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PROCESSES FOR THE CONVERGENT SYNTHESIS OF CALICHEAMICIN DERIVATIVES

FIELD OF THE INVENTION

This invention describes processes for the convergent synthesis of calicheamicin derivatives, and similar analogs using bifunctional and trifunctional linker intermediates.

BACKGROUND OF THE INVENTION

The potent family of antibacterial and antitumor agents known collectively as the calicheamicins or the LL-E33288 complex, are disclosed in U.S. Patent No. 4,970,198 (1990). The compounds contain a methyltrisulfide that can be reacted with appropriate thiols to form disulfides while at the same time introducing a functional group such as a hydrazide or similar nucleophile. Examples of this reaction with the calicheamicins are given in U.S. Patent No. 5,053,394. U.S. Patent No. 5,770,701 is directed to a process for preparing targeted forms of disulfide compounds of the LL-E33288 complex. A linker, 4-(4-acetyl-phenoxy)butanoic acid, is condensed with calicheamicin N-acetyl gamma dimethyl hydrazide to afford the carboxylic acid-hydrazone which is further treated with N-hydroxysuccinimide to give the OSu ester (N-succinimidyloxy) which is ready for conjugation with a chosen biomacromolecule.

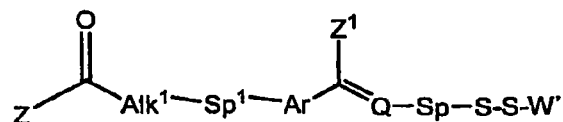
Previously disclosed synthetic methods for constructing calicheamicin derivatives are complicated by multiple calicheamicin containing synthetic steps having low overall yields. The calicheamicin moiety is inherently toxic, and when already part of a synthetic target necessitates increased safety precautions which must be observed during manipulation and purification of the products of each of the synthetic steps. The claimed process provides a method of fewer steps involving the calicheamicin moiety with increased yields.



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SUMMARY OF THE INVENTION

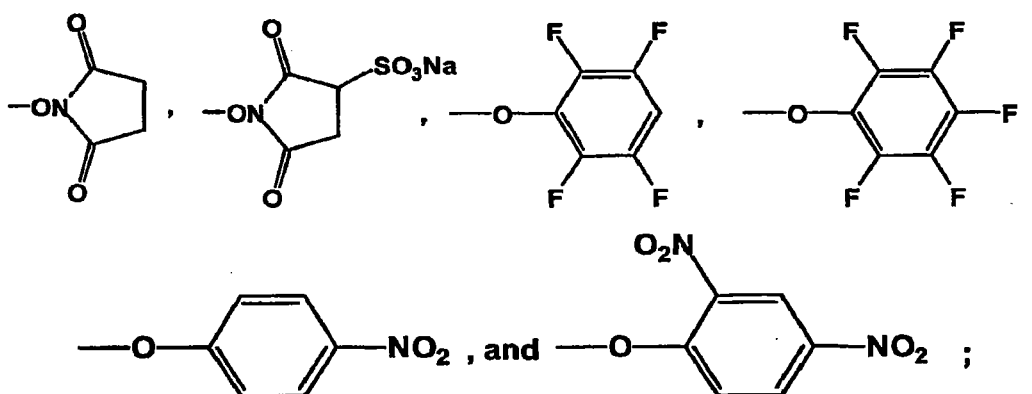
Discussed herein is a process to prepare calicheamicin derivatives of Formula (I):



Formula (I)

wherein:

Z is selected from the group consisting of



Alk¹ is a branched or unbranched alkylene chain of 2 to 6 carbon atoms;

Sp¹ is selected from -S-, -O-, -CONH-, -NHCO-, and -NR'-;

Z¹ is H, or alkyl of 1 to 5 carbon atoms;

Ar is 1,2-, 1,3-, or 1,4-phenylene optionally substituted with one, two, or three groups independently selected from alkyl of 1 to 6 carbon atoms, alkoxy of 1 to 5 carbon atoms, thioalkoxy of 1 to 4 carbon atoms, halogen, nitro, -COOR', -CONHR', -O(CH₂)_nCOOR', -S(CH₂)_nCOOR', -O(CH₂)_nCONHR', and -S(CH₂)_nCONHR' or a 1,2-, 1,3-, 1,4-, 1,5-, 1,6-, 1,7-, 1,8-, 2,3-, 2,6-, or 2,7-naphthylidene optionally substituted with one, two, three, or four groups independently selected from alkyl of 1 to 6 carbon atoms, alkoxy of 1 to 5 carbon atoms, thioalkoxy of 1 to 4 carbon atoms,

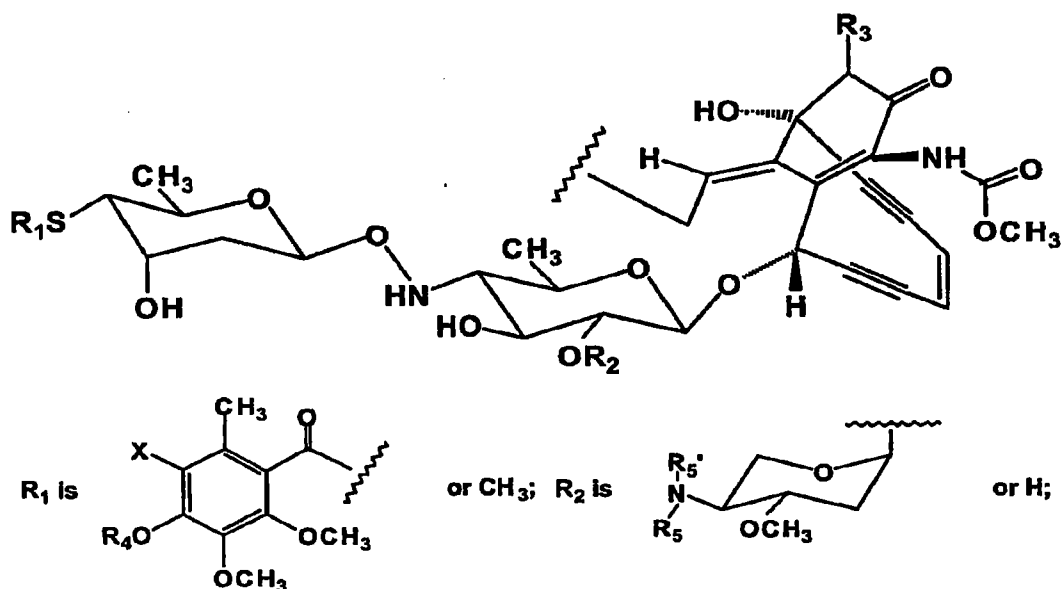
halogen, nitro, $-\text{COOR}'$, $-\text{CONHR}'$, $-\text{O}(\text{CH}_2)_n\text{COOR}'$, $-\text{S}(\text{CH}_2)_n\text{COOR}'$,
 $-\text{O}(\text{CH}_2)_n\text{CONHR}'$, and $-\text{S}(\text{CH}_2)_n\text{CONHR}'$;

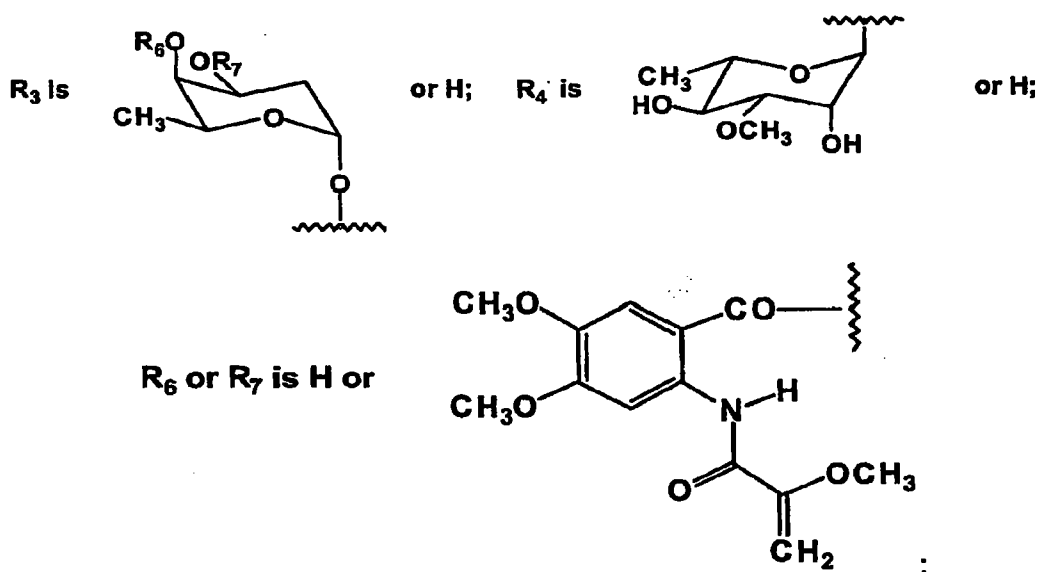
n is an integer from 0 to 5;

R' is a straight or branched alkyl of 1 to 5 carbon atoms optionally substituted by one or two groups of $-\text{OH}$, alkoxy of 1 to 4 carbon atoms, thioalkoxy of 1 to 4 carbon atoms;

Sp is a straight or branched-chain divalent or trivalent alkyl radical of 1 to 18 carbon atoms, divalent or trivalent aryl or heteroaryl radical, divalent or trivalent cycloalkyl of 3 to 18 carbon atoms or heterocycloalkyl radical, divalent or trivalent aryl- or heteroaryl-alkyl ($\text{C}_1\text{-C}_{18}$) radical, divalent or trivalent cycloalkyl- or heterocyclo-alkyl-alkyl ($\text{C}_1\text{-C}_{18}$) radical or divalent or trivalent unsaturated alkyl radical of 2 to 18 carbon atoms, wherein heteroaryl is furyl, thienyl, N-methylpyrrolyl, pyridinyl, N-methylimidazolyl, oxazolyl, pyrimidinyl, quinolyl, isoquinolyl, N-methylcarbazoyl, aminocoumarinyl, or phenazinyl and wherein if Sp is a trivalent radical, it can be additionally substituted by dialkylamino of 1 to 5 carbon atoms, alkoxy of 1 to 5 carbon atoms, hydroxy, or alkylthio of 1 to 5 carbon atoms groups;

W' is





R_5 is $-\text{CH}_3$, $-\text{C}_2\text{H}_5$, or $-\text{CH}(\text{CH}_3)_2$;

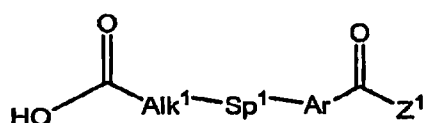
X is an iodine or bromine atom;

R_5' is a hydrogen or the group RCO , wherein R is hydrogen, branched or unbranched alkyl of 1 to 10 carbon atoms, alkylene of 2 to 10 carbon atoms, aryl of 6 to 11 carbon atoms, a $(\text{C}_6\text{-C}_{11})$ aryl-alkyl $(\text{C}_1\text{-C}_5)$ group, or a heteroaryl or heteroaryl-alkyl $(\text{C}_1\text{-C}_5)$ group wherein heteroaryl is defined as 2- or 3-furyl, 2- or 3-thienyl, 2- or 3-(N-methylpyrrolyl), 2-, 3-, or 4-pyridinyl, 2-, 4-, or 5-(N-methylimidazolyl), 2-, 4-, or 5-oxazolyl, 2-, 3-, 5-, or 6-pyrimidinyl, 2-, 3-, 4-, 5-, 6-, 7-, or 8-quinolyl, or 1-, 3-, 4-, 5-, 6-, 7-, or 8-isoquinolyl, all aryl and heteroaryl groups optionally substituted by one or more hydroxy, amino, carboxy, halo, nitro, $(\text{C}_1\text{-C}_3)$ alkoxy of 1 to 3 carbon atoms, or thioalkoxy of 1 to 5 carbon atoms; and

Q is selected from the group consisting of $-\text{NNHCO}-$, $-\text{NNHCS}-$, $-\text{NNHCONH}-$, $-\text{NNHCSNH}-$, and $-\text{NO}-$;

comprising the steps of:

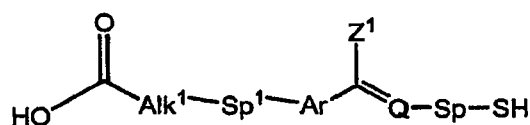
a. reacting a carboxylic acid of the formula



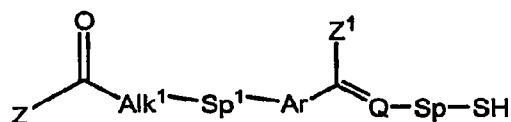
with a mercapto compound of the formula



in an alcohol solvent in the presence of an alkyl carboxylic acid, $\text{alk}^2\text{CO}_2\text{H}$ where alk^2 is 1 to 4 carbon atoms at about 20° to 70°C for about 1 to 24 hours, wherein Alk^1 , Sp^1 , Ar , Z^1 , Q , and Sp are as defined above, to produce a bilinker-carboxylic acid of the formula, wherein the mercapto compound and carboxylic acid are present in a ratio of about 1.2:1

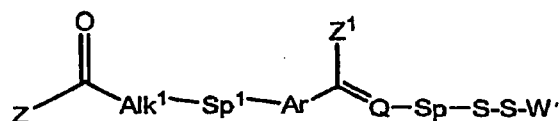


- b. isolating the bilinker-carboxylic acid of step (a);
- c. reacting the isolated bilinker-carboxylic acid of step (b) with an at least a 3 fold molar excess of N-hydroxysuccinimide, 2,3,5,6-tetrafluorophenol, pentafluorophenol, 4-nitrophenol, 2,4-dinitrophenol, or N-hydroxysulfosuccinimide in the presence of 1,3-dicyclohexylcarbodiimide (DCC), 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide (EDCI), or N,N'-disuccinimdyi carbonate in an inert solvent containing 0-50% N,N-dimethylformamide (DMF) to generate a trilinker-activated ester of the formula

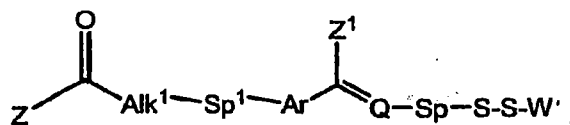


where Z is hereinbefore defined;

- d. reacting the trilinker-activated ester formed in step with a methyltrithio antitumor antibiotic $\text{CH}_3-\text{S}-\text{S}-\text{S}-\text{W}'$ in the presence of a base or an organic base with a methyltrithio antitumor antibiotic $\text{CH}_3-\text{S}-\text{S}-\text{S}-\text{W}'$ in an inert organic solvent to generate an activated ester of the formula below, wherein the trilinker-activated ester in step c and the $\text{CH}_3-\text{S}-\text{S}-\text{S}-\text{W}'$ are in a ratio of 3.3:1 and the temperature of the reaction is $\leq 5^\circ\text{C}$.

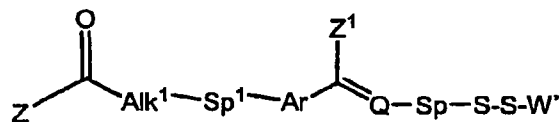


e. isolating the activated ester of step (d) and purifying to yield antitumor antibiotics of Formula (I)



Formula (I)

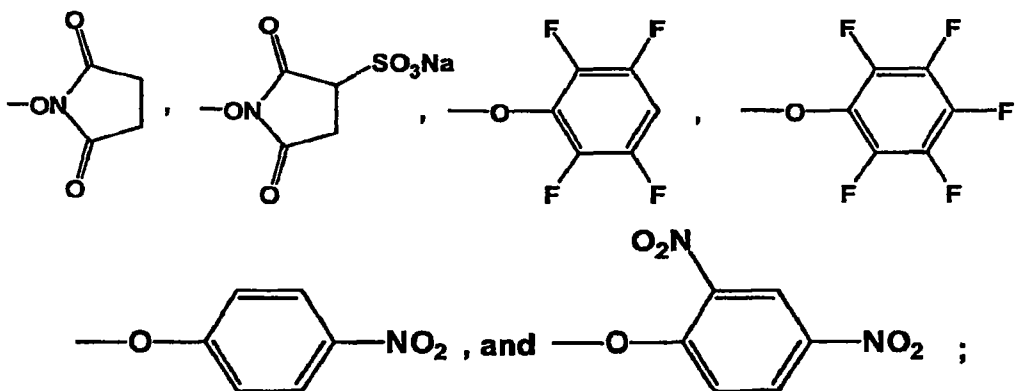
An additional process discussed includes a method of preparing antitumor antibiotics of Formula (I):



Formula (I)

wherein:

Z is selected from the group consisting of



Alk^1 is a branched or unbranched alkylene chain of 2 to 6 carbon atoms;

Sp^1 is selected from —S— , —O— , —CONH— , —NHCO— , and $\text{—NR}'\text{—}$;

Z^1 is H, or alkyl of 1 to 5 carbon atoms;

Ar is 1,2-, 1,3-, or 1,4-phenylene optionally substituted with one, two, or three groups independently selected from alkyl of 1 to 6 carbon atoms, alkoxy of 1 to 5 carbon atoms, thioalkoxy of 1 to 4 carbon atoms, halogen, nitro, $\text{—COOR}'$, $\text{—CONHR}'$,

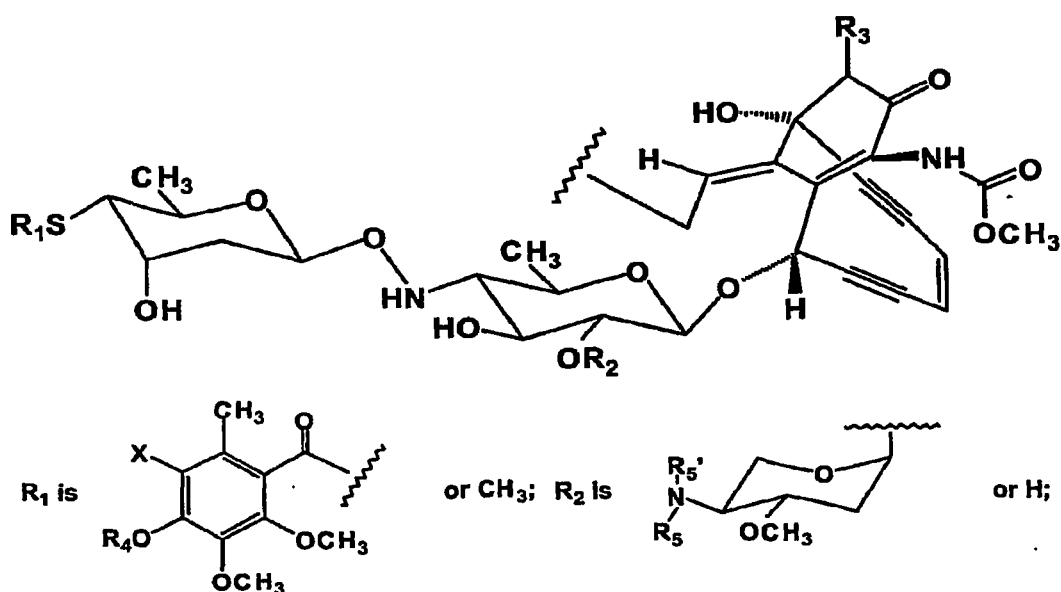
-O(CH₂)_nCOOR', -S(CH₂)_nCOOR', -O(CH₂)_nCONHR', and -S(CH₂)_nCONHR' or a 1,2-, 1,3-, 1,4-, 1,5-, 1,6-, 1,7-, 1,8-, 2,3-, 2,6-, or 2,7-naphthylidene optionally substituted with one, two, three, or four groups independently selected from alkyl of 1 to 6 carbon atoms, alkoxy of 1 to 5 carbon atoms, thioalkoxy of 1 to 4 carbon atoms, halogen, nitro, -COOR', -CONHR', -O(CH₂)_nCOOR', -S(CH₂)_nCOOR', -O(CH₂)_nCONHR', and -S(CH₂)_nCONHR';

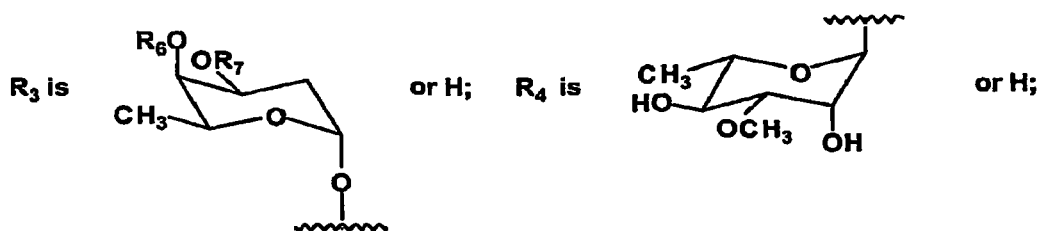
n is an integer from 0 to 5;

R' is a straight or branched alkyl of 1 to 5 carbon atoms optionally substituted by one or two groups of -OH, alkoxy of 1 to 4 carbon atoms, thioalkoxy of 1 to 4 carbon atoms;

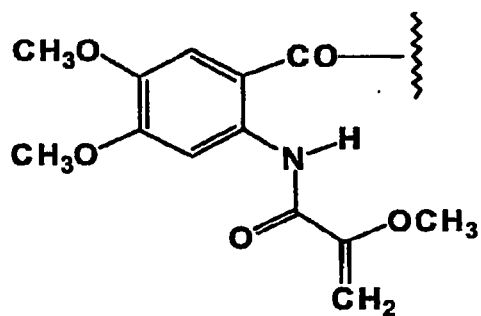
Sp is a straight or branched-chain divalent or trivalent alkyl radical of 1 to 18 carbon atoms, divalent or trivalent aryl or heteroaryl radical, divalent or trivalent cycloalkyl of 3 to 18 carbon atoms or heterocycloalkyl radical, divalent or trivalent aryl- or heteroaryl-alkyl (C₁-C₁₈) radical, divalent or trivalent cycloalkyl- or heterocyclo-alkyl-alkyl (C₁-C₁₈) radical or divalent or trivalent unsaturated alkyl radical of 2 to 18 carbon atoms, wherein heteroaryl is furyl, thienyl, N-methylpyrrolyl, pyridinyl, N-methylimidazolyl, oxazolyl, pyrimidinyl, quinolyl, isoquinolyl, N-methylcarbazoyl, aminocoumarinyl, or phenazinyl and wherein if Sp is a trivalent radical, it can be additionally substituted by dialkylamino of 1 to 5 carbon atoms, alkoxy of 1 to 5 carbon atoms, hydroxy, or alkylthio of 1 to 5 carbon atoms groups;

W' is





R_6 or R_7 is H or



R_5 is -CH₃, -C₂H₅, or -CH(CH₃)₂;

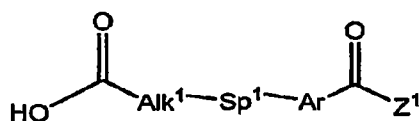
X is an iodine or bromine atom;

R_5' is a hydrogen or the group RCO, wherein R is hydrogen, branched or unbranched alkyl of 1 to 10 carbon atoms, alkylene of 2 to 10 carbon atoms, aryl of 6 to 11 carbon atoms, a (C₆-C₁₁) aryl-alkyl (C₁-C₅) group, or a heteroaryl or heteroaryl-alkyl (C₁-C₅) group wherein heteroaryl is defined as 2- or 3-furyl, 2- or 3-thienyl, 2- or 3-(N-methylpyrrolyl), 2-, 3-, or 4-pyridinyl, 2-, 4-, or 5-(N-methylimidazolyl), 2-, 4-, or 5-oxazolyl, 2-, 3-, 5-, or 6-pyrimidinyl, 2-, 3-, 4-, 5-, 6-, 7-, or 8-quinolyl, or 1-, 3-, 4-, 5-, 6-, 7-, or 8-isoquinolyl, all aryl and heteroaryl groups optionally substituted by one or more hydroxy, amino, carboxy, halo, nitro, (C₁-C₃) alkoxy of 1 to 3 carbon atoms, or thioalkoxy of 1 to 5 carbon atoms; and

Q is selected from the group consisting of -NNHCO-, -NNHCS-, -NNHCONH-, -NNHCSNH-, and -NO-;

comprising the steps of:

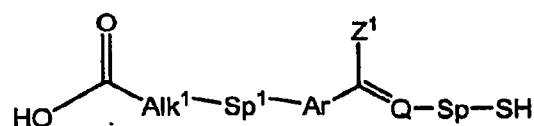
a. reacting a carboxylic acid of the formula



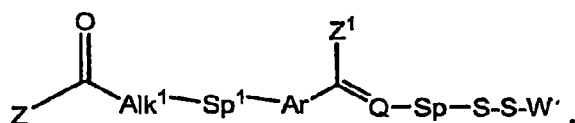
with a mercapto compound of the formula



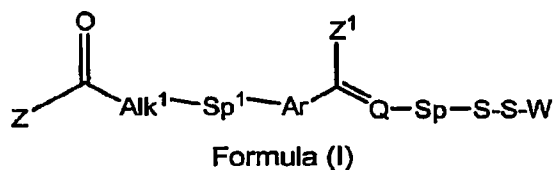
in an alcohol solvent in the presence of an alkyl carboxylic acid, $\text{alk}^2\text{CO}_2\text{H}$ where alk^2 is 1 to 4 carbon atoms at about 20° to 70°C for about 1 to 24 hours, wherein Alk^1 , Sp^1 , Ar , Z^1 , Q , and Sp are as defined above, to produce a bilinker-carboxylic acid of the formula, wherein the mercapto compound and carboxylic acid are present in a ratio of about 1.2:1



- b. isolating the bilinker-carboxylic acid of step (a);
- c. reacting the isolated bilinker-carboxylic acid of step (b) with $\text{CH}_3\text{-S-S-W'}$ in the presence of a base or an organic base with a methyltrithio antitumor antibiotic $\text{CH}_3\text{-S-S-S-W'}$ in an inert organic solvent;
- d. reacting the compound of step (c) with an at least a 3 fold molar excess of N-hydroxysuccinimide, 2,3,5,6-tetrafluorophenol, pentafluorophenol, 4-nitrophenol, 2,4-dinitrophenol, or N-hydroxysulfosuccinimide in the presence of 1,3-dicyclohexylcarbodiimide (DCC), 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide (EDCI), or N,N'-disuccinimdyi carbonate in an inert solvent containing 0-50% N,N-dimethylformamide (DMF) and purifying to yield compounds of Formula (I)

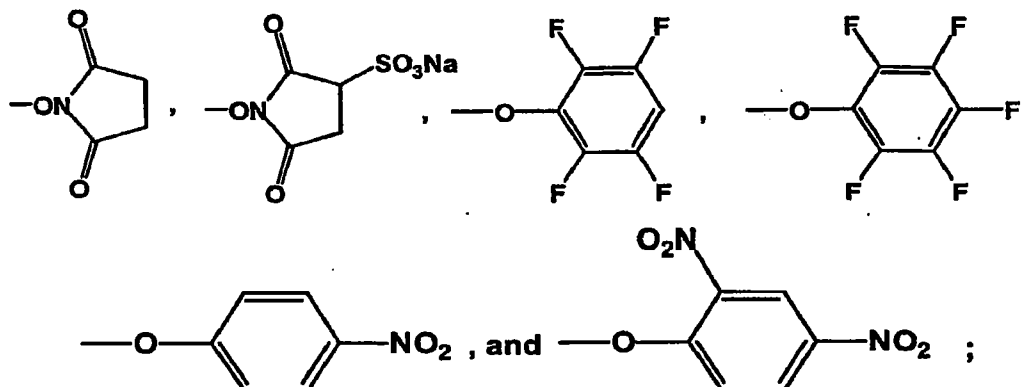


An additional process includes preparation of compounds of Formula (I):



wherein:

Z is selected from the group consisting of



Alk¹ is a branched or unbranched alkylene chain of 2 to 6 carbon atoms;

Sp¹ is selected from -S-, -O-, -CONH-, -NHCO-, and -NR'-;

Z¹ is H, or alkyl of 1 to 5 carbon atoms;

Ar is 1,2-, 1,3-, or 1,4-phenylene optionally substituted with one, two, or three groups independently selected from alkyl of 1 to 6 carbon atoms, alkoxy of 1 to 5 carbon atoms, thioalkoxy of 1 to 4 carbon atoms, halogen, nitro, -COOR', -CONHR', -O(CH₂)_nCOOR', -S(CH₂)_nCOOR', -O(CH₂)_nCONHR', and -S(CH₂)_nCONHR' or a 1,2-, 1,3-, 1,4-, 1,5-, 1,6-, 1,7-, 1,8-, 2,3-, 2,6-, or 2,7-naphthylidene optionally substituted with one, two, three, or four groups independently selected from alkyl of 1 to 6 carbon atoms, alkoxy of 1 to 5 carbon atoms, thioalkoxy of 1 to 4 carbon atoms, halogen, nitro, -COOR', -CONHR', -O(CH₂)_nCOOR', -S(CH₂)_nCOOR', -O(CH₂)_nCONHR', and -S(CH₂)_nCONHR';

n is an integer from 0 to 5;

R' is a straight or branched alkyl of 1 to 5 carbon atoms optionally substituted by one or two groups of -OH, alkoxy of 1 to 4 carbon atoms, thioalkoxy of 1 to 4 carbon atoms;

Sp is a straight or branched-chain divalent or trivalent alkyl radical of 1 to 18 carbon atoms, divalent or trivalent aryl or heteroaryl radical, divalent or trivalent cycloalkyl of 3 to 18 carbon atoms or heterocycloalkyl radical, divalent or trivalent aryl- or heteroaryl-alkyl (C₁-C₁₈) radical, divalent or trivalent cycloalkyl- or heterocyclo-alkyl-

W' is



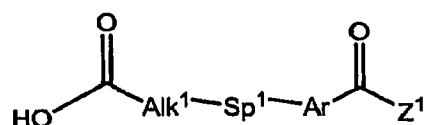
X is an iodine or bromine atom;

R₅' is a hydrogen or the group RCO, wherein R is hydrogen, branched or unbranched alkyl of 1 to 10 carbon atoms, alkylene of 2 to 10 carbon atoms, aryl of 6 to 11 carbon atoms, a (C₆-C₁₁) aryl-alkyl (C₁-C₅) group, or a heteroaryl or heteroaryl-alkyl (C₁-C₅) group wherein heteroaryl is defined as 2- or 3-furyl, 2- or 3-thienyl, 2- or 3-(N-methylpyrrolyl), 2-, 3-, or 4-pyridinyl, 2-, 4-, or 5-(N-methylimidazolyl), 2-, 4-, or 5-oxazolyl, 2-, 3-, 5-, or 6-pyrimidinyl, 2-, 3-, 4-, 5-, 6-, 7-, or 8-quinolyl, or 1-, 3-, 4-, 5-, 6-, 7-, or 8-isoquinolyl, all aryl and heteroaryl groups optionally substituted by one or more hydroxy, amino, carboxy, halo, nitro, (C₁-C₃) alkoxy of 1 to 3 carbon atoms, or thioalkoxy of 1 to 5 carbon atoms; and

Q is selected from the group consisting of -NNHCO-, -NNHCS-, -NNHCONH-, -NNHCSNH-, and -NO-;

comprising the steps of:

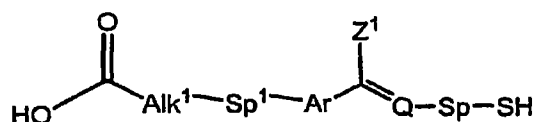
a. reacting a carboxylic acid of the formula



with a mercapto compound of the formula



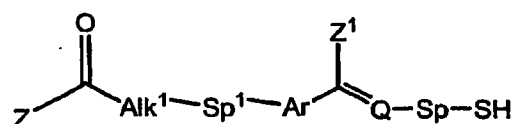
in an alcohol solvent in the presence of an alkyl carboxylic acid, alk²CO₂H where alk² is 1 to 4 carbon atoms at about 20° to 70°C for about 1 to 24 hours, wherein Alk¹, Sp¹, Ar, Z¹, Q, and Sp are as defined above, to produce a bilinker-carboxylic acid of the formula,



b. isolating the bilinker-carboxylic acid of step (a);

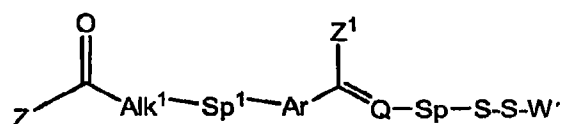
c. reacting the isolated bilinker-carboxylic acid of step (b) with an at least of N-hydroxysuccinimide, 2,3,5,6-tetrafluorophenol, pentafluorophenol, 4-nitrophenol, 2,4-dinitrophenol, or N-hydroxysulfosuccinimide in the presence of 1,3-dicyclohexylcarbodiimide (DCC), 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide

(EDCI), or N,N'-disuccinimdyd carbonate in an inert solvent containing 0-50% N,N-dimethylformamide (DMF) to generate a trilinker-activated ester of the formula

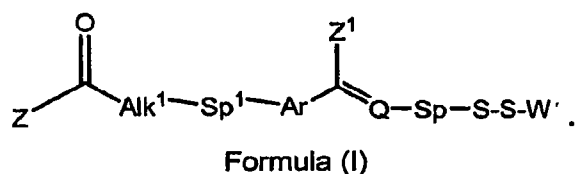


where Z is hereinbefore defined ;

d. reacting the trilinker-activated ester in step c in the presence of a base or an organic base with $\text{CH}_3\text{-S-S-S-W'}$ in an inert organic solvent to generate an activated ester of the formula



e. isolating the activated ester of step (d) and purifying to yield compounds of Formula (I)



The processes include a purifying of step comprising the use of a reverse phase high performance liquid chromatography having a mobile phase of about pH 7.0 to 9.0 followed with a normal phase chromatography.

The processes include:

alk^1 is 3 carbon atoms;

Sp^1 is $-\text{O}-$;

Z^1 is methyl;

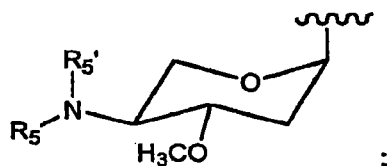
Ar is unsubstituted 1,4-phenylene;

Sp is 4 carbon atoms;

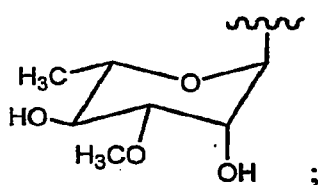
R_3 is H;

Q is NNHC(O)-;

R_2 is



R_4 is

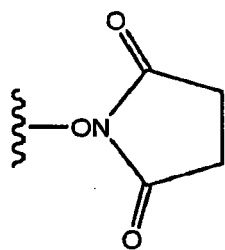


R_5 is C_2H_5 ;

R_5' is $-C(O)-R$;

R is methyl; and

Z is



The processes include but are not limited to Alk^1 is an alkylene of 2 to 5 carbon atoms, and Sp^1 is an oxygen atom.

The processes include but are not limited Alk^1 is an alkylene of 3 carbon atoms.

The processes include but are not limited Z^1 is alkyl of 1 to 3 carbon atoms.

The processes include but are not limited Ar is 1,2-, 1,3-, or 1,4-phenylene, or 1,2-, 1,3-, 1,4-, 1,5-, 1,6-, 1,7-, 1,8-, 2,3-, 2,6-, or 2,7-naphthylidene.

The processes include but are not limited Ar is 1,4-phenylene.

The processes include but are not limited Q is -NNHCO-.

The processes include but are not limited Sp is straight or branched-chain divalent or trivalent alkyl radical of 1 to 12 carbon atoms.

The processes include but are not limited Sp is straight or branched-chain divalent or trivalent alkyl radical of 1 to 6 carbon atoms.

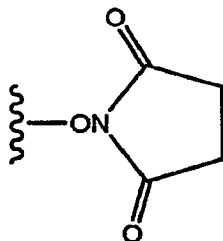
The processes include but are not limited the alcohol solvent is methanol.

The processes include but are not limited the inert solvent is acetonitrile.

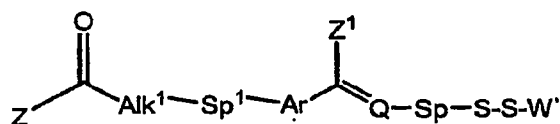
The processes include but are not limited alkyl carboxylic acid is acetic acid.

The processes include but are not limited the inert organic solvent is acetonitrile.

The processes include but are not limited Z is

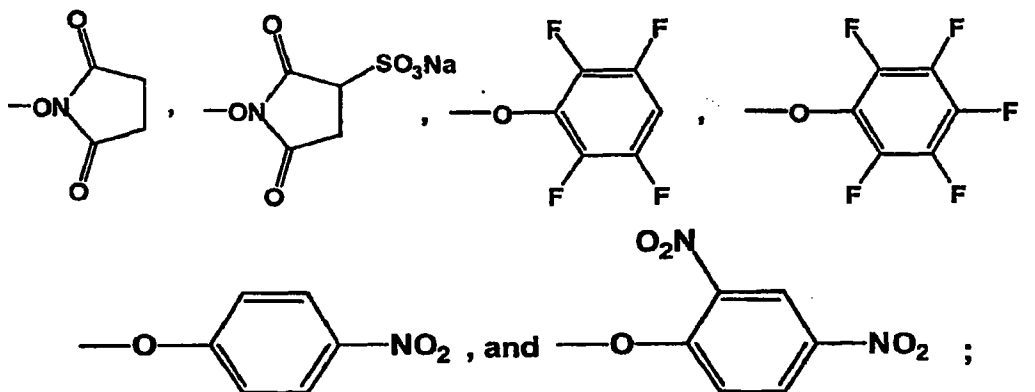


Discussed herein is a process to prepare trilinker-activated esters of the formula:



wherein:

Z is selected from the group consisting of



Alk¹ is a branched or unbranched alkylene chain of 2 to 6 carbon atoms;

Sp¹ is selected from -S-, -O-, -CONH-, -NHCO-, and -NR'-;

Z¹ is H, or alkyl of 1 to 5 carbon atoms;

Ar is 1,2-, 1,3-, or 1,4-phenylene optionally substituted with one, two, or three groups independently selected from alkyl of 1 to 6 carbon atoms, alkoxy of 1 to 5 carbon atoms, thioalkoxy of 1 to 4 carbon atoms, halogen, nitro, -COOR', -CONHR', -O(CH₂)_nCOOR', -S(CH₂)_nCOOR', -O(CH₂)_nCONHR', and -S(CH₂)_nCONHR' or a 1,2-, 1,3-, 1,4-, 1,5-, 1,6-, 1,7-, 1,8-, 2,3-, 2,6-, or 2,7-naphthylidene optionally substituted with one, two, three, or four groups independently selected from alkyl of 1 to 6 carbon atoms, alkoxy of 1 to 5 carbon atoms, thioalkoxy of 1 to 4 carbon atoms, halogen, nitro, -COOR', -CONHR', -O(CH₂)_nCOOR', -S(CH₂)_nCOOR', -O(CH₂)_nCONHR', and -S(CH₂)_nCONHR';

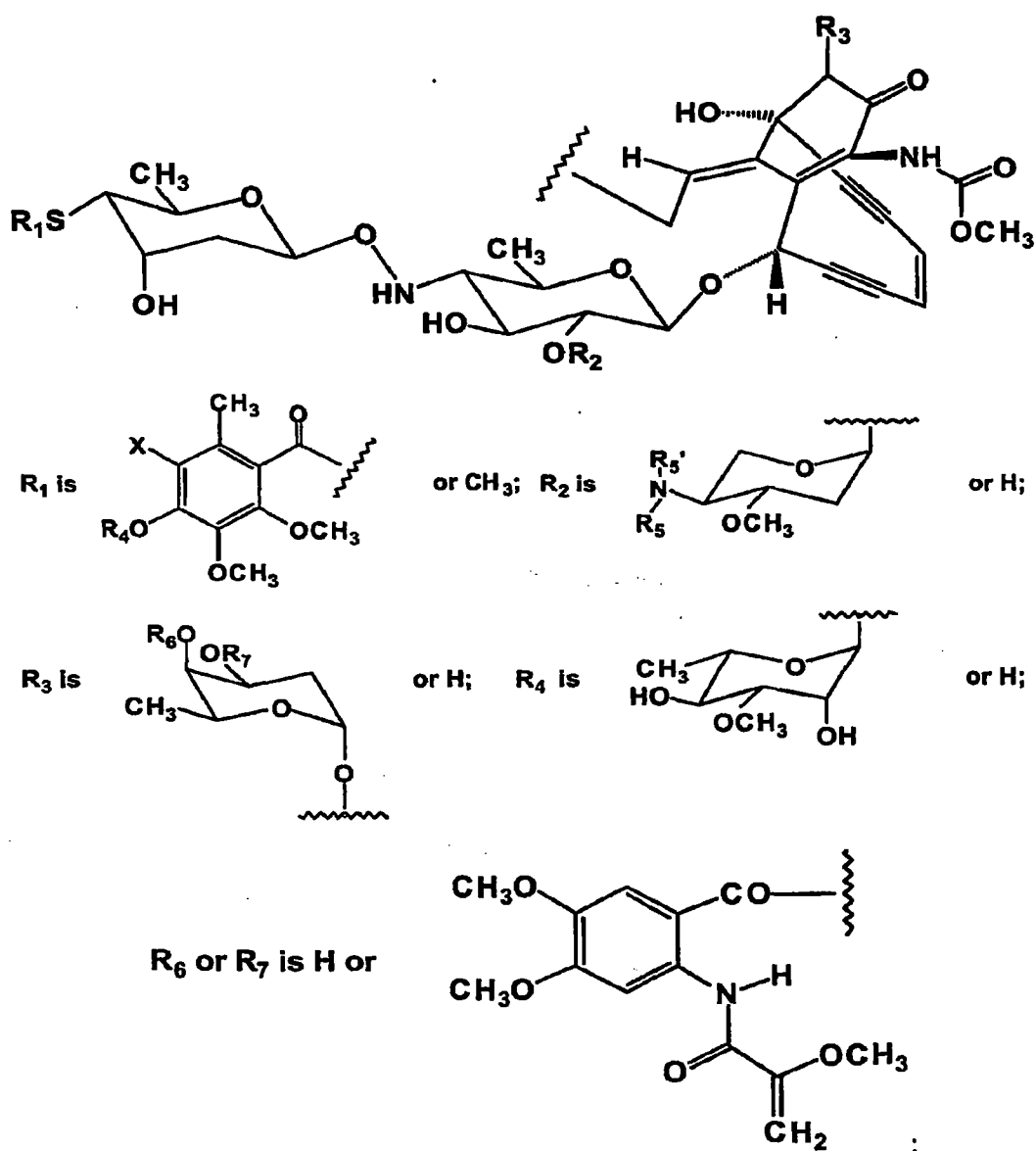
n is an integer from 0 to 5;

R' is a straight or branched alkyl of 1 to 5 carbon atoms optionally substituted by one or two groups of -OH, alkoxy of 1 to 4 carbon atoms, thioalkoxy of 1 to 4 carbon atoms;

Sp is a straight or branched-chain divalent or trivalent alkyl radical of 1 to 18 carbon atoms, divalent or trivalent aryl or heteroaryl radical, divalent or trivalent cycloalkyl of 3 to 18 carbon atoms or heterocycloalkyl radical, divalent or trivalent aryl- or heteroaryl-alkyl (C₁-C₁₈) radical, divalent or trivalent cycloalkyl- or heterocyclo-alkyl-alkyl (C₁-C₁₈) radical or divalent or trivalent unsaturated alkyl radical of 2 to 18

carbon atoms, wherein heteroaryl is furyl, thienyl, N-methylpyrrolyl, pyridinyl, N-methylimidazolyl, oxazolyl, pyrimidinyl, quinolyl, isoquinolyl, N-methylcarbazoyl, aminocoumarinyl, or phenazinyl and wherein if Sp is a trivalent radical, it can be additionally substituted by dialkylamino of 1 to 5 carbon atoms, alkoxy of 1 to 5 carbon atoms, hydroxy, or alkylthio of 1 to 5 carbon atoms groups;

W' is



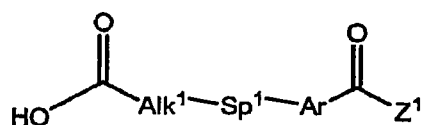
R_5 is $-CH_3$, $-C_2H_5$, or $-CH(CH_3)_2$;

X is an iodine or bromine atom;

R₅' is a hydrogen or the group RCO, wherein R is hydrogen, branched or unbranched alkyl of 1 to 10 carbon atoms, alkylene of 2 to 10 carbon atoms, aryl of 6 to 11 carbon atoms, a (C₆-C₁₁) aryl-alkyl (C₁-C₅) group, or a heteroaryl or heteroaryl-alkyl (C₁-C₅) group wherein heteroaryl is defined as 2- or 3-furyl, 2- or 3-thienyl, 2- or 3-(N-methylpyrrolyl), 2-, 3-, or 4-pyridinyl, 2-, 4-, or 5-(N-methylimidazolyl), 2-, 4-, or 5-oxazolyl, 2-, 3-, 5-, or 6-pyrimidinyl, 2-, 3-, 4-, 5-, 6-, 7-, or 8-quinolyl, or 1-, 3-, 4-, 5-, 6-, 7-, or 8-isoquinolyl, all aryl and heteroaryl groups optionally substituted by one or more hydroxy, amino, carboxy, halo, nitro, (C₁-C₃) alkoxy of 1 to 3 carbon atoms, or thioalkoxy of 1 to 5 carbon atoms; and Q is selected from the group consisting of -NNHCO-, -NNHCS-, -NHNCONH-, -NNCSNH-, and -NO-;

comprising the steps of:

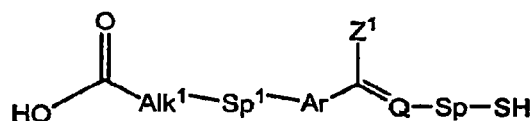
a. reacting a carboxylic acid of the formula



with a mercapto compound of the formula

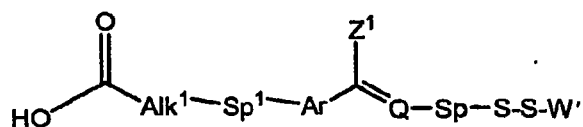


in an alcohol solvent in the presence of an alkyl carboxylic acid, $\text{alk}^2\text{CO}_2\text{H}$ where alk^2 is 1 to 4 carbon atoms at about 20° to 70°C for about 1 to 24 hours, wherein Alk¹, Sp¹, Ar, Z¹, Q, and Sp are as defined above, to produce a bilinker-carboxylic acid of the formula

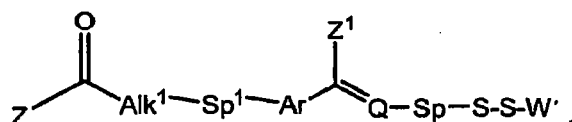


b. isolating the bilinker-carboxylic acid of step (a);

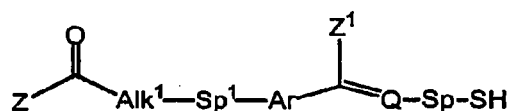
c. reacting the bilinker-carboxylic acid from step (b) in the presence of a base or an organic base with CH₃-S-S-S-W' in an inert organic solvent to generate a bilinker-methyltrithio compound of the formula



d. reacting the isolated bilinker-methyltrithio compound of step (c) with N-hydroxysuccinimide, 2,3,5,6-tetrafluorophenol, pentafluorophenol, 4-nitrophenol, 2,4-dinitrophenol, or N-hydroxysulfosuccinimide in the presence of 1,3-dicyclohexylcarbodiimide (DCC), 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide (EDCI), or N,N'-disuccinimdyi carbonate in an inert solvent containing 0-50% N,N-dimethylformamide (DMF) to generate a trilinker-activated ester of the formula



Presented herein is a process for the preparation of trifunctional linker intermediates, of the formula



wherein:

Alk^1 is a branched or unbranched alkylene chain of 2 to 6 carbon atoms;

Sp^1 is selected from -S-, -O-, -CONH-, -NHCO-, and -NR'-;

Z^1 is H, or alkyl of 1 to 5 carbon atoms;

Ar is 1,2-, 1,3-, or 1,4-phenylene optionally substituted with one, two, or three groups independently selected from alkyl of 1 to 6 carbon atoms, alkoxy of 1 to 5 carbon atoms, thioalkoxy of 1 to 4 carbon atoms, halogen, nitro, -COOR', -CONHR', -O(CH₂)_nCOOR', -S(CH₂)_nCOOR', -O(CH₂)_nCONHR', and -S(CH₂)_nCONHR' or a

1,2-, 1,3-, 1,4-, 1,5-, 1,6-, 1,7-, 1,8-, 2,3-, 2,6-, or 2,7-naphthylidene optionally substituted with one, two, three, or four groups independently selected from alkyl of 1 to 6 carbon atoms, alkoxy of 1 to 5 carbon atoms, thioalkoxy of 1 to 4 carbon atoms, halogen, nitro, -COOR', -CONHR', -O(CH₂)_nCOOR', -S(CH₂)_nCOOR', -O(CH₂)_nCONHR', and -S(CH₂)_nCONHR';

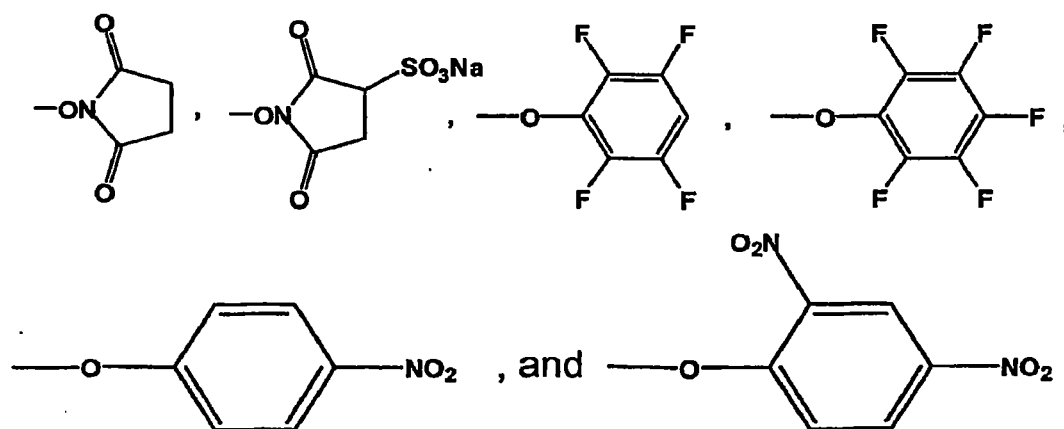
n is an integer from 0 to 5;

R' is a straight or branched alkyl of 1 to 5 carbon atoms optionally substituted by one or two groups of -OH, alkoxy of 1 to 4 carbon atoms, thioalkoxy of 1 to 4 carbon atoms;

Sp is a straight or branched-chain divalent or trivalent alkyl radical of 1 to 18 carbon atoms, divalent or trivalent aryl or heteroaryl radical, divalent or trivalent cycloalkyl of 3 to 18 carbon atoms or heterocycloalkyl radical, divalent or trivalent aryl- or heteroaryl-alkyl (C₁-C₁₈) radical, divalent or trivalent cycloalkyl- or heterocyclo-alkyl-alkyl (C₁-C₁₈) radical or divalent or trivalent unsaturated alkyl radical of 2 to 18 carbon atoms, wherein heteroaryl is furyl, thienyl, N-methylpyrrolyl, pyridinyl, N-methylimidazolyl, oxazolyl, pyrimidinyl, quinolyl, isoquinolyl, N-methylcarbazoyl, aminocoumarinyl, or phenazinyl and wherein if Sp is a trivalent radical, it can be additionally substituted by dialkylamino of 1 to 5 carbon atoms, alkoxy of 1 to 5 carbon atoms, hydroxy, or alkylthio of 1 to 5 carbon atoms groups;

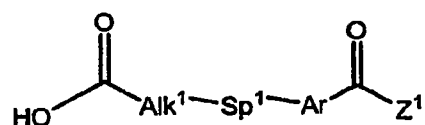
Q is selected from the group consisting of -NNHCO-, -NNHCS-, and -NNHCONH-;

Z is selected from the group consisting of



comprising the steps of:

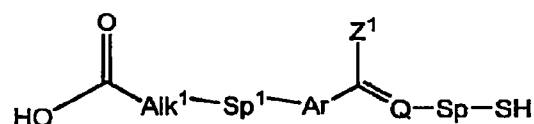
a. reacting a carboxylic acid of the formula



with a mercapto compound of the formula



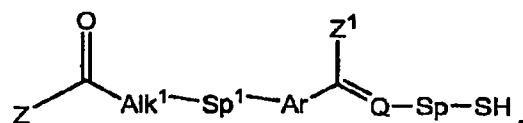
in an alcohol solvent in the presence of an alkyl carboxylic acid, $\text{alk}^2\text{CO}_2\text{H}$, where alk^2 is 1 to 4 carbon atoms at about 20° to 70°C for about 1 to 24 hours, wherein Alk^1 , Sp^1 , Ar , Z^1 , Q , and Sp are as defined above, to produce a bilinker-carboxylic acid of the formula



b. isolating the bilinker-carboxylic acid of step (a);

c. reacting the isolated bilinker-carboxylic acid of step (b) with

N-hydroxysuccinimide, 2,3,5,6-tetrafluorophenol, pentafluorophenol, 4-nitrophenol, 2,4-dinitrophenol, or N-hydroxysulfosuccinimide in the presence of 1,3-dicyclohexylcarbodiimide (DCC), 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide (EDCI), or N,N'-disuccinimdyd carbonate in an inert solvent containing 0-50% DMF to generate trifunctional linker intermediates, of the formula



The terms used in this specification generally have their ordinary meanings in the art, within the context of the invention, and in the specific context where each term is used. Certain terms are discussed below, or elsewhere in the specification, to provide additional guidance to the practitioner in describing the compounds, compositions, and methods of the invention and how to make and use them. Moreover, it will be appreciated that the same thing can be said in more than one way. Consequently, alternative language and synonyms may be used for any one or more of the terms discussed herein, nor is any special significance to be placed upon

whether or not a term is elaborated or discussed herein. The use of examples anywhere in this specification, including examples of any terms discussed herein, is illustrative only, and in no way limits the scope and meaning of the invention or of any exemplified term. Likewise, the invention is not limited to the examples presented.

The terms, "*about*" or "*approximately*" shall generally mean within 20 percent, preferably within 10 percent, and more preferably within 5 percent of a given value or range.

The term "alkoxy" as used herein refers to an alkyl group, as defined above, having an oxygen radical attached thereto. The term "thioalkoxy" refers to an alkoxy group as defined, having a sulfur radical attached thereto.

The term "alkyl" refers to the radical of saturated aliphatic groups, including straight-chain alkyl groups, branched-chain alkyl groups, cycloalkyl (alicyclic) groups, alkyl substituted cycloalkyl groups, and cycloalkyl substituted alkyl groups. In an embodiment, a straight chain or branched chain alkyl has 6 or fewer carbon atoms in its backbone. The term "alkyl" can be used alone or as part of a chemical name. The term "aryl" is defined as an aromatic carbocyclic moiety and may be substituted or unsubstituted. Aryl groups have 6 to 14 carbon atoms and include phenyl and naphthyl. The term "aryl" also includes polycyclic ring systems having two or more rings in which two or more carbons are common to two adjoining rings (the rings are "fused") wherein at least one of the carbocyclic rings is aromatic, *e.g.*, the other rings can be cycloalkyls, cycloalkenyls, cycloalkynyls, and/or aryls.

Carboxy is defined as a $\text{-CO}_2\text{H}$ radical.

The term "halogen" or "halo" refers to an atom of fluorine, chlorine, bromine, or iodine.

The term "heteroaryl" refers to a 4 to 10 membered ring structure, which ring structure includes one to four heteroatoms. A heteroaryl comprises a heterocyclic ring system of one to three fused rings, in which at least one ring may have an aromatic character and contains 1 to 4 heteroatoms the same or different selected from the group consisting of S, N, and O. The remaining rings of the ring system may be fully unsaturated, partially saturated, or fully saturated. Each ring comprises three to ten members. The term "heteroatom" as used herein means an atom of any

element other than carbon or hydrogen and include for example nitrogen, oxygen, sulfur, phosphorus, and selenium.

The term "nitro" means -NO_2 .

The term "substituted" is contemplated to include all permissible substituents of organic compounds. In a broad aspect, the permissible substituents of organic compounds include acyclic and cyclic, branched and unbranched, carbocyclic and heterocyclic, aromatic and nonaromatic substituents of organic compounds. The permissible substituents can be one or more and the same or different for appropriate organic compounds. For purposes of this invention, the heteroatoms such as nitrogen may have hydrogen substituents and/or any permissible substituents of organic compounds described herein which satisfy the valencies of the heteroatoms. This invention is not intended to be limited in any manner by the permissible substituents of organic compounds.

The term alkyl means a straight or branched alkyl of 1 to 18 carbon atoms, preferably 2 to 5 carbon atoms, 1 to 4 carbon atoms or 1 to 3 carbon atoms. In some embodiments of the invention the term alkyl is methyl.

The term alcohol solvent means methanol, ethanol and the like with a boiling point of less than about 100°C .

Alkylene refers to an alkyl, as defined above, which is a diradical, rather than a radical. An alkylene can be branched or unbranched and can have 2-18 carbons.

Ambient temperature is about 25°C .

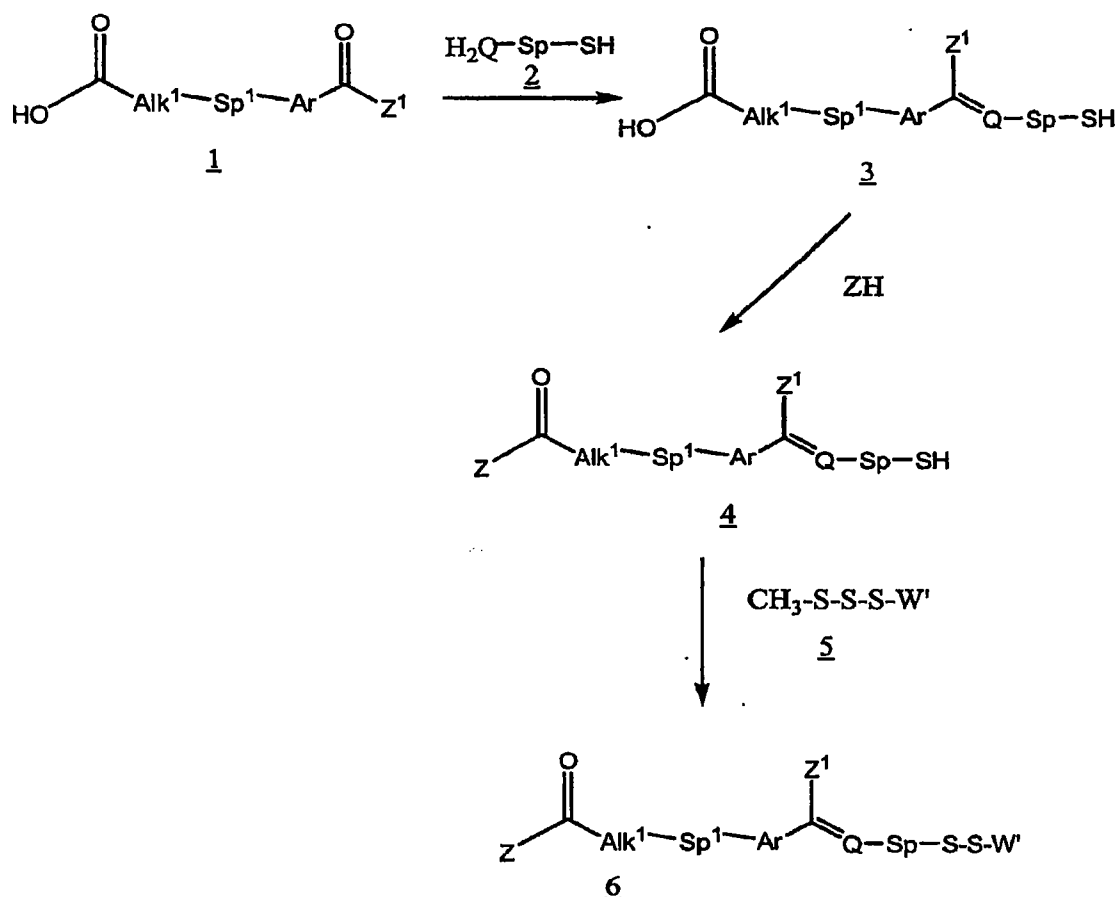
Inert solvent or inert organic solvent describes a solvent that will neither react or form a covalent bond in the steps to prepare compounds of Formula (I), trilinear-activated esters or trifunctional linker intermediates as described herein. An example of an inert solvent or inert organic solvent may be mixtures such as but not limited to acetonitrile/ethylacetate (1:1), dichloromethane, N,N-dimethylformamide, tetrahydrofuran, dioxane or acetonitrile. An inert solvent may contain 0-50% N,N-dimethylformamide. An inert organic solvent is for example acetonitrile, ethyl acetate or dichloromethane.

An organic base is for example an alkylamine base which includes triethylamine, N,N-diethylmethylaniline, N,N-diethylaniline, N,N-diethylethylenediamine, N,N-diisopropylethylamine, tributylamine or tripropylamine and further include dimethylaminopyridine(DMAP) with diisopropylethylamine (DIEA), N-methylmorpholine, N-methylpyrrolidine, 2,6-di-tertbutyl-4-methylpyridine or pyridine. A base is an alkali metal hydroxide, alkali metal carbonate or alkali metal bicarbonate.

DETAILED DESCRIPTION OF THE INVENTION

The process for the preparation of calicheamicin derivatives of Formula I and tri and bifunctional linker intermediates useful in the preparation of said derivatives of the present invention are described in the following reaction Schemes I and II.

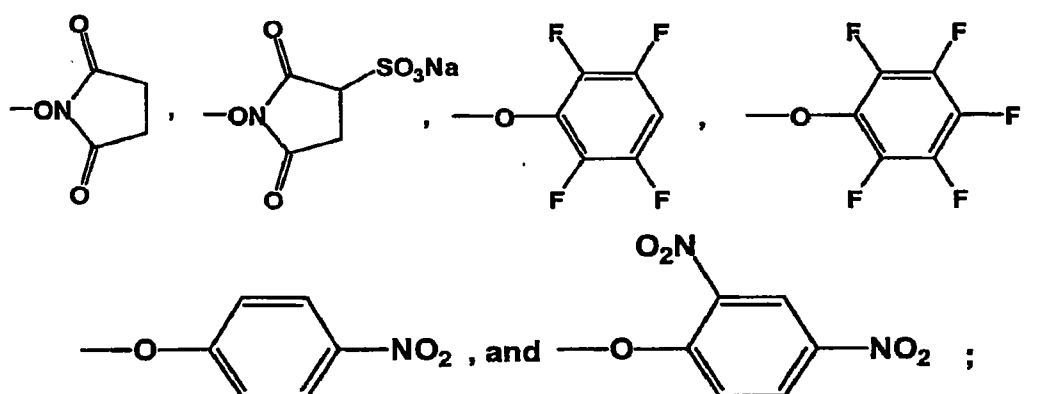
SCHEME I



In accordance with Scheme I, a carboxylic acid **1** wherein Alk^1 , Sp^1 , Ar and Z^1 are hereinbefore defined, found in U.S. Pat.No. 5,773,001, which is hereby

incorporated herein by reference, are condensed with mercapto compound 2 where Sp and Q are hereinbefore defined in an alcoholic solvent with a boiling point of less than about 100° C in the presence of an alkyl carboxylic acid in a about 5% acetic acid at about 20° to about 70° C for about 1 to about 24 hours, to afford bilinker-carboxylic acid 3 wherein Alk¹, Sp¹, Ar, Q, Sp and Z¹ are as defined above.

Bilinker-carboxylic acid 3 is reacted with N-hydroxysuccinimide, 2,3,5,6-tetrafluorophenol, pentafluorophenol, 4-nitrophenol, 2,4-dinitrophenol, or N-hydroxysulfosuccinimide in the presence of 1,3-dicyclohexylcarbodiimide (DCC), 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide (EDCI), or other carbodiimide or N,N'-disuccinimidyl carbonate in an inert solvent such as dichloromethane, tetrahydrofuran, dioxane, or acetonitrile containing 0-50% DMF or DMF to generate trilinker-activated ester 4 where Z is selected from the group consisting of



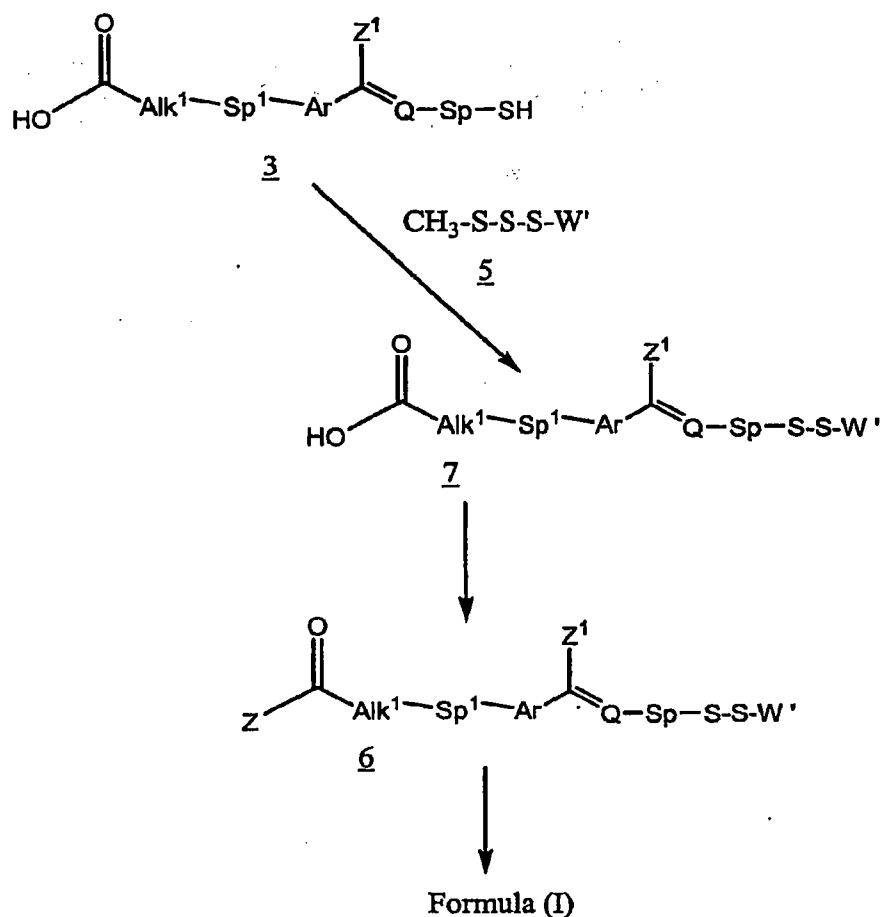
For example, reaction of bilinker-carboxylic acid 3 with a coupling agent, such as 1,3-dicyclohexylcarbodiimide(DCC) or 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride, and N-hydroxysuccinimide or other comparable carboxyl-activating group in an inert solvent, such as N,N-dimethylformamide (DMF), tetrahydrofuran, dioxane or acetonitrile, leads to the formation of a trilinker-activated ester 4, such as the N-hydroxysuccinimide ester described herein. Preferred is N-hydroxysuccinimide, DCC at ambient temperature in dioxane. A preferred solvent mixture is acetonitrile containing 0-50% DMF. Reaction of the bilinker-carboxylic acid 3 with N-hydroxysuccinimide, 2,3,5,6-tetrafluorophenol, pentafluorophenol, 4-nitrophenol, 2,4-dinitrophenol, or N-hydroxysulfosuccinimide in the presence of 1,3-dicyclohexylcarbodiimide (DCC), 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide (EDCI), or other carbodiimide in an inert solvent such as dioxane or acetonitrile

containing 0-50% N,N-dimethylformamide (DMF) leads to the formation of a trilinear-activated ester 4. The trilinear-activated ester 4 can be isolated by removal of the volatile solvents and further purified by reverse or normal phase chromatography on an inert support which includes silica-60.

Trilinear-activated ester 4 is first reacted with an alkali metal carbonate which includes but is not limited to sodium carbonate and forms the sodium salt of trilinear-activated ester 4 in acetonitrile by heating at gentle reflux. Further reaction of the sodium salt of trilinear-activated ester 4 with methyltrithioantitumor antibiotic 5 at about -15°C in an inert organic solvent, preferably acetonitrile gives activated ester 6 wherein Z, Alk¹, Sp¹, Ar, Z¹, Q, Sp and W' are hereinbefore defined. In particular, N-acetyl-LL-E33288 γ_1 is the preferred methyltrithioantitumor antibiotic 5. Preferred is the reaction in acetonitrile at about 0°C. Optionally an organic base may replace the alkali metal carbonate which preferably includes triethylamine, in acetonitrile at about 0°C.

As further described in Scheme II, reaction of bilinear-carboxylic 3 prepared by condensation of carboxylic acid 1 wherein Alk¹, Sp¹, Ar and Z¹ are hereinbefore defined, with mercapto compound 2 according to scheme I, is reacted with methyltrithioantitumor antibiotic 5 in the presence of triethylamine in N,N-dimethylformamide (DMF) at about -5°C affords intermediate 7 which is further converted to trilinear-activated ester 6 by reaction with N-hydroxysuccinimide, 2,3,5,6-tetrafluorophenol, pentafluorophenol, 4-nitrophenol, 2,4-dinitrophenol, or N-hydroxysulfosuccinimide in the presence of 1,3-dicyclohexylcarbodiimide (DCC), 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide (EDCI), or other carbodiimide or N,N'-disuccinimidyl carbonate in an inert solvent mixture of DMF and acetonitrile which is then purified preferably by chromatography to afford antitumor antibiotics of Formula (I).

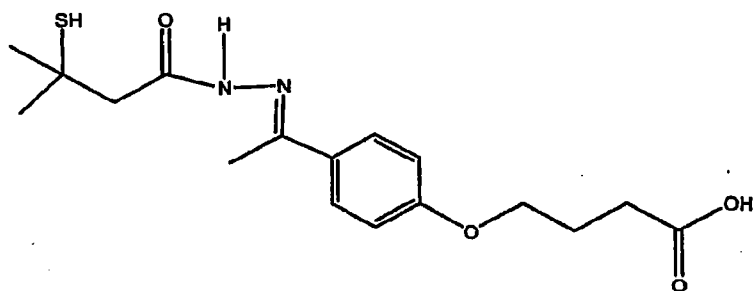
SCHEME II



The following examples are presented to illustrate certain embodiments of the present invention, but should not be construed as limiting the scope of this invention. Those skilled in the art will readily understand that known variations of the conditions of the following preparative procedures can be used to prepare these compounds.

Example 1

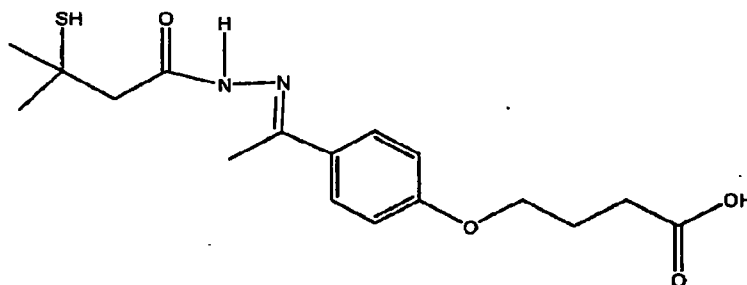
Butanoic acid, 3-mercapto-3-methyl-2-[(E)-1-[4-(4-hydroxy-4-oxobutoxy)phenyl]ethylidene]hydrazide



To a stirred mixture of 0.5 g [3.4 mmol] of 3-methyl-3-mercapto-butanoic acid hydrazide in 5.0 ml of methanol is rapidly added 0.91 g [4.1 mmol] of 4-(4-acetylphenoxy)-butanoic acid followed by an additional 10 ml of methanol and 1.5 ml of acetic acid and stirring continued for 24 hours. The reaction mixture is filtered and the solid washed with 100 ml of methanol to give 0.78 g of the title compound as a solid.

Example 2

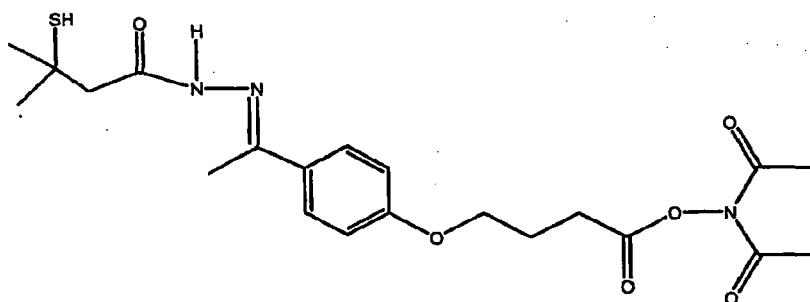
Butanoic acid, 3-mercapto-3-methyl-,2-[(E)-1-[4-(4-hydroxy-4-oxobutoxy)phenyl]ethylidene]hydrazide



A mixture of 3-methyl-3-mercapto-butanoic acid hydrazide (4.0 g, 27 mmol), 4-(4-acetylphenoxy)-butanoic acid (5.0 g, 22.5 mmol) and acetic acid (7.5 mL) in methyl alcohol (75 mL) is heated at about 45 °C for about 7 h. The mixture is allowed to cool to room temperature. The white solid (7.12 g, 90%) is collected on a Buchner funnel and washed with MeOH (2x10 mL). ¹H NMR (DMSO-d₆): δ (ppm) 12.14 (s, 1H), 10.37 and 10.21 (s, 1H), 7.74-7.70 (m, 2H), 6.97-6.95 (m, 2H), 4.04 (t, 2H), 3.09 and 3.04 (s, 2H), 2.66 (s, 1H), 2.41-2.37 (t, 2H), 2.22 and 2.20 (s, 3H), 1.97-1.93 (m, 2H), 1.8 (s, 3H), 1.47 (s, 3H). MS: 375 (M⁺ + Na).

Example 3

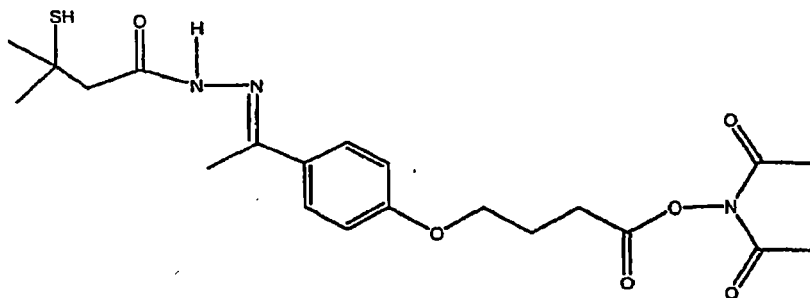
Butanoic acid, 3-mercapto-3-methyl-, 2-[(E)-1-[4-[4-[(2,5-dioxo-1-pyrrolidinyl)oxy]-4-oxobutoxy]phenyl]ethylidene]hydrazide



To a mixture of 0.5 g [1.42 mmol] of butanoic acid, 3-mercapto-3-methyl-, 2-[(E)-1-[4-(4-hydroxy-4-oxobutoxy) phenyl]ethylidene]hydrazide (Example 1 or 2) and 0.22 g [1.89 mmol] of N-hydroxysuccinimide is added 10 ml of N,N-dimethylformamide followed by the rapid addition of 0.70 g [3.65 mmol] of 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride and the mixture stirred at room temperature for 3 hours. The reaction mixture is concentrated in vacuo to a residue which is partitioned between ethyl acetate and water. The separated organic layer is washed with water, saturated sodium chloride and dried (MgSO₄). The organic layer is evaporated in vacuo to give an oily residue which crystallized from ethyl acetate-hexane affording 0.21 g of the title compound as a colorless solid.

Example 4

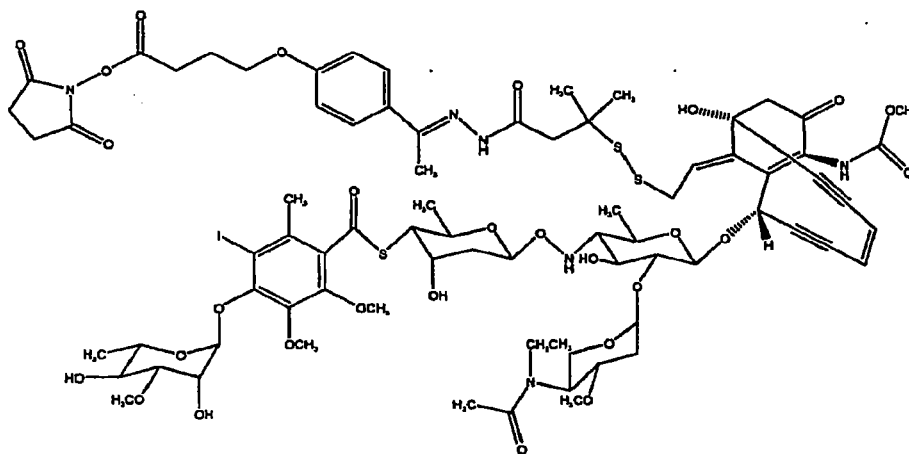
Butanoic acid, 3-mercapto-3-methyl-, 2-[(E)-1-[4-[4-[(2,5-dioxo-1-pyrrolidinyl)oxy]-4-oxobutoxy]phenyl]ethylidene]hydrazide



A mixture of butanoic acid, 3-mercapto-3-methyl-2-[(E)-1-[4-(4-hydroxy-4-oxobutoxy)phenyl]ethylidene]hydrazide (Examples 1 or 2) (3.69 g, 10.48 mmol) and N-hydroxysuccinimide (1.386 g, 12.05 mmol) is suspended in dioxane (60 mL), DCC (2.482 g, 12.05 mmol) in dioxane (30 mL) is added dropwise over 15 min. The mixture is stirred at room temperature for 24 h. The precipitated dicyclohexylurea is filtered off and washed with dioxane (2X10 mL). The filtrate is concentrated to about 50 mL and while stirring, water (250 mL) is added. The resulting white solid is collected on a Buchner funnel, washed with water (2X50 mL), and dried in vacuo at room temperature. To this white solid is added MeCN (60 mL) and the mixture is heated at 50 °C until it became solution, isopropyl alcohol (IPA) (400 mL) is added. The mixture is then cooled to 0-5 °C for 2 h. The solid is collected on a Buchner funnel, washed with cold IPA (2x20 mL) and dried in vacuo to afford the product of the example as a white solid (3.58 g, 70%). MS: 450 ($M^+ + 1$).

Example 5

Butanoic acid, 3-mercapto-3-methyl-2-[(E)-1-[4-[4-[(2,5-dioxo-1-pyrrolidinyl)oxy]-4-oxobutoxy]phenyl]ethylidene]hydrazide condensed with N-acetyl-LL-E33288 γ_1

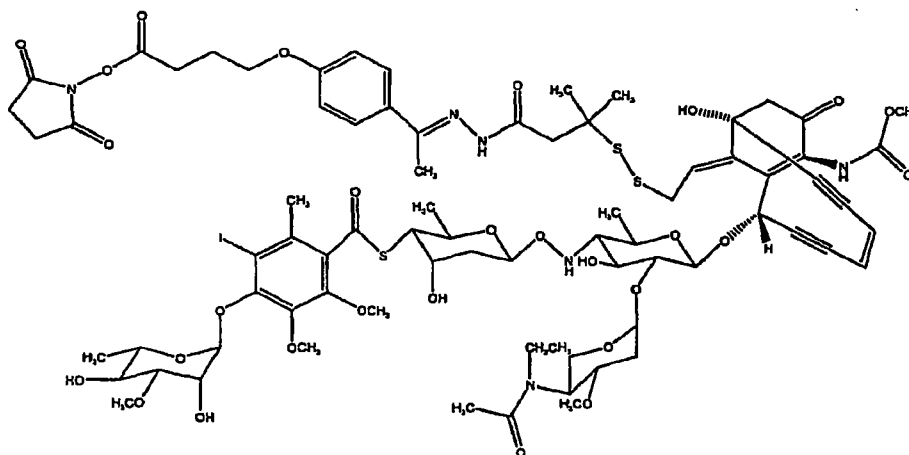


To a stirred solution of 0.505 g [1.12 mmol] butanoic acid, 3-mercapto-3-methyl-2-[(E)-1-[4-[4-[(2,5-dioxo-1-pyrrolidinyl)oxy]-4-oxobutoxy]phenyl]ethylidene]hydrazide (Example 4) in 50 ml of acetonitrile is added 0.123 g [1.16 mmol] of sodium carbonate followed by heating at gentle reflux for 1 hour, cooled to room temperature and filtered. The filtrate is cooled to -15°C and a solution of 1.4969 g [1.1 mmol] of N-acetyl-LL-E33288 γ_1 in 5 ml of acetonitrile added slowly by dropwise addition over 20 minutes and stirring continued for about 1.5

hours. The reaction mixture is allowed to warm to room temperature and stirred for about 3 hours. The volatiles are evaporated in vacuo to a residue which is stored in a freezer. To the residue is added 25 ml of ethyl acetate followed by storage in a freezer for about 1 hour. The reaction mixture is filtered and the ethyl acetate evaporated to a residue which is dissolved in 10 ml of ethyl acetate and applied to a column of 110 g of silica gel. The column is eluted with 1-5% methyl alcohol in ethyl acetate to give 0.322 g of the desired product having 65.27% purity as determined by HPLC.

Example 6

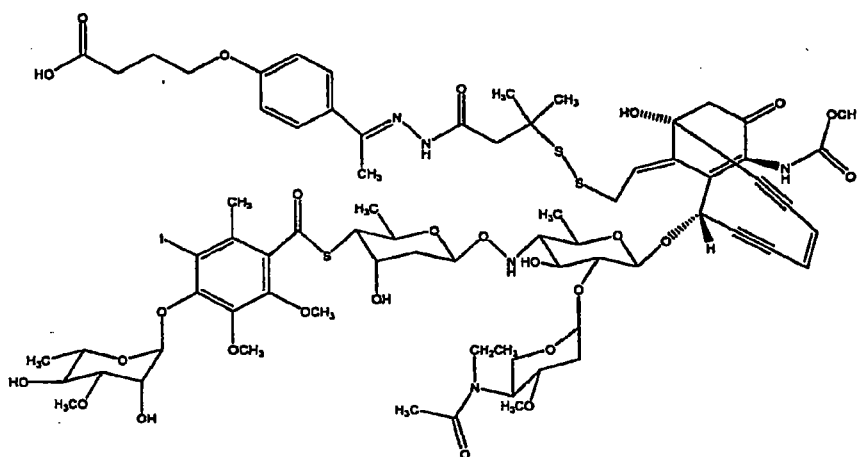
Butanoic acid, 3-mercapto-3-methyl-,2-[(E)-1-[4-[4-[(2,5-dioxo-1-pyrrolidinyl)oxy]-4-oxobutoxy]phenyl]ethylidene]hydrazide condensed with N-acetyl-LL-E33288 γ_1 ¹



A solution of butanoic acid, 3-mercapto-3-methyl-,2-[(E)-1-[4-[4-[(2,5-dioxo-1-pyrrolidinyl)oxy]-4-oxobutoxy]phenyl]ethylidene]hydrazide(450 mg, 1 mmol) (Example 4) in CH₃CN (100 mL) containing Et₃N (0.35 mL) is treated with a solution of N-acetyl-LL-E33288 γ_1 ¹ (500 mg, 0.355 mmol) in CH₃CN (100 mL) at 0-5 °C. The mixture is then stirred for another 1 h while cooling with a ice-bath. The solvent is removed and the residue is purified on a silica gel column eluting with CH₂Cl₂-MeOH to afford the product of the example (340 mg, 54%) as a white solid. MS: 1780 (M⁺ + 1)

Example 7

Butanoic acid, 3-mercapto-3-methyl-,2[(E)-1-[4-(4-hydroxy-4-oxobutoxy)phenyl]ethylidene]hydrazide condensed with N-acetyl-LL-E33288 γ_1 ¹



To a stirring solution of N-acetyl-LL-E33288 γ_1 ¹ (200 mg, 0.142 mmol) in 10 ml acetonitrile/ethyl acetate (1:1) at -5°C is added in 1 ml aliquots every 10 min a solution of butanoic acid, 3-mercapto-3-methyl-,2-[(E)-1-[4-(4-hydroxy-4-oxobutoxy)phenyl]ethylidene]hydrazide (150 mg, 0.43 mmol) (Examples 1 or 2) in 10 ml acetonitrile/ethyl acetate (1:1) and 0.06 ml triethyl amine. The solution is stirred for two hours at -5°C after the last addition of the butanoic acid, 3-mercapto-3-methyl-,2-[(E)-1-[4-(4-hydroxy-4-oxobutoxy)phenyl]ethylidene]hydrazide solution. The solvent was removed under reduced pressure and the residue is purified on a silica gel column eluting with CH₂Cl₂-MeOH to afford the product of the example as a white solid. MS 1684 (M⁺ +1)

Example 8

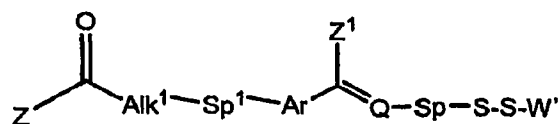
Butanoic acid, 3-mercapto-3-methyl-,2-[(E)-1-[4-[4-[(2,5-dioxo-1-pyrrolidinyl)oxy]-4-oxobutoxy]phenyl]ethylidene]hydrazide condensed with N-acetyl-LL-E33288 γ_1 ¹

To a stirring solution of butanoic acid, 3-mercapto-3-methyl-,2[(E)-1-[4-(4-hydroxy-4-oxobutoxy)phenyl]ethylidene]hydrazide with N-acetyl-LL-E33288 γ_1 ¹ (100mg, 0.059mmol) in 0.5 mL of DMF and 1.8 mL of acetonitrile at 25°C is added N-hydroxysuccinimide (236mg, 2.05mmol) and 1-(3-dimethylaminopropyl)-3-ethyl-

carbodiimide (160mg 0.835mmol). Following the addition, the solution is stirred for one hour at 25°C. The acetonitrile is removed under reduced pressure and the resulting DMF solution is added to 3 mL of stirring water giving a precipitate. The precipitate is filtered, dried and purified on a silica gel column eluting with CH₂Cl₂-isopropyl alcohol giving the product of the example (53mg, 50%) obtained as a white solid. MS: 1780 (M⁺ + 1)

What is claimed is:

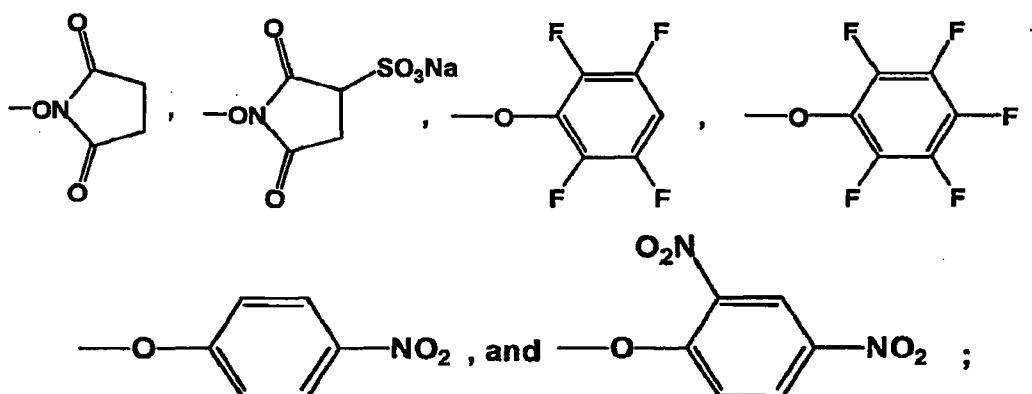
1. A process to prepare compounds of Formula (I):



Formula (I)

wherein:

Z is selected from the group consisting of



Alk^1 is a branched or unbranched alkylene chain of 2 to 6 carbon atoms;

Sp^1 is selected from —S— , —O— , —CONH— , —NHCO— , and —NR'— ;

Z^1 is H, or alkyl of 1 to 5 carbon atoms;

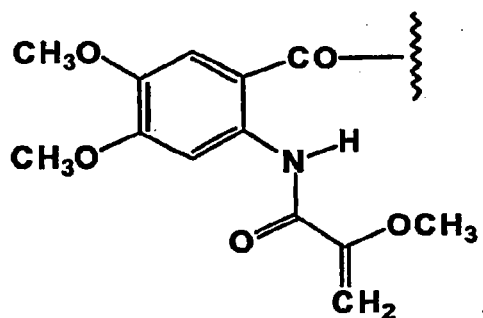
Ar is 1,2-, 1,3-, or 1,4-phenylene optionally substituted with one, two, or three groups independently selected from alkyl of 1 to 6 carbon atoms, alkoxy of 1 to 5 carbon atoms, thioalkoxy of 1 to 4 carbon atoms, halogen, nitro, —COOR' , —CONHR' , $\text{—O(CH}_2)_n\text{COOR'}$, $\text{—S(CH}_2)_n\text{COOR'}$, $\text{—O(CH}_2)_n\text{CONHR'}$, and $\text{—S(CH}_2)_n\text{CONHR'}$ or a 1,2-, 1,3-, 1,4-, 1,5-, 1,6-, 1,7-, 1,8-, 2,3-, 2,6-, or 2,7-naphthylidene optionally substituted with one, two, three, or four groups independently selected from alkyl of 1 to 6 carbon atoms, alkoxy of 1 to 5 carbon atoms, thioalkoxy of 1 to 4 carbon atoms, halogen, nitro, —COOR' , —CONHR' , $\text{—O(CH}_2)_n\text{COOR'}$, $\text{—S(CH}_2)_n\text{COOR'}$, $\text{—O(CH}_2)_n\text{CONHR'}$, and $\text{—S(CH}_2)_n\text{CONHR'}$;

n is an integer from 0 to 5;

W' is



R_6 or R_7 is H or



R_5 is $-CH_3$, $-C_2H_5$, or $-CH(CH_3)_2$;

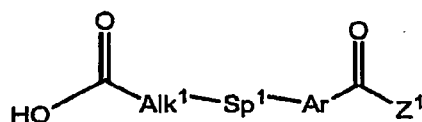
X is an iodine or bromine atom;

R_5' is a hydrogen or the group RCO, wherein R is hydrogen, branched or unbranched alkyl of 1 to 10 carbon atoms, alkylene of 2 to 10 carbon atoms, aryl of 6 to 11 carbon atoms, a (C₆-C₁₁) aryl-alkyl (C₁-C₅) group, or a heteroaryl or heteroaryl-alkyl (C₁-C₅) group wherein heteroaryl is defined as 2- or 3-furyl, 2- or 3-thienyl, 2- or 3-(N-methylpyrrolyl), 2-, 3-, or 4-pyridinyl, 2-, 4-, or 5-(N-methylimidazolyl), 2-, 4-, or 5-oxazolyl, 2-, 3-, 5-, or 6-pyrimidinyl, 2-, 3-, 4-, 5-, 6-, 7-, or 8-quinolyl, or 1-, 3-, 4-, 5-, 6-, 7-, or 8-isoquinolyl, all aryl and heteroaryl groups optionally substituted by one or more hydroxy, amino, carboxy, halo, nitro, (C₁-C₃) alkoxy of 1 to 3 carbon atoms, or thioalkoxy of 1 to 5 carbon atoms; and

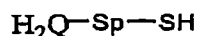
Q is selected from the group consisting of $-NNHCO-$, $-NNHCS-$, $-NNHCONH-$, $-NNHCSNH-$, and $-NO-$;

comprising the steps of:

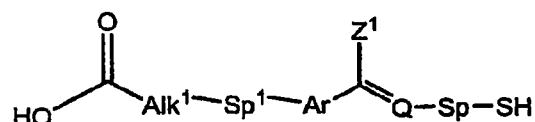
a. reacting a carboxylic acid of the formula



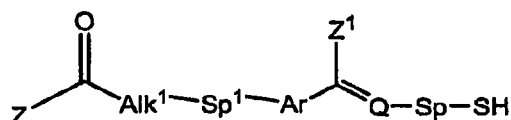
with a mercapto compound of the formula



in an alcohol solvent in the presence of an alkyl carboxylic acid, $\text{alk}^2\text{CO}_2\text{H}$ where alk^2 is 1 to 4 carbon atoms at about 20° to 70°C for about 1 to 24 hours, wherein Alk^1 , Sp^1 , Ar , Z^1 , Q , and Sp are as defined above, to produce a bilinker-carboxylic acid of the formula, wherein the mercapto compound and carboxylic acid are present in a ratio of about 1.2:1

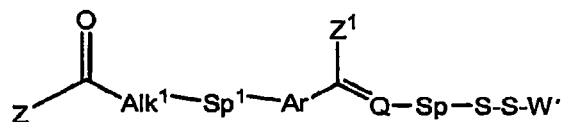


- b. isolating the bilinker-carboxylic acid of step (a);
- c. reacting the isolated bilinker-carboxylic acid of step (b) with an at least a 3 fold molar excess of N-hydroxysuccinimide, 2,3,5,6-tetrafluorophenol, pentafluorophenol, 4-nitrophenol, 2,4-dinitrophenol, or N-hydroxysulfosuccinimide in the presence of 1,3-dicyclohexylcarbodiimide (DCC), 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide (EDCI), or N,N'-disuccinimidyl carbonate in an inert solvent containing 0-50% N,N-dimethylformamide (DMF) to generate a trilinker-activated ester of the formula

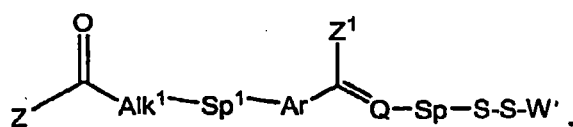


where Z is hereinbefore defined;

- d. reacting the trilinker-activated ester formed in step c with a methyltrithio antitumor antibiotic $\text{CH}_3-\text{S}-\text{S}-\text{S}-\text{W}'$ in the presence of a base or an organic base with a methyltrithio antitumor antibiotic $\text{CH}_3-\text{S}-\text{S}-\text{S}-\text{W}'$ in an inert organic solvent to generate an activated ester of the formula below, wherein the trilinker-activated ester in step c and the $\text{CH}_3-\text{S}-\text{S}-\text{S}-\text{W}'$ are in a ratio of 3.3:1 and the temperature of the reaction is $\leq 5^\circ\text{C}$.



- e. isolating the activated ester of step (d) and purifying to yield antitumor antibiotics of Formula (I)



Formula (I)

2. The process of claim 1 wherein the purifying of step (e) comprises the use of reverse phase high performance liquid chromatography having a mobile phase of about pH 7.0 to 9.0 followed by normal phase chromatography.

3. A process according to claim 1, wherein

alk¹ is 3 carbon atoms;

Sp¹ is -O-;

Z¹ is methyl;

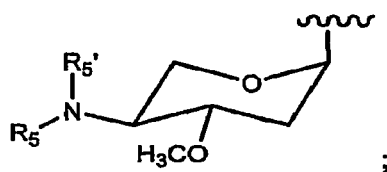
Ar is unsubstituted 1,4-phenylene;

Sp is 4 carbon atoms;

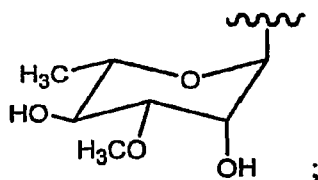
R₃ is H;

Q is NNHC(O)-;

R₂ is



R₄ is

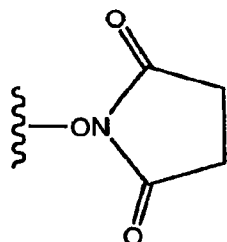


R₅ is C₂H₅;

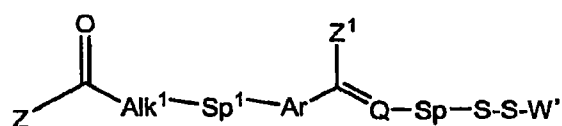
R₅' is -C(O)-R;

R is methyl; and

Z is



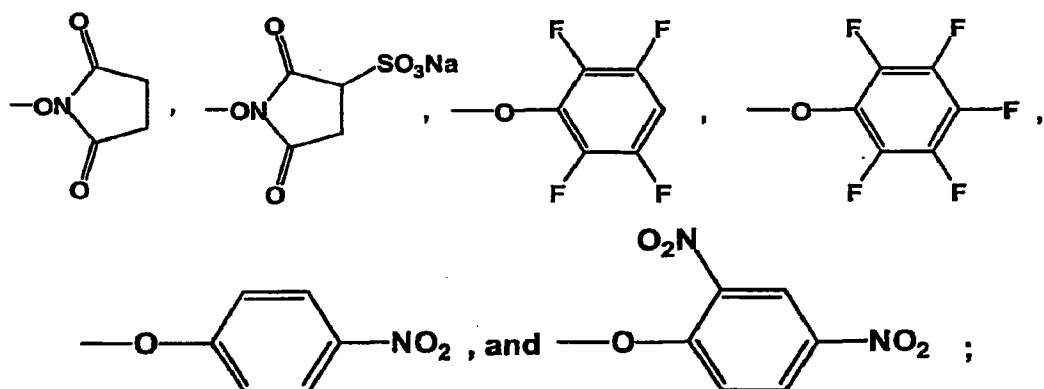
4. A process to prepare antitumor antibiotics of Formula (I):



Formula (I)

wherein:

Z is selected from the group consisting of



Alk¹ is a branched or unbranched alkylene chain of 2 to 6 carbon atoms;

Sp¹ is selected from -S-, -O-, -CONH-, -NHCO-, and -NR'-;

Z¹ is H, or alkyl of 1 to 5 carbon atoms;

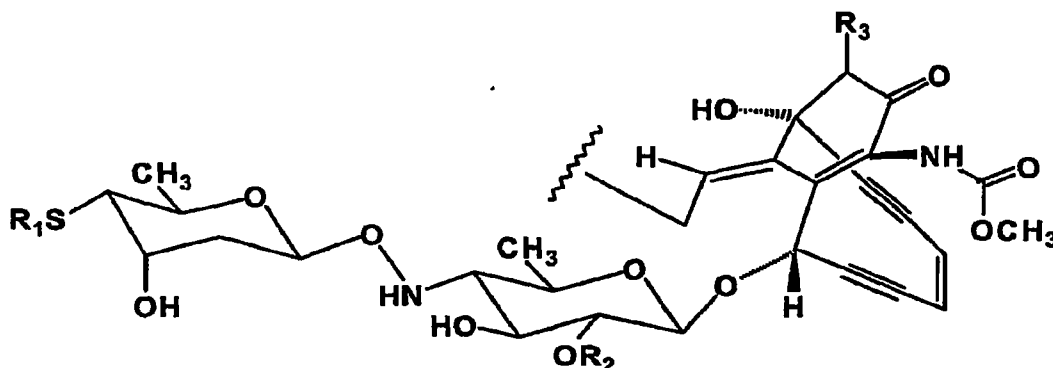
Ar is 1,2-, 1,3-, or 1,4-phenylene optionally substituted with one, two, or three groups independently selected from alkyl of 1 to 6 carbon atoms, alkoxy of 1 to 5 carbon atoms, thioalkoxy of 1 to 4 carbon atoms, halogen, nitro, $-\text{COOR}'$, $-\text{CONHR}'$, $-\text{O}(\text{CH}_2)_n\text{COOR}'$, $-\text{S}(\text{CH}_2)_n\text{COOR}'$, $-\text{O}(\text{CH}_2)_n\text{CONHR}'$, and $-\text{S}(\text{CH}_2)_n\text{CONHR}'$ or a 1,2-, 1,3-, 1,4-, 1,5-, 1,6-, 1,7-, 1,8-, 2,3-, 2,6-, or 2,7-naphthylidene optionally substituted with one, two, three, or four groups independently selected from alkyl of 1 to 6 carbon atoms, alkoxy of 1 to 5 carbon atoms, thioalkoxy of 1 to 4 carbon atoms, halogen, nitro, $-\text{COOR}'$, $-\text{CONHR}'$, $-\text{O}(\text{CH}_2)_n\text{COOR}'$, $-\text{S}(\text{CH}_2)_n\text{COOR}'$, $-\text{O}(\text{CH}_2)_n\text{CONHR}'$, and $-\text{S}(\text{CH}_2)_n\text{CONHR}'$;

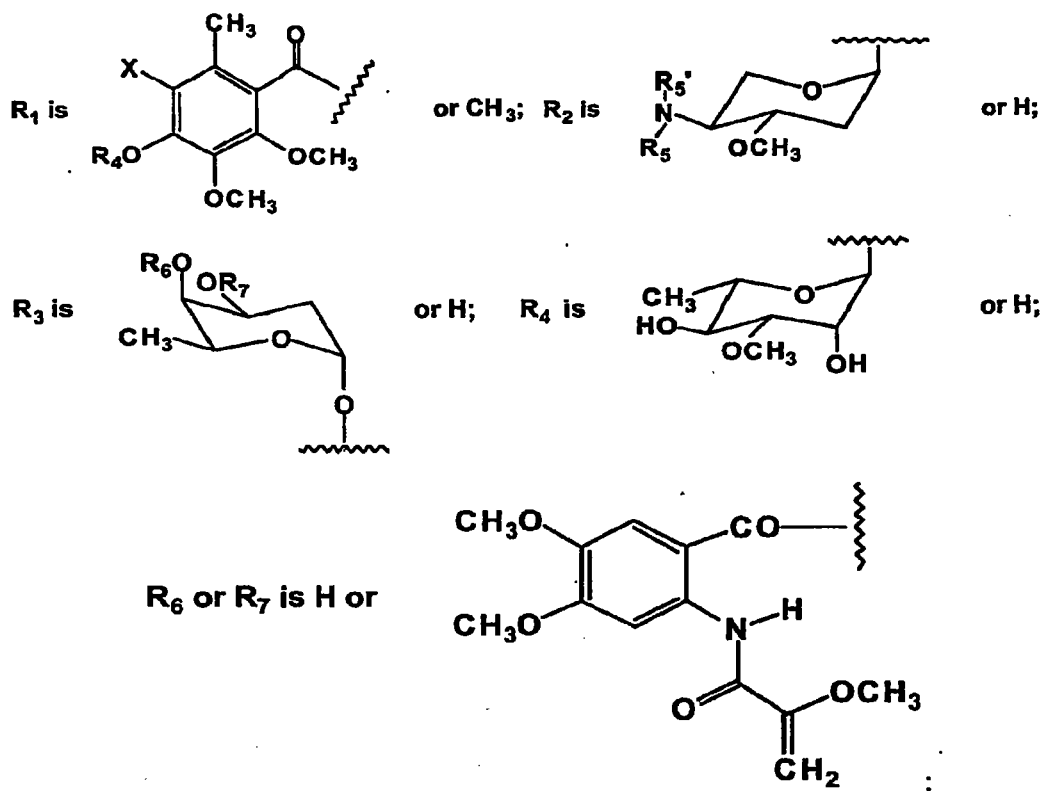
n is an integer from 0 to 5;

R' is a straight or branched alkyl of 1 to 5 carbon atoms optionally substituted by one or two groups of $-\text{OH}$, alkoxy of 1 to 4 carbon atoms, thioalkoxy of 1 to 4 carbon atoms;

Sp is a straight or branched-chain divalent or trivalent alkyl radical of 1 to 18 carbon atoms, divalent or trivalent aryl or heteroaryl radical, divalent or trivalent cycloalkyl of 3 to 18 carbon atoms or heterocycloalkyl radical, divalent or trivalent aryl- or heteroaryl-alkyl ($\text{C}_1\text{-C}_{18}$) radical, divalent or trivalent cycloalkyl- or heterocyclo-alkyl-alkyl ($\text{C}_1\text{-C}_{18}$) radical or divalent or trivalent unsaturated alkyl radical of 2 to 18 carbon atoms, wherein heteroaryl is furyl, thienyl, N-methylpyrrolyl, pyridinyl, N-methylimidazolyl, oxazolyl, pyrimidinyl, quinolyl, isoquinolyl, N-methylcarbazoyl, aminocoumarinyl, or phenazinyl and wherein if Sp is a trivalent radical, it can be additionally substituted by dialkylamino of 1 to 5 carbon atoms, alkoxy of 1 to 5 carbon atoms, hydroxy, or alkylthio of 1 to 5 carbon atoms groups;

W' is





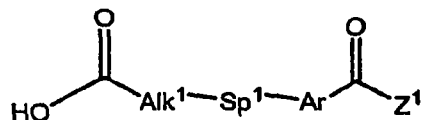
R_5 is $-CH_3$, $-C_2H_5$, or $-CH(CH_3)_2$;

X is an iodine or bromine atom;

R_5' is a hydrogen or the group RCO , wherein R is hydrogen, branched or unbranched alkyl of 1 to 10 carbon atoms, alkylene of 2 to 10 carbon atoms, aryl of 6 to 11 carbon atoms, a (C_6-C_{11}) aryl-alkyl (C_1-C_5) group, or a heteroaryl or heteroaryl-alkyl (C_1-C_5) group wherein heteroaryl is defined as 2- or 3-furyl, 2- or 3-thienyl, 2- or 3-(N-methylpyrrolyl), 2-, 3-, or 4-pyridinyl, 2-, 4-, or 5-(N-methylimidazolyl), 2-, 4-, or 5-oxazolyl, 2-, 3-, 5-, or 6-pyrimidinyl, 2-, 3-, 4-, 5-, 6-, 7-, or 8-quinolyl, or 1-, 3-, 4-, 5-, 6-, 7-, or 8-isoquinolyl, all aryl and heteroaryl groups optionally substituted by one or more hydroxy, amino, carboxy, halo, nitro, (C_1-C_3) alkoxy of 1 to 3 carbon atoms, or thioalkoxy of 1 to 5 carbon atoms; and

Q is selected from the group consisting of $-NNHCO-$, $-NNHCS-$, $-NNHCONH-$, $-NNHCSNH-$, and $-NO-$;
comprising the steps of:

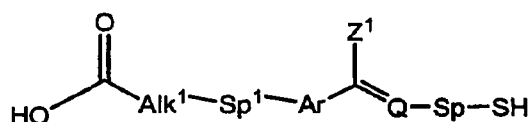
- a. reacting a carboxylic acid of the formula



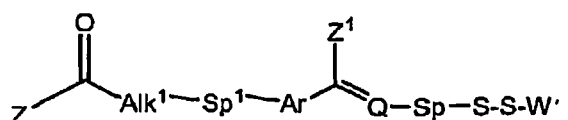
with a mercapto compound of the formula



in an alcohol solvent in the presence of an alkyl carboxylic acid, $\text{alk}^2\text{CO}_2\text{H}$ where alk^2 is 1 to 4 carbon atoms at about 20° to 70°C for about 1 to 24 hours, wherein Alk^1 , Sp^1 , Ar , Z^1 , Q , and Sp are as defined above, to produce a bilinker-carboxylic acid of the formula, wherein the mercapto compound and carboxylic acid are present in a ratio of about 1.2:1



- b. isolating the bilinker-carboxylic acid of step (a);
- c. reacting the isolated bilinker-carboxylic acid of step (b) with a methyltrithio antitumor antibiotic $\text{CH}_3\text{-S-S-S-W'}$ in the presence of a base or an organic base with a methyltrithio antitumor antibiotic $\text{CH}_3\text{-S-S-S-W'}$ in an inert organic solvent;
- d. reacting the compound of step (c) with an at least a 3 fold molar excess of N-hydroxysuccinimide, 2,3,5,6-tetrafluorophenol, pentafluorophenol, 4-nitrophenol, 2,4-dinitrophenol, or N-hydroxysulfosuccinimide in the presence of 1,3-dicyclohexylcarbodiimide (DCC), 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide (EDCI), or N,N'-disuccinimidyl carbonate in an inert solvent containing 0-50% N,N-dimethylformamide (DMF) and purifying to yield antitumor antibiotics of Formula (I)



5. The process of claim 4 wherein the purifying of step (e) comprises the use of a reverse phase high performance liquid chromatography having a mobile phase of about pH 7.0 to 9.0 followed with a normal phase chromatography.

6. A process according to claim 4, wherein

alk¹ is 3 carbon atoms;

Sp¹ is -O-;

Z¹ is methyl;

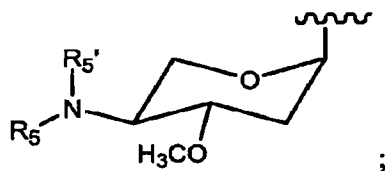
Ar is unsubstituted 1,4-phenylene;

Sp is 4 carbon atoms;

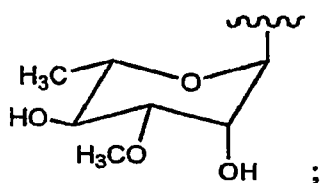
R₃ is H;

Q is NNHC(O)-;

R₂ is



R₄ is

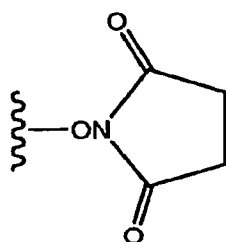


R₅ is C₂H₅;

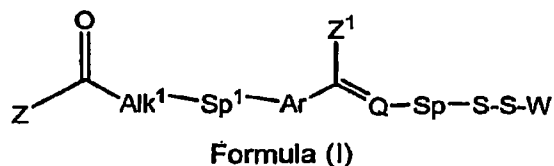
R₅' is -C(O)-R;

R is methyl; and

Z is

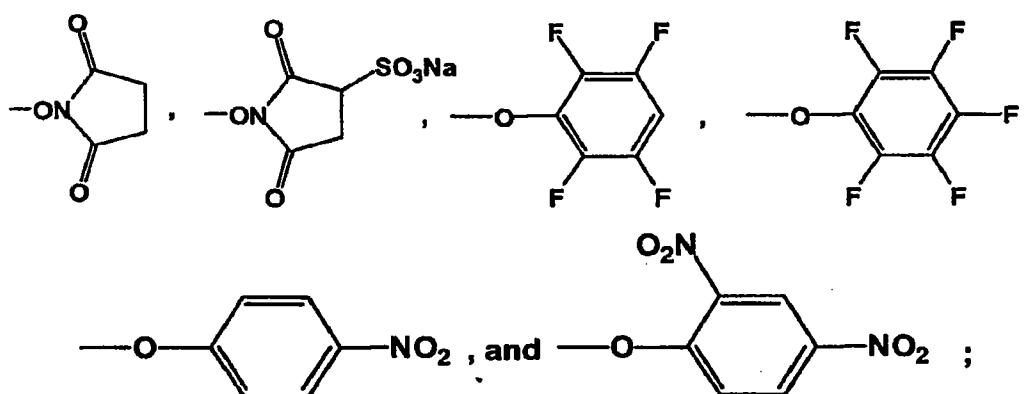


7. A process to prepare antitumor antibiotics of Formula (I):



wherein:

Z is selected from the group consisting of



Alk^1 is a branched or unbranched alkylene chain of 2 to 6 carbon atoms;

Sp^1 is selected from $-\text{S}-$, $-\text{O}-$, $-\text{CONH}-$, $-\text{NHCO}-$, and $-\text{NR}'-$;

Z^1 is H, or alkyl of 1 to 5 carbon atoms;

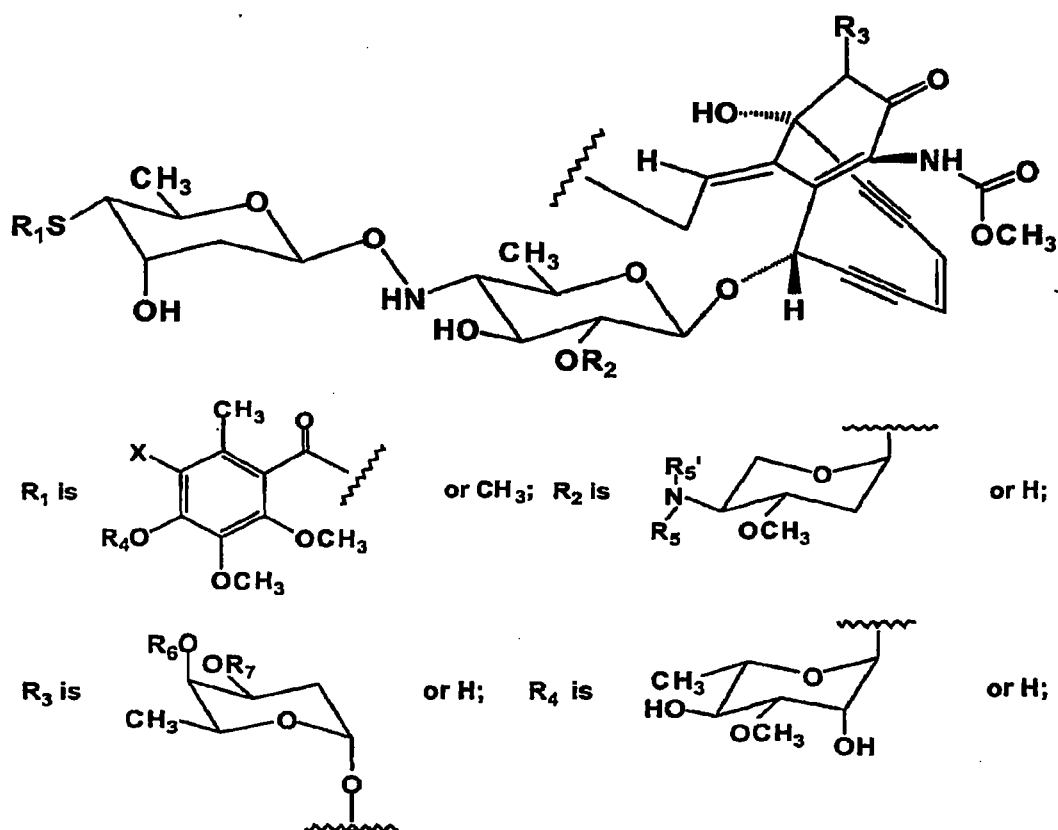
Ar is 1,2-, 1,3-, or 1,4-phenylene optionally substituted with one, two, or three groups independently selected from alkyl of 1 to 6 carbon atoms, alkoxy of 1 to 5 carbon atoms, thioalkoxy of 1 to 4 carbon atoms, halogen, nitro, $-\text{COOR}'$, $-\text{CONHR}'$, $-\text{O}(\text{CH}_2)_n\text{COOR}'$, $-\text{S}(\text{CH}_2)_n\text{COOR}'$, $-\text{O}(\text{CH}_2)_n\text{CONHR}'$, and $-\text{S}(\text{CH}_2)_n\text{CONHR}'$ or a 1,2-, 1,3-, 1,4-, 1,5-, 1,6-, 1,7-, 1,8-, 2,3-, 2,6-, or 2,7-naphthylidene optionally substituted with one, two, three, or four groups independently selected from alkyl of 1 to 6 carbon atoms, alkoxy of 1 to 5 carbon atoms, thioalkoxy of 1 to 4 carbon atoms, halogen, nitro, $-\text{COOR}'$, $-\text{CONHR}'$, $-\text{O}(\text{CH}_2)_n\text{COOR}'$, $-\text{S}(\text{CH}_2)_n\text{COOR}'$, $-\text{O}(\text{CH}_2)_n\text{CONHR}'$, and $-\text{S}(\text{CH}_2)_n\text{CONHR}'$;

n is an integer from 0 to 5;

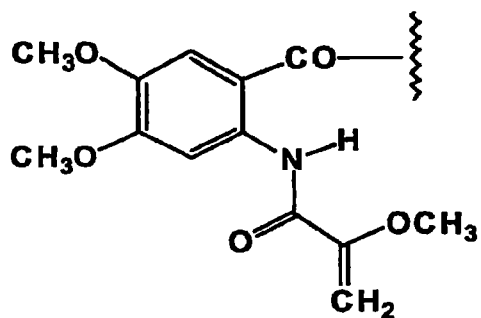
R' is a straight or branched alkyl of 1 to 5 carbon atoms optionally substituted by one or two groups of -OH, alkoxy of 1 to 4 carbon atoms, thioalkoxy of 1 to 4 carbon atoms;

Sp is a straight or branched-chain divalent or trivalent alkyl radical of 1 to 18 carbon atoms, divalent or trivalent aryl or heteroaryl radical, divalent or trivalent cycloalkyl of 3 to 18 carbon atoms or heterocycloalkyl radical, divalent or trivalent aryl- or heteroaryl-alkyl (C₁-C₁₈) radical, divalent or trivalent cycloalkyl- or heterocyclo-alkyl-alkyl (C₁-C₁₈) radical or divalent or trivalent unsaturated alkyl radical of 2 to 18 carbon atoms, wherein heteroaryl is furyl, thienyl, N-methylpyrrolyl, pyridinyl, N-methylimidazolyl, oxazolyl, pyrimidinyl, quinolyl, isoquinolyl, N-methylcarbazoyl, aminocoumarinyl, or phenazinyl and wherein if Sp is a trivalent radical, it can be additionally substituted by dialkylamino of 1 to 5 carbon atoms, alkoxy of 1 to 5 carbon atoms, hydroxy, or alkylthio of 1 to 5 carbon atoms groups;

W' is



R_6 or R_7 is H or



R_5 is $-CH_3$, $-C_2H_5$, or $-CH(CH_3)_2$;

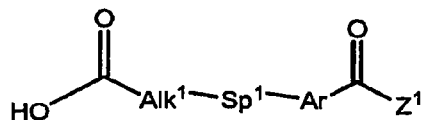
X is an iodine or bromine atom;

R_5' is a hydrogen or the group RCO, wherein R is hydrogen, branched or unbranched alkyl of 1 to 10 carbon atoms, alkylene of 2 to 10 carbon atoms, aryl of 6 to 11 carbon atoms, a (C₆-C₁₁) aryl-alkyl (C₁-C₅) group, or a heteroaryl or heteroaryl-alkyl (C₁-C₅) group wherein heteroaryl is defined as 2- or 3-furyl, 2- or 3-thienyl, 2- or 3-(N-methylpyrrolyl), 2-, 3-, or 4-pyridinyl, 2-, 4-, or 5-(N-methylimidazolyl), 2-, 4-, or 5-oxazolyl, 2-, 3-, 5-, or 6-pyrimidinyl, 2-, 3-, 4-, 5-, 6-, 7-, or 8-quinolyl, or 1-, 3-, 4-, 5-, 6-, 7-, or 8-isoquinolyl, all aryl and heteroaryl groups optionally substituted by one or more hydroxy, amino, carboxy, halo, nitro, (C₁-C₃) alkoxy of 1 to 3 carbon atoms, or thioalkoxy of 1 to 5 carbon atoms; and

Q is selected from the group consisting of $-NNHCO-$, $-NNHCS-$, $-NNHCONH-$, $-NNHCSNH-$, and $-NO-$;

comprising the steps of:

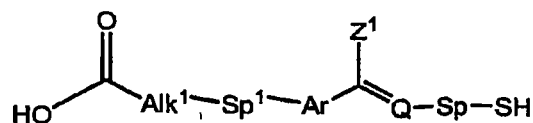
a. reacting a carboxylic acid of the formula



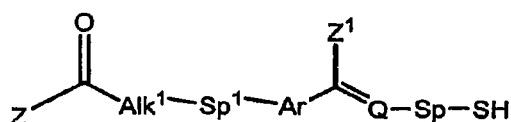
with a mercapto compound of the formula



in an alcohol solvent in the presence of an alkyl carboxylic acid, alk^2CO_2H where alk^2 is 1 to 4 carbon atoms at about 20° to 70°C for about 1 to 24 hours, wherein Alk^1 , Sp^1 , Ar, Z^1 , Q, and Sp are as defined above, to produce a bilinker-carboxylic acid of the formula,

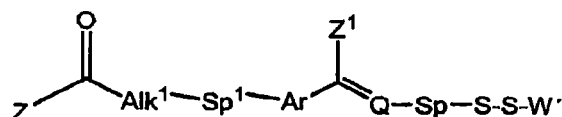


- b. isolating the bilinker-carboxylic acid of step (a);
- c. reacting the isolated bilinker-carboxylic acid of step (b) with at least one of N-hydroxysuccinimide, 2,3,5,6-tetrafluorophenol, pentafluorophenol, 4-nitrophenol, 2,4-dinitrophenol, or N-hydroxysulfosuccinimide in the presence of 1,3-dicyclohexylcarbodiimide (DCC), 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide (EDCI), or N,N'-disuccinimidyl carbonate in an inert solvent containing 0-50% N,N-dimethylformamide (DMF) to generate a trilinker-activated ester of the formula

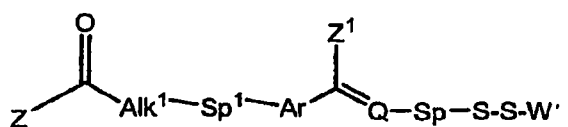


where Z is hereinbefore defined ;

- d. reacting the trilinker-activated ester in step c in the presence of a base or an organic base with a methyltrithio antitumor antibiotic $\text{CH}_3\text{-S-S-S-W'}$ in an inert organic solvent to generate an activated ester of the formula



- e. isolating the activated ester of step (d) and purifying to yield antitumor antibiotics of Formula (I)



Formula (I)

8. A process according to claim 1, wherein

alk^1 is 3 carbon atoms;

Sp^1 is $-\text{O}-$;

Z¹ is methyl;

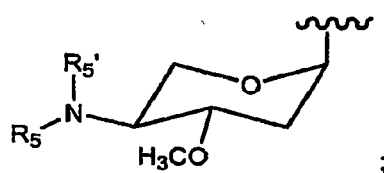
Ar is unsubstituted 1,4-phenylene;

Sp is 4 carbon atoms;

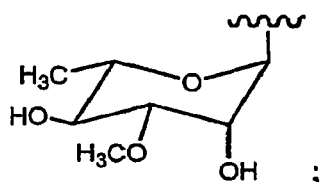
R₃ is H;

Q is NNHC(O)-;

R₂ is



R₄ is

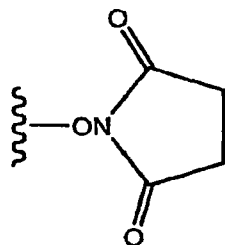


R₅ is C₂H₅;

R₅' is -C(O)-R;

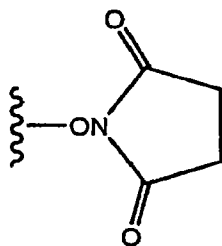
R is methyl; and

Z is

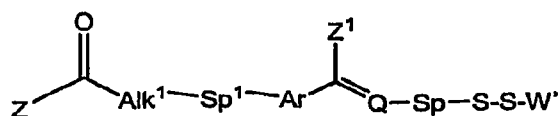


9. A process according to claim 1, wherein Alk¹ is an alkylene of 2 to 5 carbon atoms, and Sp¹ is an oxygen atom.

10. A process according to claim 9, wherein Alk¹ is an alkylene of 3 carbon atoms.
11. A process according to claim 1, wherein Z¹ is alkyl of 1 to 3 carbon atoms.
12. A process according to claim 1, wherein Ar is 1,2-, 1,3-, or 1,4-phenylene, or 1,2-, 1,3-, 1,4-, 1,5-, 1,6-, 1,7-, 1,8-, 2,3-, 2,6-, or 2,7-naphthylidene.
13. A process according to claim 12, wherein Ar is 1,4-phenylene.
14. A process according to claim 1, wherein Q is -NNHCO-.
15. A process according to claim 1, wherein Sp is straight or branched-chain divalent or trivalent alkyl radical of 1 to 12 carbon atoms.
16. A process according to claim 15, wherein Sp is straight or branched-chain divalent or trivalent alkyl radical of 1 to 6 carbon atoms.
17. The process according to claim 1, wherein the alcohol solvent is methanol.
18. The process according to claim 1, wherein the inert solvent is acetonitrile.
19. The process according to claim 1, wherein alkyl carboxylic acid is acetic acid.
20. The process according to claim 1, wherein the inert organic solvent is acetonitrile.
21. A process according to claim 1, wherein Z is

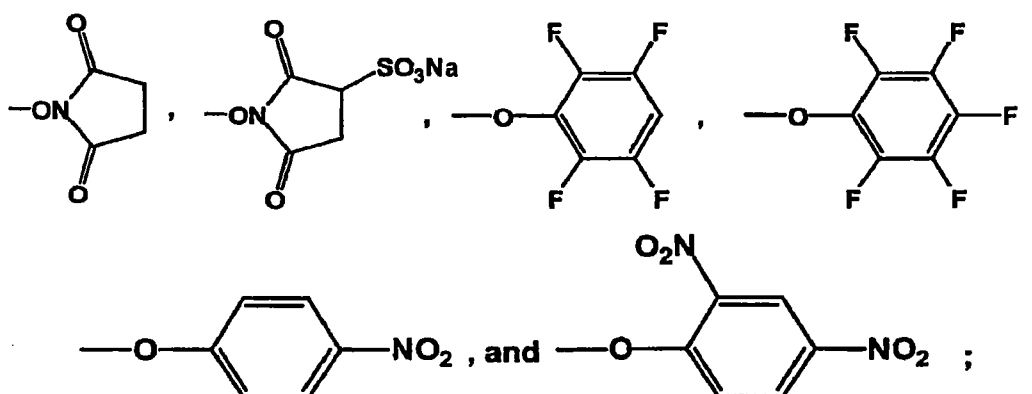


22. A process to prepare trilinker-activated esters of the formula:



wherein:

Z is selected from the group consisting of



Alk¹ is a branched or unbranched alkylene chain of 2 to 6 carbon atoms;

Sp¹ is selected from -S-, -O-, -CONH-, -NHCO-, and -NR'-;

Z¹ is H, or alkyl of 1 to 5 carbon atoms;

Ar is 1,2-, 1,3-, or 1,4-phenylene optionally substituted with one, two, or three groups independently selected from alkyl of 1 to 6 carbon atoms, alkoxy of 1 to 5 carbon atoms, thioalkoxy of 1 to 4 carbon atoms, halogen, nitro, -COOR', -CONHR', -O(CH₂)_nCOOR', -S(CH₂)_nCOOR', -O(CH₂)_nCONHR', and -S(CH₂)_nCONHR' or a 1,2-, 1,3-, 1,4-, 1,5-, 1,6-, 1,7-, 1,8-, 2,3-, 2,6-, or 2,7-naphthylidene optionally substituted with one, two, three, or four groups independently selected from alkyl of 1 to 6 carbon atoms, alkoxy of 1 to 5 carbon atoms, thioalkoxy of 1 to 4 carbon atoms, halogen, nitro, -COOR', -CONHR', -O(CH₂)_nCOOR', -S(CH₂)_nCOOR', -O(CH₂)_nCONHR', and -S(CH₂)_nCONHR';

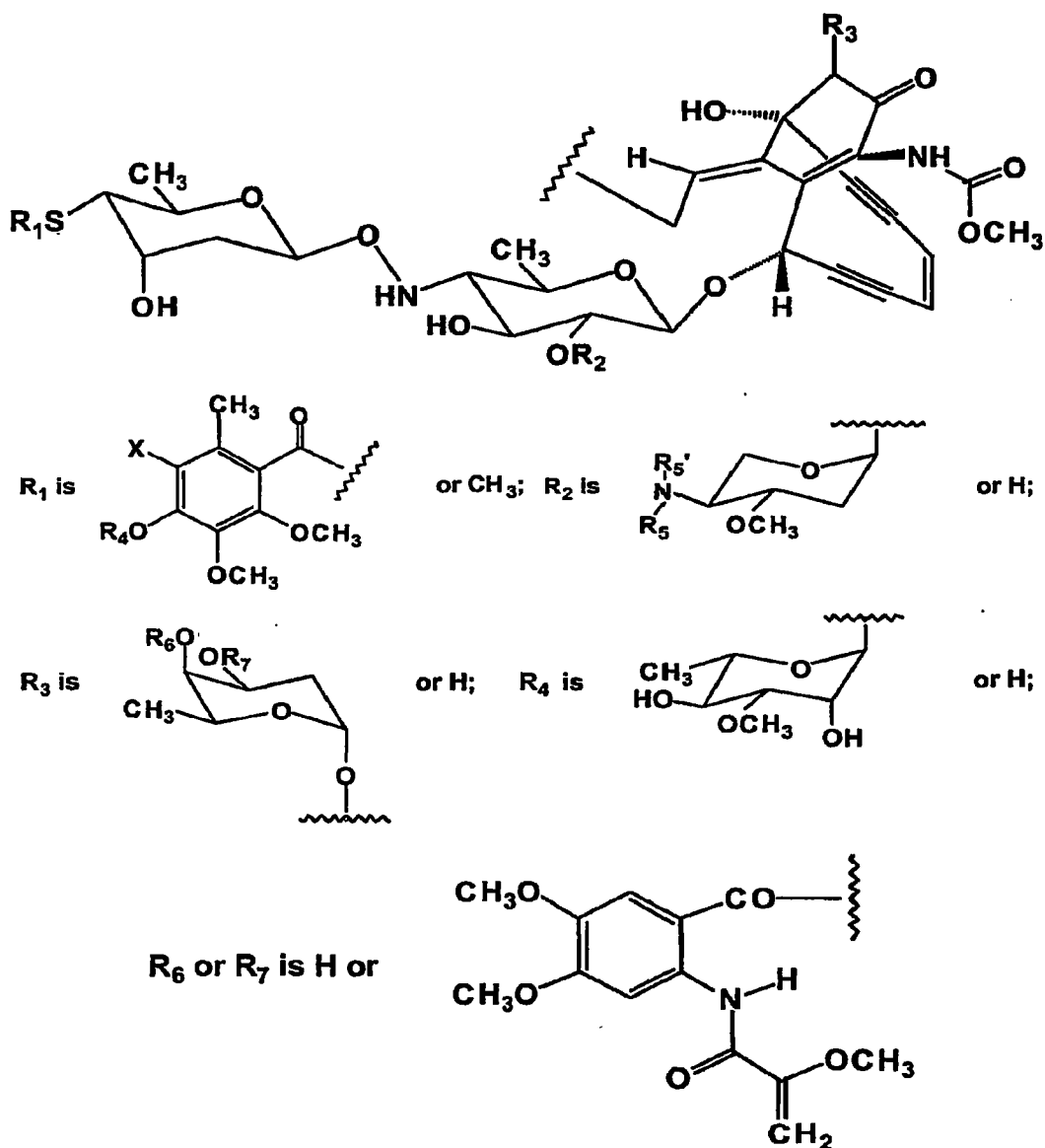
n is an integer from 0 to 5;

R' is a straight or branched alkyl of 1 to 5 carbon atoms optionally substituted by one or two groups of -OH, alkoxy of 1 to 4 carbon atoms, thioalkoxy of 1 to 4 carbon atoms;

Sp is a straight or branched-chain divalent or trivalent alkyl radical of 1 to 18 carbon atoms, divalent or trivalent aryl or heteroaryl radical, divalent or trivalent cycloalkyl of

3 to 18 carbon atoms or heterocycloalkyl radical, divalent or trivalent aryl- or heteroaryl-alkyl (C_1 - C_{18}) radical, divalent or trivalent cycloalkyl- or heterocyclo-alkyl (C_1 - C_{18}) radical or divalent or trivalent unsaturated alkyl radical of 2 to 18 carbon atoms, wherein heteroaryl is furyl, thienyl, N-methylpyrrolyl, pyridinyl, N-methylimidazolyl, oxazolyl, pyrimidinyl, quinolyl, isoquinolyl, N-methylcarbazoyl, aminocoumarinyl, or phenazinyl and wherein if Sp is a trivalent radical, it can be additionally substituted by dialkylamino of 1 to 5 carbon atoms, alkoxy of 1 to 5 carbon atoms, hydroxy, or alkylthio of 1 to 5 carbon atoms groups;

W' is



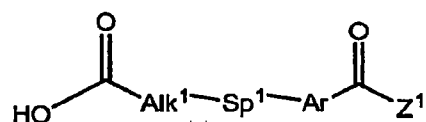
R₅ is -CH₃, -C₂H₅, or -CH(CH₃)₂;

X is an iodine or bromine atom;

R₅' is a hydrogen or the group RCO, wherein R is hydrogen, branched or unbranched alkyl of 1 to 10 carbon atoms, alkylene of 2 to 10 carbon atoms, aryl of 6 to 11 carbon atoms, a (C₆-C₁₁) aryl-alkyl (C₁-C₅) group, or a heteroaryl or heteroaryl-alkyl (C₁-C₅) group wherein heteroaryl is defined as 2- or 3-furyl, 2- or 3-thienyl, 2- or 3-(N-methylpyrrolyl), 2-, 3-, or 4-pyridinyl, 2-, 4-, or 5-(N-methylimidazolyl), 2-, 4-, or 5-oxazolyl, 2-, 3-, 5-, or 6-pyrimidinyl, 2-, 3-, 4-, 5-, 6-, 7-, or 8-quinolyl, or 1-, 3-, 4-, 5-, 6-, 7-, or 8-isoquinolyl, all aryl and heteroaryl groups optionally substituted by one or more hydroxy, amino, carboxy, halo, nitro, (C₁-C₃) alkoxy of 1 to 3 carbon atoms, or thioalkoxy of 1 to 5 carbon atoms; and Q is selected from the group consisting of -NNHCO-, -NNHCS-, -NHNCONH-, -NNCSNH-, and -NO-;

comprising the steps of:

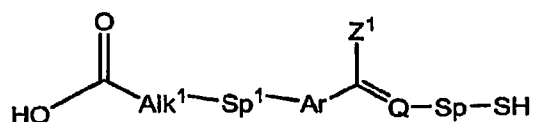
- a. reacting a carboxylic acid of the formula



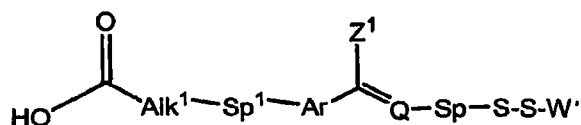
with a mercapto compound of the formula



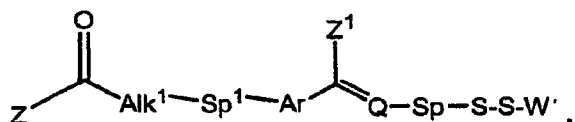
in an alcohol solvent in the presence of an alkyl carboxylic acid, alk²CO₂H where alk² is 1 to 4 carbon atoms at about 20° to 70°C for about 1 to 24 hours, wherein Alk¹, Sp¹, Ar, Z¹, Q, and Sp are as defined above, to produce a bilinker-carboxylic acid of the formula



- b. isolating the bilinker-carboxylic acid of step (a);
- c. reacting the bilinker-carboxylic acid from step (b) in the presence of a base or an organic base with a methyltrithio antitumor antibiotic CH₃-S-S-S-W' in an inert organic solvent to generate a bilinker-methyltrithio antitumor antibiotic of the formula

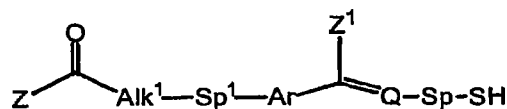


d. reacting the isolated bilinker-methyltrithio antitumor antibiotic of step (c) with N-hydroxysuccinimide, 2,3,5,6-tetrafluorophenol, pentafluorophenol, 4-nitrophenol, 2,4-dinitrophenol, or N-hydroxysulfosuccinimide in the presence of 1,3-dicyclohexylcarbodiimide (DCC), 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide (EDCI), or N,N'-disuccinimidyl carbonate in an inert solvent containing 0-50% N,N-dimethylformamide (DMF) to generate a trilinker-activated ester of the formula



23. The process according to claim 17, wherein Alk^1 is an alkylene of 2 to 5 carbon atoms, and Sp^1 is an oxygen atom.

24. A process for the preparation of trifunctional linker intermediates, of the formula



wherein:

Alk^1 is a branched or unbranched alkylene chain of 2 to 6 carbon atoms;

Sp^1 is selected from -S-, -O-, -CONH-, -NHCO-, and -NR'-;

Z^1 is H, or alkyl of 1 to 5 carbon atoms;

Ar is 1,2-, 1,3-, or 1,4-phenylene optionally substituted with one, two, or three groups independently selected from alkyl of 1 to 6 carbon atoms, alkoxy of 1 to 5 carbon atoms, thioalkoxy of 1 to 4 carbon atoms, halogen, nitro, -COOR', -CONHR',

-O(CH₂)_nCOOR', -S(CH₂)_nCOOR', -O(CH₂)_nCONHR', and -S(CH₂)_nCONHR' or a 1,2-, 1,3-, 1,4-, 1,5-, 1,6-, 1,7-, 1,8-, 2,3-, 2,6-, or 2,7-naphthylidene optionally substituted with one, two, three, or four groups independently selected from alkyl of 1 to 6 carbon atoms, alkoxy of 1 to 5 carbon atoms, thioalkoxy of 1 to 4 carbon atoms, halogen, nitro, -COOR', -CONHR', -O(CH₂)_nCOOR', -S(CH₂)_nCOOR', -O(CH₂)_nCONHR', and -S(CH₂)_nCONHR';

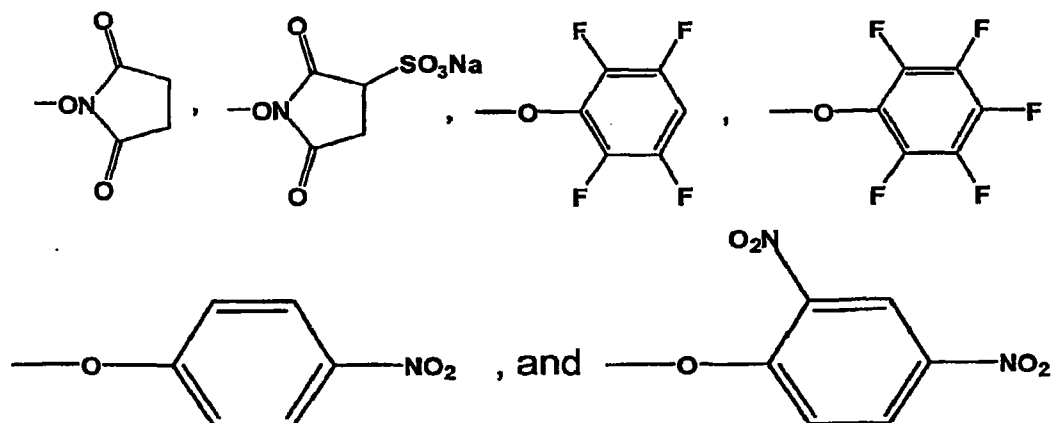
n is an integer from 0 to 5;

R' is a straight or branched alkyl of 1 to 5 carbon atoms optionally substituted by one or two groups of -OH, alkoxy of 1 to 4 carbon atoms, thioalkoxy of 1 to 4 carbon atoms;

Sp is a straight or branched-chain divalent or trivalent alkyl radical of 1 to 18 carbon atoms, divalent or trivalent aryl or heteroaryl radical, divalent or trivalent cycloalkyl of 3 to 18 carbon atoms or heterocycloalkyl radical, divalent or trivalent aryl- or heteroaryl-alkyl (C₁-C₁₈) radical, divalent or trivalent cycloalkyl- or heterocyclo-alkyl-alkyl (C₁-C₁₈) radical or divalent or trivalent unsaturated alkyl radical of 2 to 18 carbon atoms, wherein heteroaryl is furyl, thienyl, N-methylpyrrolyl, pyridinyl, N-methylimidazolyl, oxazolyl, pyrimidinyl, quinolyl, isoquinolyl, N-methylcarbazoyl, aminocoumarinyl, or phenazinyl and wherein if Sp is a trivalent radical, it can be additionally substituted by dialkylamino of 1 to 5 carbon atoms, alkoxy of 1 to 5 carbon atoms, hydroxy, or alkylthio of 1 to 5 carbon atoms groups;

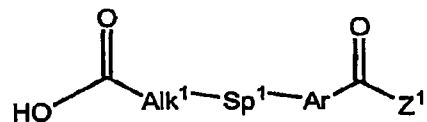
Q is selected from the group consisting of -NNHCO-, -NNHCS-, and -NNHCONH-;

Z is selected from the group consisting of



comprising the steps of:

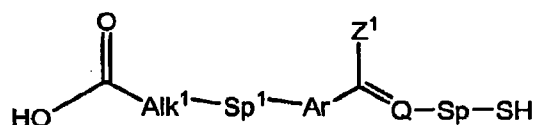
- a. reacting a carboxylic acid of the formula



with a mercapto compound of the formula



in an alcohol solvent in the presence of an alkyl carboxylic acid, $\text{alk}^2\text{CO}_2\text{H}$, where alk^2 is 1 to 4 carbon atoms at about 20° to 70°C for about 1 to 24 hours, wherein Alk^1 , Sp^1 , Ar , Z^1 , Q , and Sp are as defined above, to produce a bilinker-carboxylic acid of the formula



- b. isolating the bilinker-carboxylic acid of step (a);
- c. reacting the isolated bilinker-carboxylic acid of step (b) with N-hydroxysuccinimide, 2,3,5,6-tetrafluorophenol, pentafluorophenol, 4-nitrophenol, 2,4-dinitrophenol, or N-hydroxysulfosuccinimide in the presence of 1,3-dicyclohexylcarbodiimide (DCC), 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide (EDCI), or N,N'-disuccinimdyl carbonate in an inert solvent containing 0-50% DMF to generate trifunctional linker intermediates, of the formula

