 mL). The combined organic layers were washed with water (3 X 10 mL), and taken to dryness under reduced pressure to give 3.3 g of solid crude product 17. Compound 17 was re-crystallized from ethyl acetate/heptane to give 1.72 g of pure product as a white crystalline solid.

**[00044]** From the foregoing description those skilled in the art will appreciate that economical and efficient methods for the synthesis of known and novel 14-hydroxyl opiates are provided.

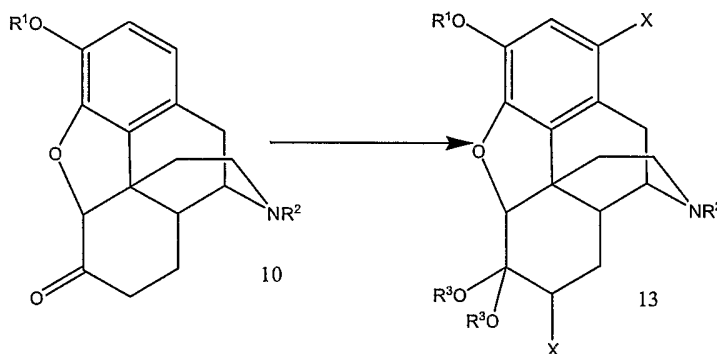
## Claims

1. A process for the preparation of compositions according to Formula 17, the process comprising:

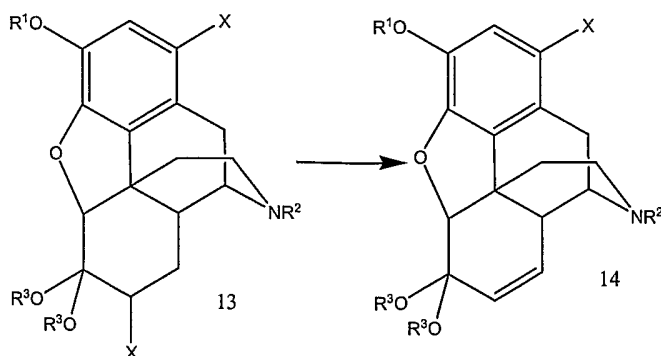
a) catalytically converting a composition according to Formula 9 into a composition according to Formula 10 in the presence of at least one catalyst, wherein the catalyst is at least one transition metal complex of the formula  $[M(PR^4R^5R^6)_nX_m]_p$ ; wherein M is a Group VIII transition metal;  $R^4$ ,  $R^5$  and  $R^6$  are selected from the group consisting of alkyl, aryl, alkoxy, phenoxy and combinations thereof; X is a halide or an anion; n is 1, 2, 3 or 4; m is 1 or 2; and p is at least 1;



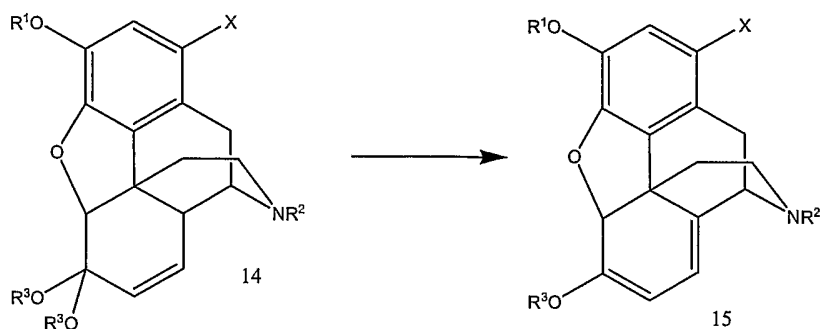
b) halogenating the composition according to Formula 10 with at least one halogenating reagent in at least one protic solvent in the presence of  $R^7C(OMe)_3$  and at least one first acid to form a composition according to Formula 13;



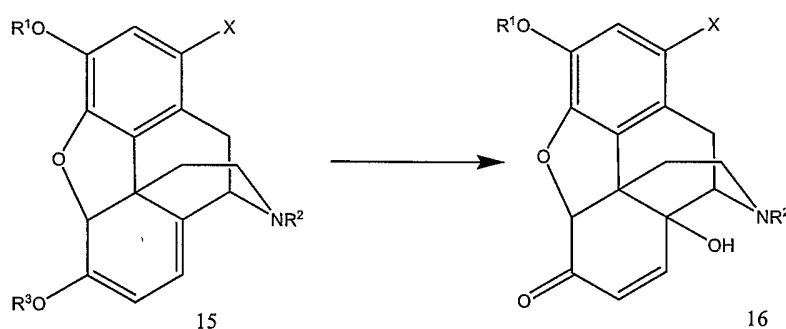
c) reacting the composition according to Formula 13 with less than about two equivalents of at least one base to form a composition according to Formula 14;



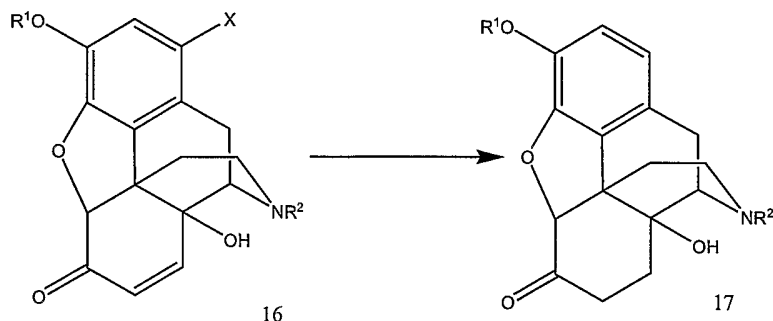
d) heating the composition according to formula 14 in the presence of at least one second acid to form a composition according to Formula 15;



e) oxidizing the composition according to Formula 15 with at least one oxidizing agent to form a composition according to Formula 16;



f) reducing the composition according to Formula 16 with at least one reductive agent to form the composition according to Formula 17;



wherein  $R^1$  is H, a benzyl group, an aryl group, an acyl group, an alkoxy carbonyl group or tetrahydropyranyl group;

$R^2$  is H, a benzyl group, an aryl group, an acyl group, a formyl group, a formyl ester, an alkoxy carbonyl group or an alkylamidocarbonyl;

$R^3$  is H, an alkyl group or an aryl group; and

$R^7$  is H, an alkyl or an alkoxy.

2. The process of Claim 1 wherein the at least one first acid includes an acid selected from the group consisting of sulfuric acid ( $H_2SO_4$ ), phosphoric acid ( $H_3PO_4$ ), methanesulfonic acid

(MeSO<sub>3</sub>H), p-toluenesulfonic acid, trifluoroacetic acid, trifluoromethanesulfonic acid, hydrogen chloride (HCl), hydrogen bromide (HBr) and mixtures thereof;

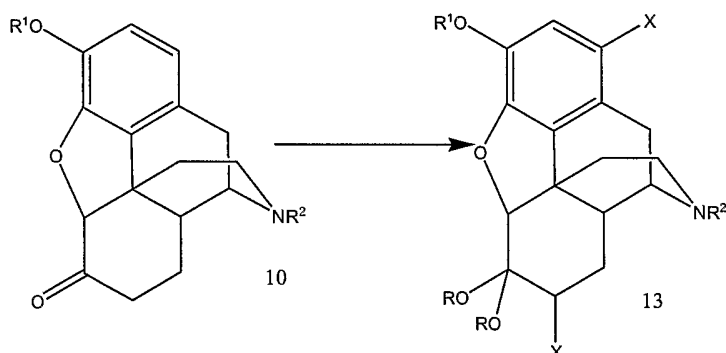
the at least one halogenating reagent includes a halogenating reagent selected from the group consisting of bromine (Br<sub>2</sub>), N-bromoacetamide (NBA), N-bromosuccinimide (NBS), 1,3-dibromo-5,5-dimethylhydantoin (DBDMH), 1,3-dichloro-5,5-dimethylhydantoin (DCDMH), N-chlorosuccinimide (NCS) and mixtures thereof;

the at least one second acid includes an acid selected from the group consisting of HOAc, HCO<sub>2</sub>H, RCO<sub>2</sub>H wherein R is an alkyl, benzyl or aryl, MeSO<sub>3</sub>H, p-toluenesulfonic acid, CF<sub>3</sub>CO<sub>2</sub>, POCl<sub>3</sub> and mixtures thereof;

the at least one oxidizing agent includes an oxidizing agent selected from the group consisting of hydrogen peroxide solution, peroxyacetic acid, 3-chloroperoxybenzoic acid, RCO<sub>3</sub>H wherein R is H, an alkyl, or an aryl, and mixtures thereof; and

the at least one reductive agent includes a reductive agent selected from the group consisting of a combination of pressurized hydrogen on metal supported catalyst such as M/C, wherein M is Pd, Pt, Ru, or Rh and C is carbon.

3. A process for the conversion of a composition according to Formula 10 into a composition according to Formula 13, the process comprising halogenating the composition according to Formula 10 with at least one halogenating reagent in at least one protic solvent in the presence of of R<sup>7</sup>C(OMe)<sub>3</sub> and at least one acid;



wherein R<sup>1</sup> is H, a benzyl group, an aryl group, an acyl group, an alkoxy carbonyl group or tetrahydropyranyl group;

R<sup>2</sup> is H, a benzyl group, an aryl group, an acyl group, a formyl group, a formyl ester, an alkoxy carbonyl group or an alkylamidocarbonyl;

R<sup>3</sup> is H, an alkyl group or an aryl group; and

R<sup>7</sup> is H, an alkyl group or an alkoxy group.

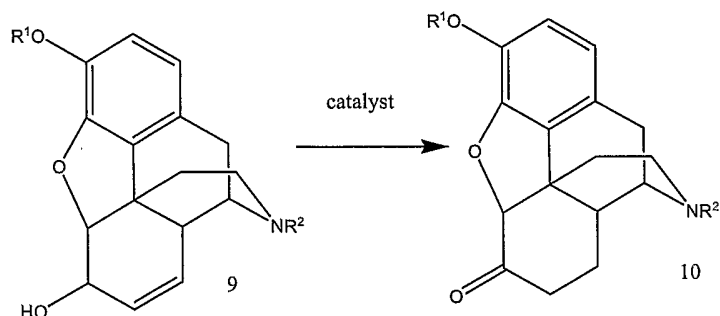
4. The process Claim 3 wherein the at least one acid includes an acid selected from the group consisting of H<sub>2</sub>SO<sub>4</sub>, H<sub>3</sub>PO<sub>4</sub>, MeSO<sub>3</sub>H, p-toluenesulfonic acid, trifluoroacetic acid, trifluoromethanesulfonic acid, HCl, HBr and mixtures thereof; and at least one halogenating reagent includes a halogenating reagent selected from the group consisting of bromine (Br<sub>2</sub>), chlorine (Cl<sub>2</sub>), N-

bromoacetamide (NBA), N-bromosuccinimide (NBS), 1,3-dibromo-5,5-methylhydantoin (DBDMH,) 1,3-dichloro-5,5-methylhydantoin (DCDMH,), N-chlorosuccinimide (NCS), pyridinium tribromide.

5. The process of Claim 3 wherein the conversion of the composition according to Formula 10 into the composition according to Formula 13 is a "one-pot" reaction sequence.

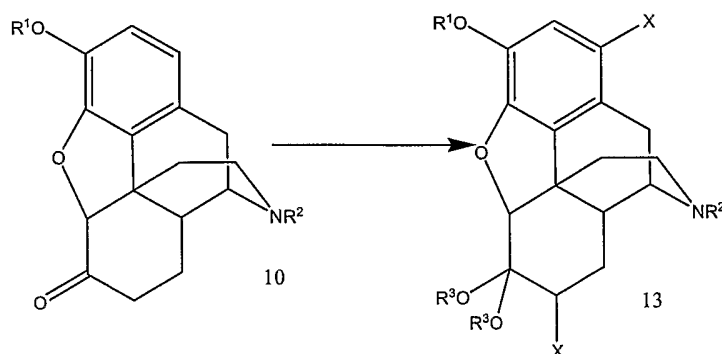
6. A "one pot" process for the conversion of a composition according to Formula 9 into a composition according to Formula 13, the process comprising:

a) catalytically converting the composition according to Formula 9 to form the composition according to Formula 10;



wherein the catalyst is at least one transition metal complex of the formula  $[M(PR^4R^5R^6)_nX_m]_p$ ; wherein M is a Group VIII transition metal;  $R^4$ ,  $R^5$  and  $R^6$  are selected from the group consisting of alkyl, aryl, alkoxy, phenoxy and combinations thereof; X is a halide or an anion; n is 1, 2, 3 or 4; m is 1 or 2; and p is at least 1; and

b) halogenating the composition according to Formula 10 with at least one halogenating reagent in at least one protic solvent in the presence of  $R^7C(OMe)_3$  and at least one acid to form the composition of Formula 13;



wherein  $R^1$  is H, a benzyl group, an aryl group, an acyl group, an alkoxy carbonyl group or tetrahydropyranyl group;

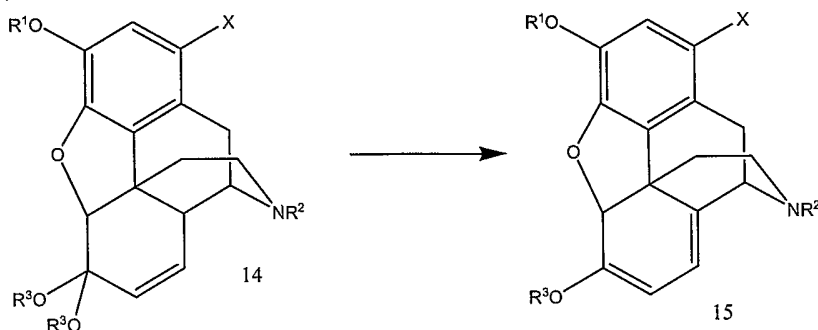
$R^2$  is H, a benzyl group, an aryl group, an acyl group, a formyl group, a formyl ester, an alkoxy carbonyl group or alkylamidocarbonyl;

$R^3$  is H, an alkyl group or an aryl group.

7. The process Claim 6 wherein the at least one acid includes an acid selected from the group consisting of sulfuric acid ( $H_2SO_4$ ), phosphoric acid ( $H_3PO_4$ ),  $MeSO_3H$ , p-toluenesulfonic acid, trifluoroacetic acid, trifluoromethanesulfonic acid, hydrogen chloride (HCl), hydrogen bromide (HBr) and mixtures thereof; and

the at least one halogenating reagent is selected from the group consisting of bromine ( $Br_2$ ), chlorine ( $Cl_2$ ), N-bromoacetamide (NBA), N-bromosuccinimide (NBS), 1,3-dibromo-5,5-methylhydantoin (DBDMH), 1,3-dichloro-5,5-methylhydantoin (DCDMH), N-chlorosuccinimide (NCS), pyridinium tribromide; and at least one protic solvent includes a solvent selected from the group consisting of methanol, ethanol, n-propanol, n-butanol, ethylene glycol, propylene glycol and mixtures thereof.

8. A process for the conversion of a composition according to formula 14 into a composition according to formula 15, the process comprising heating the composition of formula 14 in the presence of at least one acid to form the composition of Formula 15;



wherein  $R^1$  is H, a benzyl group, an aryl group, an acyl group, an alkoxy carbonyl group or tetrahydropyranyl group;

$R^2$  is H, a benzyl group, an aryl group, an acyl group, a formyl group, a formyl ester, an alkoxy carbonyl group or alkylamidocarbonyl group;

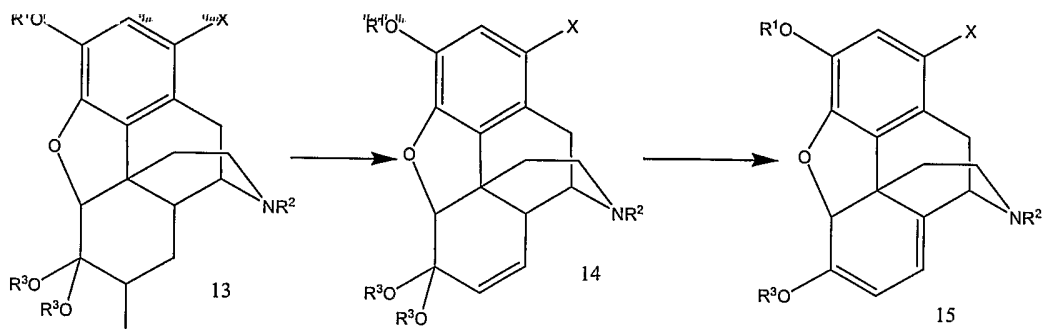
$R^3$  is H, an alkyl group or an aryl group.

9. The process of Claim 8 wherein the at least one acid includes an acid selected from the group consisting of acetic acid ( $HOAc$ ), formic acid ( $HCO_2H$ ), carboxylic acid ( $RCO_2H$ ) wherein R is an alkyl, benzyl or aryl, methanesulfonic ( $MeSO_3H$ ), p-toluenesulfonic acid, trifluoroacetic acid ( $CF_3CO_2H$ ), phosphorous oxychloride ( $POCl_3$ ) and mixtures thereof.

10. A process for the conversion of a composition according to Formula 13 into a composition according to Formula 15, the process comprising:

a) reacting the composition according to Formula 13 with less than about two equivalents of at least one base to form a composition according to Formula 14; and

b) heating the composition according to Formula 14 in the presence of at least one acid to form the composition according to Formula 15;



wherein

$R^1$  is H, a benzyl group, an aryl group, an acyl group, an alkoxy carbonyl group or tetrahydropyranyl group;

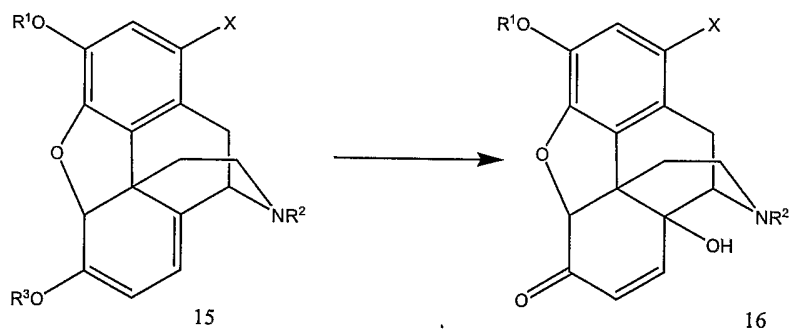
$R^2$  is H, a benzyl group, an aryl group, an acyl group, a formyl group, a formyl ester, an alkoxy carbonyl group or alkylamidocarbonyl group;

$R^3$  is H, an alkyl group, an aryl group or an acyl group.

11. The process of Claim 10 wherein the at least one base includes a base selected from the group consisting of salts of alkoxides, hydroxides, amides, anhydrous fluoride, carbonate and mixtures thereof; and

the at least one acid includes an acid selected from the group consisting of acetic acid (HOAc), formic acid ( $HCO_2H$ ), carboxylic acid ( $RCO_2H$ ) wherein R is an alkyl, benzyl or aryl, methanesulfonic acid ( $MeSO_3H$ ), p-toluenesulfonic acid, trifluoroacetic acid ( $CF_3CO_2H$ ),  $POCl_3$  and mixtures thereof.

12. A process for the conversion of a composition according to Formula 15 into a composition of Formula 16, the process comprising:  
oxidizing the composition according to Formula 15 with at least one oxidizing agent to form the composition according to Formula 16;



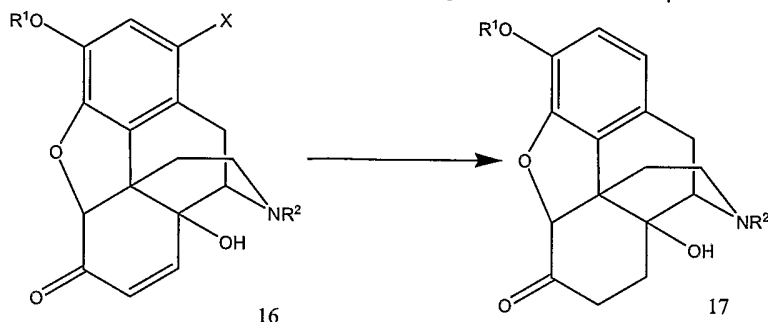
wherein  $R^1$  is H, a benzyl group, an aryl group, an acyl group, an alkoxy carbonyl group or tetrahydropyranyl group;

$R^2$  is H, a benzyl group, an aryl group, an acyl group, a formyl group, a formyl ester, an alkoxy carbonyl group or alkylamidocarbonyl group;

$R^3$  is H, an alkyl group, an aryl group or an acyl group.

13. The process of Claim 12 wherein the at least one oxidizing agent includes an oxidizing agent selected from the group consisting of hydrogen peroxide solution, peroxyacetic acid, 3-chloroperoxybenzoic acid,  $\text{RCO}_3\text{H}$  wherein R is H, an alkyl, an aryl, hydrogen peroxide in a carboxylic acid and mixtures thereof.

14. A process for the conversion of a composition according to Formula 16 into a composition according to Formula 17, the process comprising reducing the composition according to Formula 16 with at least one reductive agent to form the composition according to Formula 17;



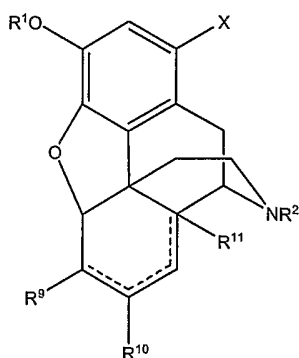
wherein  $\text{R}^1$  is H, a benzyl group, an aryl group, an acyl group, an alkoxy carbonyl group or tetrahydropyranyl group;

$\text{R}^2$  is H, a benzyl group, an aryl group, an acyl group, a formyl group, a formyl ester, an alkoxy carbonyl group or alkylamidocarbonyl group;

$\text{R}^3$  is H, an alkyl group, an aryl group or an acyl group.

15. The process of Claim 14 wherein the at least one reductive agent includes a reductive agent selected from the group consisting of a combination of pressurized hydrogen on metal supported catalyst such as  $\text{M/C}$ , wherein M is Pd, Pt, Ru, or Rh and C is carbon.

16. A composition according to Formula 29:



wherein  $\text{R}^1$  is H,  $\text{CH}_3$ ,  $\text{PhCH}_2$ ,  $\text{R}^8\text{CO}$ ,  $\text{R}^8\text{OCO}$  or THP;

$\text{R}^2$  is H,  $\text{CH}_3$ ,  $\text{PhCH}_2$ , CHO,  $\text{R}^8\text{CO}$ ,  $\text{R}^8\text{OCO}$ ;

$\text{R}^3$  is C1-4 alkyl, aryl or acetate;

$\text{R}^8$  is C1-6 alkyl;

$R^9$  is  $\begin{array}{c} \text{OR}^3 \\ | \\ \text{OR}^3 \end{array}$  as part of a ketal;  $\text{OR}^3$  as part of an enol ether or acetate; or  $\text{O}=\text{C}$  as part of a ketone;

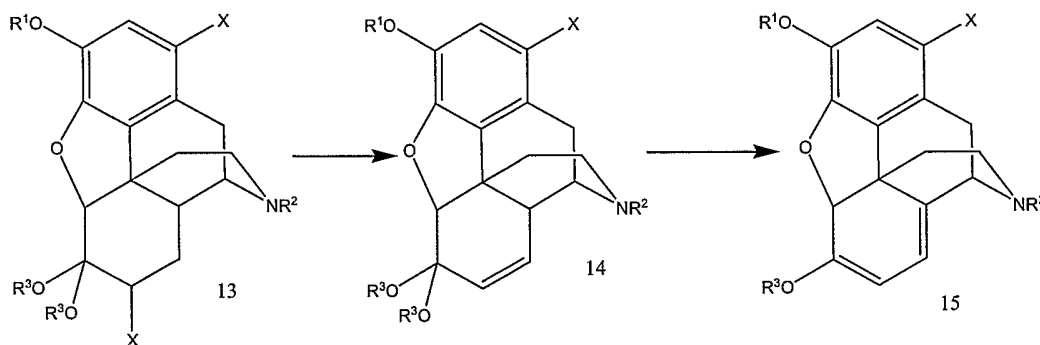
$R^{10}$  is H, Cl or Br; and

$R^{11}$  is H or OH.

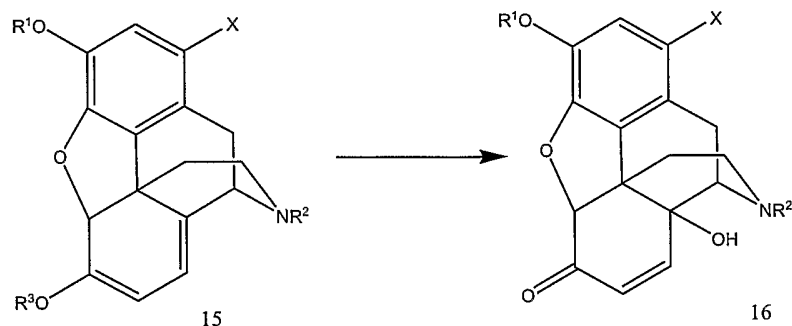
17. A one-pot process for the conversion of a composition according to Formula 13 into a composition according to Formula 16, the process comprising:

a) reacting the composition according to Formula 13 with less than about two equivalents of at least one base to form a composition according to Formula 14; and

b) heating the composition according to formula 14 in the presence of at least one acid to form the composition according to Formula 15; and



c) oxidizing the composition according to Formula 15 with at least one oxidizing agent to form the composition according to Formula 16;



wherein  $R^1$  is H, a benzyl group, an aryl group, an acyl group, an alkoxy carbonyl group or tetrahydropyranyl group;

$R^2$  is H, a benzyl group, an aryl group, an acyl group, a formyl group, a formyl ester, an alkoxy carbonyl group or alkylamidocarbonyl group;

$R^3$  is H, an alkyl group, an aryl group or an acyl group.

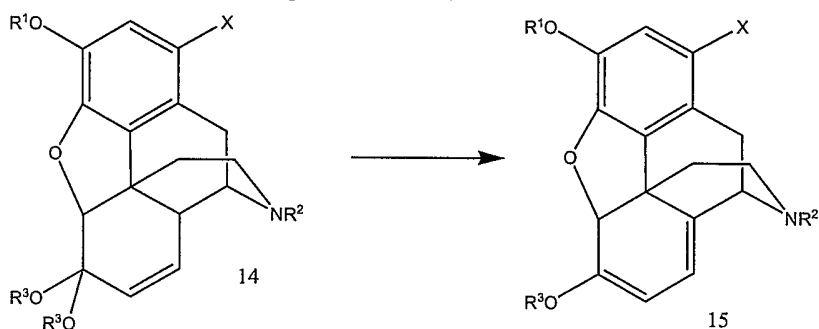
18. The process of claim 17 wherein the at least one oxidizing agent includes an oxidizing agent selected from the group consisting of hydrogen peroxide solution, peroxyacetic acid, 3-

chloroperoxybenzoic acid, hydrogen peroxide in a carboxylic acid,  $\text{RCO}_3\text{H}$  wherein R is H, an alkyl, or an aryl, and mixtures thereof.

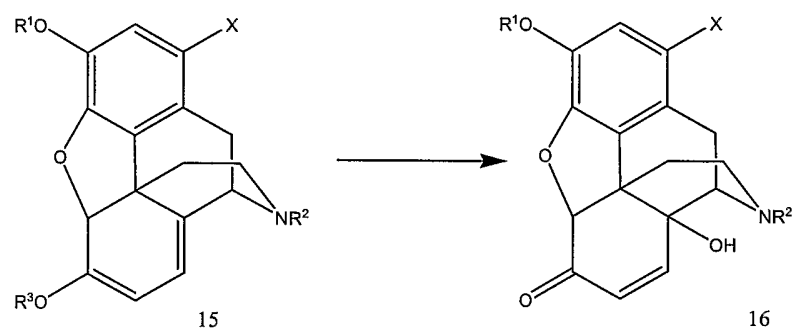
19. The process of claim 17 wherein the at least one acid includes an acid selected from the group consisting of acetic acid ( $\text{HOAc}$ ), formic acid ( $\text{HCO}_2\text{H}$ ), carboxylic acid ( $\text{RCO}_2\text{H}$ ) wherein R is an alkyl, benzyl or aryl, methanesulfonic acid ( $\text{MeSO}_3\text{H}$ ), p-toluenesulfonic acid, trifluoroacetic acid ( $\text{CF}_3\text{CO}_2\text{H}$ ),  $\text{POCl}_3$  and mixtures thereof.

20. A one-pot process for the conversion of a composition according to Formula 14 into a composition according to Formula 17, the process comprising:

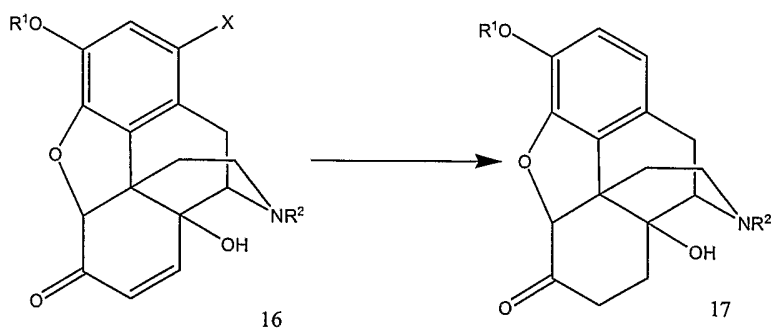
a) heating the composition according to formula 14 in the presence of at least one acid to form a composition according to formula 15;



b) oxidizing the composition according to Formula 15 with at least one oxidizing agent to form a composition according to Formula 16; and



c) reducing the composition according to Formula 16 with at least one to form a composition according to Formula 17;



wherein R<sup>1</sup> is H, a benzyl group, an aryl group, an acyl group, an alkoxy carbonyl group or tetrahydropyranyl group;

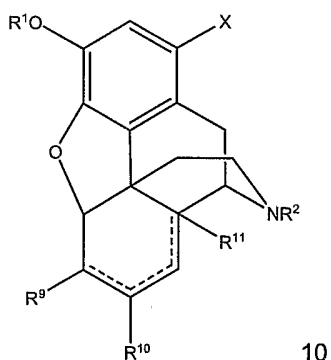
R<sup>2</sup> is H, a benzyl group, an aryl group, an acyl group, a formyl group, a formyl ester, an alkoxy carbonyl group or alkylamidocarbonyl group;

R<sup>3</sup> is H, an alkyl group, an aryl group or an acyl group.

21. The process of Claim 20 wherein the at least one reductive agent includes a reductive agent that is selected from the group consisting of a combination of pressurized hydrogen on metal supported catalyst such as M/C, wherein M is Pd, Pt, Ru, or Rh and C is carbon.

22. The process of Claim 20 wherein the at least one oxidizing agent includes an oxidizing agent that is selected from the group consisting of hydrogen peroxide solution, peroxyacetic acid, 3-chloroperoxybenzoic acid, RCO<sub>3</sub>H wherein R is H, an alkyl, or an aryl, and mixtures thereof.

23. A composition according to Formula 10



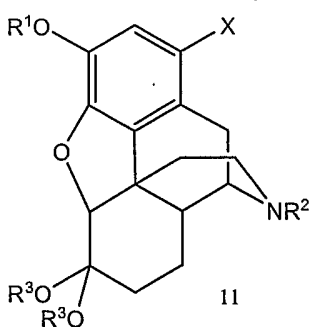
wherein R<sup>1</sup> is H, CH<sub>3</sub>, PhCH<sub>2</sub>, R<sup>8</sup>CO, R<sup>8</sup>OCO, or THP.

R<sup>2</sup> is H, CH<sub>3</sub>, PhCH<sub>2</sub>, CHO, R<sup>8</sup>CO or R<sup>8</sup>OCO;

R<sup>8</sup> is C1-6 alkyl; and

X is H, Cl or Br.

24. A composition according to Formula 11



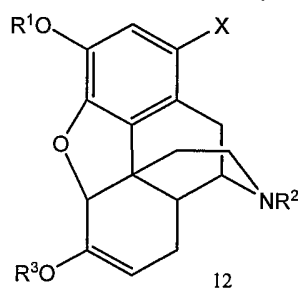
wherein R<sup>1</sup> is H, CH<sub>3</sub>, PhCH<sub>2</sub>, R<sup>8</sup>CO, R<sup>8</sup>OCO or THP.

R<sup>2</sup> is H, CH<sub>3</sub>, PhCH<sub>2</sub>, CHO, R<sup>8</sup>CO or R<sup>8</sup>OCO;

R<sup>8</sup> is C1-6 alkyl;

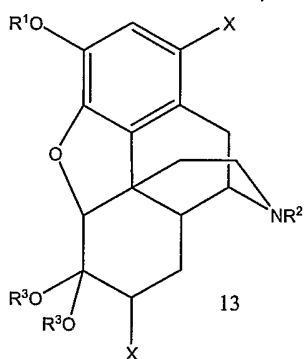
$R^1$  is alkyl or taken together is a cyclic alkyl and  
 $X$  is H, Cl or Br.

25. A composition according to Formula 12



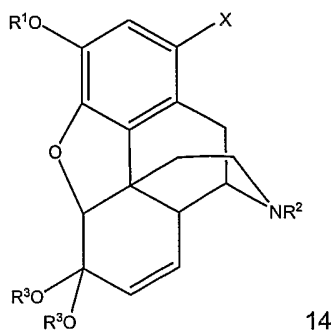
wherein  $R^1$  is H,  $CH_3$ ,  $PhCH_2$ ,  $R^8CO$ ,  $R^8OCO$  or THP;  
 $R^2$  is H,  $CH_3$ ,  $PhCH_2$ , CHO,  $R^8CO$ ,  $R^8OCO$ ;  
 $R^8$  is C1-6 alkyl;  
 $R^3$  is C1-4 alkyl or acetate; and  
 $X$  is H, Cl or Br.

26. A composition according to Formula 13



wherein  $R^1$  is H,  $CH_3$ ,  $PhCH_2$ ,  $R^8CO$ ,  $R^8OCO$  or THP;  
 $R^2$  is H,  $CH_3$ ,  $PhCH_2$ , CHO,  $R^8CO$ ,  $R^8OCO$ ;  
 $R^8$  is C1-6 alkyl;  
 $R^3$  is C1-4 alkyl or acetate; and  
 $X$  is H, Cl or Br.

27. A composition according to Formula 14



wherein R<sup>1</sup> is H, CH<sub>3</sub>, PhCH<sub>2</sub>, R<sup>8</sup>CO, R<sup>8</sup>OCO or THP;

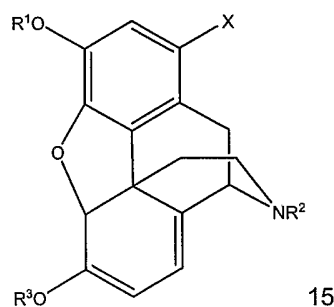
R<sup>2</sup> is H, CH<sub>3</sub>, PhCH<sub>2</sub>, CHO, R<sup>8</sup>CO, R<sup>8</sup>OCO;

R<sup>8</sup> is C1-6 alkyl;

R<sup>3</sup> is C1-4 alkyl or acetate and

X is H, Cl or Br.

28. A composition according to Formula 15



wherein R<sup>1</sup> is H, CH<sub>3</sub>, PhCH<sub>2</sub>, R<sup>8</sup>CO, R<sup>8</sup>OCO or THP;

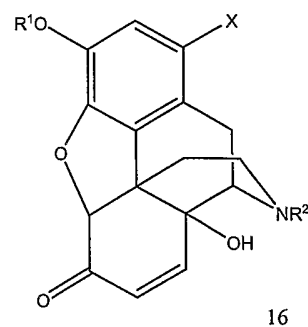
R<sup>2</sup> is H, CH<sub>3</sub>, PhCH<sub>2</sub>, CHO, R<sup>8</sup>CO, R<sup>8</sup>OCO;

R<sup>8</sup> is C1-6 alkyl;

R<sup>3</sup> is C1-4 alkyl or acetate and

X is H, Cl or Br.

29. A composition according to Formula 16



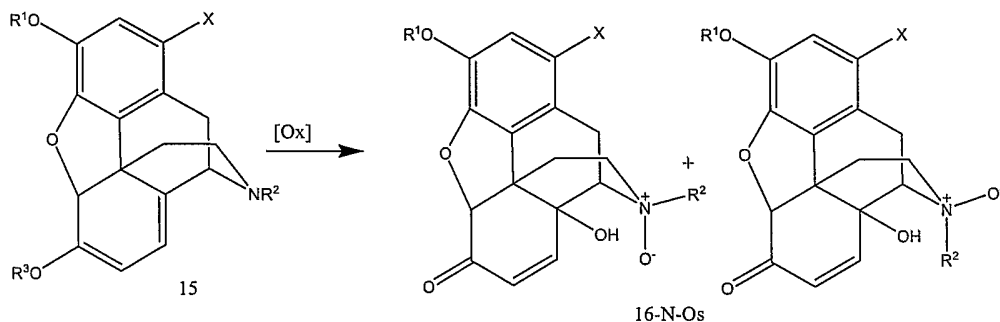
wherein R<sup>1</sup> is H, CH<sub>3</sub>, PhCH<sub>2</sub>, R<sup>8</sup>CO, R<sup>8</sup>OCO or THP;

R<sup>2</sup> is H, CH<sub>3</sub>, PhCH<sub>2</sub>, CHO, R<sup>8</sup>CO, R<sup>8</sup>OCO;

$R^2$  is C1-6 alkyl; and

X is H, Cl or Br.

30. A process for the conversion of a composition according to Formula 15 into a composition of Formula 16-N-Os, the process comprising:  
oxidizing the composition according to Formula 15 with at least one oxidizing agent to form the composition according to Formula 16-N-Os;



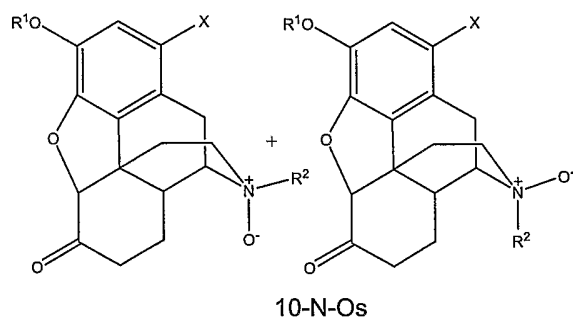
wherein  $R^1$  is H, a benzyl group, an aryl group, an acyl group, an alkoxy carbonyl group or tetrahydropyranyl group;

$R^2$  is H, a benzyl group, an aryl group, an acyl group, a formyl group, a formyl ester, an alkoxy carbonyl group or alkylamidocarbonyl group;

$R^3$  is H, an alkyl group, an aryl group or an acyl group.

31. The process of Claim 30 wherein the at least one oxidizing agent includes an oxidizing agent selected from the group consisting of hydrogen peroxide solution, peroxyacetic acid, 3-chloroperoxybenzoic acid,  $RCO_3H$  wherein R is H, an alkyl, an aryl, hydrogen peroxide in a carboxylic acid and mixtures thereof.

32. A composition according to Formula 10-N-Os



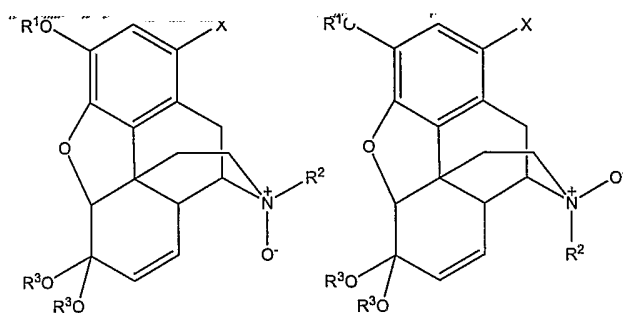
wherein  $R^1$  is H,  $CH_3$ ,  $PhCH_2$ ,  $R^8CO$ ,  $R^8OCO$ , or THP.

$R^2$  is H,  $CH_3$ ,  $PhCH_2$ ,  $R^8CO$ ;

$R^8$  is C1-6 alkyl; and

X is Cl or Br.

33. A composition according to Formula 14-N-Os



14-N-Os

wherein  $R^1$  is H,  $CH_3$ ,  $PhCH_2$ ,  $R^8CO$ ,  $R^8OCO$  or THP;

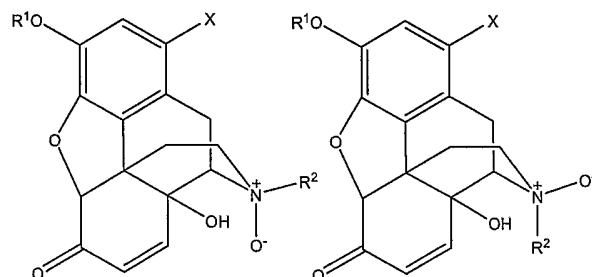
$R^2$  is H,  $CH_3$ ,  $PhCH_2$ ,  $R^8CO$ ;

$R^3$  is C1-4 alkyl or cyclic alkyl or acetate; and

$R^8$  is C1-6 alkyl; and

X is H, Cl or Br.

34. A composition according to Formula 16-N-Os



16-N-Os

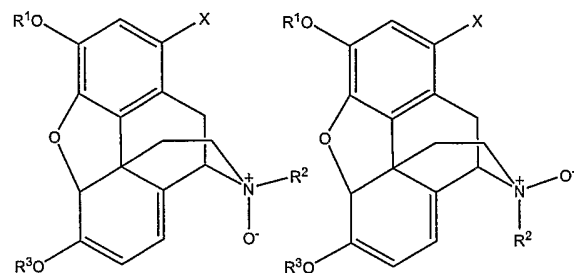
wherein  $R^1$  is H,  $CH_3$ ,  $PhCH_2$ ,  $R^8CO$ ,  $R^8OCO$  or THP;

$R^2$  is H,  $CH_3$ ,  $PhCH_2$ ,  $R^8CO$ ;

$R^8$  is C1-6 alkyl; and

X is Cl or Br.

35. A composition according to Formula 15-N-Os



15-N-Os

wherein  $R^1$  is H,  $CH_3$ ,  $PhCH_2$ ,  $R^8CO$ ,  $R^8OCO$  or THP;

$R^2$  is H,  $CH_3$ ,  $PhCH_2$ ,  $R^8CO$ ;

$R^8$  is C1-6 alkyl; and

X is Cl or Br.