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(54) Title: BICYCLOPOLYAZAMACROCYCLOCARBOXYLIC ACID COMPLEXES, THEIR CONJUGATES, PROCESSES FOR THEIR PREPARATION, AND USE AS CONTRAST AGENTS

(57) Abstract

Complexes of bicyclopolyazamacrocyclocarboxylic acid with Gd, Mn or Fe ions are disclosed. The complexes can be covalently attached to a biologically active molecule, e.g. an antibody or antibody fragment, to form conjugates. The complexes and conjugates are useful as contrast agents for diagnostic purposes. Processes for preparing both the complex and conjugate are disclosed.

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Chem. 634-639 (1966)]. Paramagnetic metal chelates used in this manner are referred to as contrast enhancement agents or contrast agents.

There are a number of paramagnetic metal ions which can be considered when undertaking the design of an MRI contrast agent. In practice, however, the most useful paramagnetic metal ions are gadolinium (Gd^{+3}), iron (Fe^{+3}), manganese (Mn^{+2}) and (Mn^{+3}), and chromium (Cr^{+3}), because these ions exert the greatest effect on water protons by virtue of their large magnetic moments. In a non-complexed form (e.g. $GdCl_3$), these metal ions are toxic to an animal, thereby precluding their use in the simple salt form. Therefore, a fundamental role of the organic chelating agent (also referred to as a ligand) is to render the paramagnetic metal non-toxic to the animal while preserving its desirable influence on T1 and T2 relaxation rates of the surrounding water protons.

Art in the MRI field is quite extensive, such that the following summary, not intended to be exhaustive, is provided only as a review of this area and other compounds that are possibly similar in structure. U.S. Patent 4,899,755 discloses a method of alternating the proton NMR relaxation times in the liver or bile duct of an animal using Fe^{+3}-ethylene-bis(2-hydroxyphenylglycine) complexes and its derivatives, and suggests among various other compounds the possible use of a pyridine macrocyclomethylenecarboxylic acid. U.S. Patent 4,880,008 (a CIP of U.S. Patent 4,899,755) discloses additional imaging data for liver tissue of rats, but without any additional complexes being shown. U.S. Patent 4,980,148 disclose gadolinium complexes for MRI which are non-cyclic compounds. C. J. Broan et al., *J. Chem. Soc., Chem. Commun.*, 1739-1741 (1990) describe some bifunctional macrocyclic phosphinic acid compounds. C. J. Broan et al., *J. Chem. Soc., Chem. Commun.*, 1738-1739 (1990) describe compounds that are triazabicyclo compounds. I. K. Adzamli et al., *J. Med. Chem.* 32, 139-144 (1989) describes acyclic phosphonate derivatives of gadolinium complexes for NMR imaging.

At the present time, the only commercial contrast agent available in the U.S. is the complex of gadolinium with diethylenetriaminepentaacetic acid (DTPA-Gd^{+3} - MAGNEVIST™ by Shering). MAGNEVIST™ is considered as a non-specific/perfusion agent since it freely distributes in extracellular fluid followed by efficient elimination through the renal system. MAGNEVIST™ has proven to be extremely valuable in the diagnosis of brain lesions since the accompanying breakdown of the blood/brain barrier allows perfusion of the contrast agent into the affected regions. In addition to MAGNEVIST™, Guerbet is commercially marketing a macrocyclic perfusion agent (DOTAREM™) which presently is only available in Europe. A number of other potential contrast agents are in various stages of development.

It would be advantageous if contrast agents were developed that could have site specificity for the tissue desired to be imaged, rather than non-specific/perfusion agents. The present invention is directed to just such novel complexes comprising a ligand that is a bicyclo-polyazamacrocyclocarboxylic acid of the formula

BICYCLOPOLYAZAMACROCYCLOCARBOXYLIC ACID COMPLEXES, THEIR CONJUGATES, PROCESSES FOR THEIR PREPARATION, AND USE AS CONTRAST AGENTS

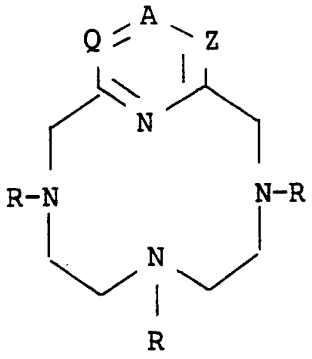
This invention concerns complexes that contain as the ligand bicyclopolyaza-macrocyclocarboxylic acids, and conjugates thereof, for use as contrast agents in magnetic resonance imaging (MRI). Processes for preparing these complexes and conjugates are also provided. To better understand this invention, a brief background on MRI is provided in the following section.

Background

MRI is a non-invasive diagnostic technique which produces well resolved cross-sectional images of soft tissue within an animal body, preferably a human body. This technique is based upon the property of certain atomic nuclei (e.g. water protons) which possess a magnetic moment [as defined by mathematical equations; see G. M. Barrow, Physical Chemistry, 3rd Ed., McGraw-Hill, NY (1973)] to align in an applied magnetic field. Once aligned, this equilibrium state can be perturbed by applying an external radio frequency (RF) pulse which causes the protons to be tilted out of alignment with the magnetic field. When the RF pulse is terminated, the nuclei return to their equilibrium state and the time required for this to occur is known as the relaxation time. The relaxation time consists of two parameters known as spin-lattice (T1) and spin-spin (T2) relaxation and it is these relaxation measurements which give information on the degree of molecular organization and interaction of protons with the surrounding environment.

Since water content of living tissue is substantial and variations in content and environment exist among tissue types, diagnostic images of biological organisms are obtained which reflect proton density and relaxation times. The greater the differences in relaxation times (T1 and T2) of protons present in tissue being examined, the greater will be the contrast in the obtained image [*J. Magnetic Resonance* 33, 83-106 (1979)].

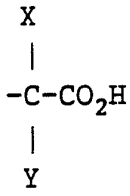
It is known that paramagnetic chelates possessing a symmetric electronic ground state can dramatically affect the T1 and T2 relaxation rates of juxtaposed water protons and that the effectiveness of the chelate in this regard is related, in part, to the number of unpaired electrons producing the magnetic moment [*Magnetic Resonance Annual* 231-266 (Raven Press, NY (1985)]. It has also been shown that when a paramagnetic chelate of this type is administered to a living animal, its effect on the T1 and T2 of various tissues can be directly observed in the magnetic resonance (MR) images with increased contrast being observed in the areas of chelate localization. It has therefore been proposed that stable, non-toxic paramagnetic chelates be administered to animals in order to increase the diagnostic information obtained by MRI [*Frontiers of Biol. Energetics* I, 752-759 (1978); *J. Nucl. Med.* 25, 506-513 (1984); Proc. of NMR Imaging Symp. (Oct. 26-27, 1980); F. A. Cotton et al., *Adv. Inorg.*



(I)

wherein:

R is hydrogen,



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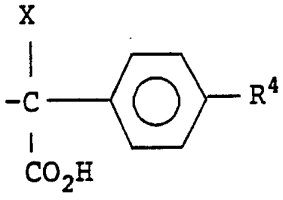
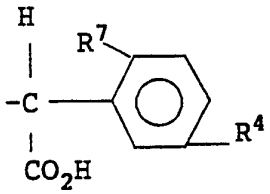


or



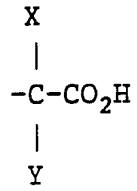
;

where: X and Y are independently H, OH, C_1-C_3 alkyl or COOH;

R^7 is H or OH; and

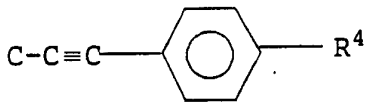
R^4 is H, NO_2, NH_2, isothiocyanato, semicarbazido, thiosemicarbazido, maleimido, bromoacetamido or carboxyl;

with the proviso that at least two R terms must be



;

A = CH, N, C-Br, C-Cl, C-OR^1, C-OR^2, N^+-R^3 X^-, or



;

R^1 = H, C_1-C_5 alkyl, benzyl, or benzyl substituted with at least one R^4;

R^2 is C_1-C_{16} alkylamino;

R^3 is C_1-C_{16} alkyl, benzyl, or benzyl substituted with at least one R^4;

R^4 is defined as before;

X^- is Cl^-, Br^-, I^- or $H_3CCO_2^-$;

Q and Z independently are CH, N, N^+-R^3 X^-, C-CH_2-OR^1 or C-C(O)-R^5;

R^1 and R^3 are defined as above;

R^5 is -O-(C_1-C_3 alkyl), OH or NHR^6;

R^6 is C_1-C_5 alkyl or a biologically active material;

X^- is defined as above; and

with the provisos that:

a) when Q, A or Z is N or N^+-R^3 X^-, then the other two groups must be CH;

b) when A is C-Br, C-Cl, C-OR^1 or C-OR^2, then both Q and Z must be CH;

c) the sum of the R^2, R^4 and R^6 terms, when present, may not exceed one; and

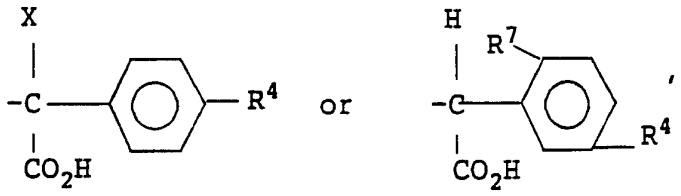
d) only one of Q or Z can be C-C(O)-R^5 and when one of Q or Z is C-C(O)-R^5, then A must be CH; and

complexed with a metal ion selected from Gd^{+3}, Mn^{+2} or Fe^{+3}; or

pharmaceutically-acceptable salts thereof.

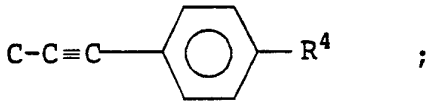
Bifunctional complexes of Formula (I) are desirable to prepare the conjugates of this invention. Such ligands must have:

one R term is



where R^4 and R^7 are defined as above; or

A is C-OR^1, C-OR^2, where R^1 and R^2 are defined as above or



where R^4 is defined as above; or

A is CH, and one of Q or Z is CH and the other is C-C(O)-R^5 or C-CH_2-OR^1, where R^1 and R^5 are defined as above;

especially those ligands where R^5 is NHR^6, where R^6 is a biologically active material.

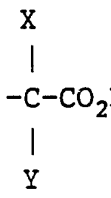
The ligands of Formula (I) are complexed with various metal ions, such as gadolinium (Gd^{+3}), iron (Fe^{+3}), and manganese (Mn^{+2}), and Gd^{+3} being preferred. The complexes so formed can be used by themselves or can be attached, by being covalently

bonded, to a larger molecule, such as a dextran, a polypeptide or a biologically active molecule, including an antibody or fragment thereof, and used for diagnostic purposes. Such conjugates and complexes are useful as contrast agents.

The complexes and conjugates of this invention can be modified to provide a specific overall charge. For example, when the metal ion is + 3 the following can be obtained:

(A) an overall neutral charge - when

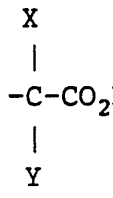
R is



and X and Y are all equal to H;

(B) an overall + 1 charge - when

one of A, Q or Z is N^{+}-R^{3} X^{-}, where R^{3} and X^{-} are defined as above; and the three R terms are



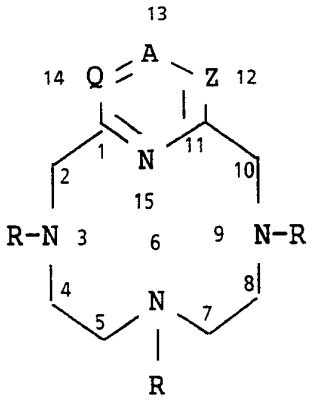
and X and Y are all equal to H; or

when A, Q and Z are CH; X and Y are H; and one R term is H.

Both the complexes and conjugates may be formulated to be in a pharmaceutically acceptable form for administration to an animal.

Use of the ligands of this invention with other metal ions for diagnosis of disease states such as cancer is possible. The use of those complexes and conjugates is discussed in another copending application.

The complex has the ligand of Formula (I) numbered for nomenclature purposes as follows:



(I)

The present invention concerns development of contrast agents having a neutral or + 1 charge which enables site specific delivery of the contrast agent to a desired tissue. The advantage being increased contrast in the areas of interest based upon tissue affinity as opposed to contrast arising from non-specific perfusion which may or may not be apparent with an extracellular agent. The specificity of the ligand of Formula (I) may be controlled by adjusting the total charge and lipophilic character of the complex. The overall range of the charge of the complex is from + 1 to 0. For example, for a complex having a + 1 overall charge has heart and/or bone uptake expected; whereas when the overall charge of the complex is 0 (thus neutral), the complex may have the ability to cross the blood brain barrier and normal brain uptake may be possible.

Tissue specificity may also be realized by ionic or covalent attachment of the chelate to a naturally occurring or synthetic macromolecule having specificity for a desired target tissue. One possible application of this approach is through the use of chelate conjugated monoclonal antibodies which would transport the paramagnetic chelate to diseased tissue enabling visualization by MRI. In addition, attachment of a paramagnetic chelate to a macromolecule can further increase the contrast agent efficiency resulting in improved contrast relative to the unbound chelate. Recent work by Lauffer (U.S. Patents 4,880,008 and 4,899,755) has demonstrated that variations in lipophilicity can result in tissue-specific agents and that increased lipophilic character favors non-covalent interactions with blood proteins resulting in enhancement of relaxivity.

Additionally, the present contrast agents of Formula (I) which are neutral in charge are particularly preferred for forming the conjugates of this invention since undesirable ionic interactions between the chelate and protein are minimized which preserves the antibody immunoreactivity. Also the present neutral complexes reduce the osmolarity relative to DTPA-Gd^{+3}, which may alleviate the discomfort of injection.

While not wishing to be bound by theory, it is believed that when a charged complex of the invention is made (e.g. + 1 for heart), the variations in that chelate ionic charge can influence biolocalization. Thus, if the antibody or other directing moiety is also specific for the same site, then the conjugate displays two portions to aid in site specific delivery.

The terms used in Formula (I) and for this invention are further defined as follows. "C_1-C_3 alkyl", "C_1-C_5 alkyl", "C_1-C_{18} alkyl", include both straight and branched chain alkyl groups. An "animal" includes a warmblooded mammal, preferably a human being.

"Biologically active material" refers to, for example, a dextran, peptide, or molecules that have specific affinity for a receptor, or preferably antibodies or antibody fragments.

"Antibody" refers to any polyclonal, monoclonal, chimeric antibody or heteroantibody, preferably a monoclonal antibody; "antibody fragment" includes Fab fragments and F(ab')$_2$ fragments, and any portion of an antibody having specificity toward a desired epitope or epitopes. When using the term "radioactive metal chelate/antibody conjugate" or "conjugate", the "antibody" is meant to include whole antibodies and/or antibody fragments, including semisynthetic or genetically engineered variants thereof. Possible antibodies are 1116-NS-19-9 (anti-colorectal carcinoma), 1116-NS-3d (anti-CEA), 703D4 (anti-human lung cancer), 704A1 (anti-human lung cancer), CC49 (anti-TAG-72), CC83 (anti-TAG-72) and B72.3. The hybridoma cell lines 1116-NS-19-9, 1116-NS-3d, 703D4, 704A1, CC49, CC83 and B72.3 are deposited with the American Type Culture Collection, having the accession numbers ATCC HB 8059, ATCC CRL 8019, ATCC HB 8301, ATCC HB 8302, ATCC HB 9459, ATCC HB 9453 and ATCC HB 8108, respectively.

As used herein, "complex" refers to a complex of the compound of the invention, e.g. Formula (I), complexed with a metal ion, where at least one metal atom is chelated or sequestered; "conjugate" refers to a metal ion chelate that is covalently attached to an antibody or antibody fragment. The terms "bifunctional coordinator", "bifunctional chelating agent" and "functionalized chelant" are used interchangeably and refer to compounds that have a chelant moiety capable of chelating a metal ion and a moiety covalently bonded to the chelant moiety that is capable of serving as a means to covalently attach to an antibody or antibody fragment.

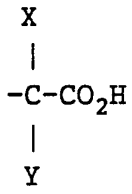
The bifunctional chelating agents described herein (represented by Formula I) can be used to chelate or sequester the metal ions so as to form metal ion chelates (also referred to herein as "complexes"). The complexes, because of the presence of the functionalizing moiety (represented by R^2, R^4 or R^6 in Formula I), can be covalently attached to biologically active materials, such as dextran, molecules that have specific affinity for a receptor, or preferably covalently attached to antibodies or antibody fragments. Thus the complexes described herein may be covalently attached to an antibody or antibody fragment or have specific affinity for a receptor and are referred to herein as "conjugates".

As used herein, "pharmaceutically-acceptable salt" means any salt or mixtures of salts of a complex or conjugate of formula (I) which is sufficiently non-toxic to be useful in therapy or diagnosis of animals, preferably mammals. Thus, the salts are useful in accordance with this invention. Representative of those salts formed by standard reactions from both

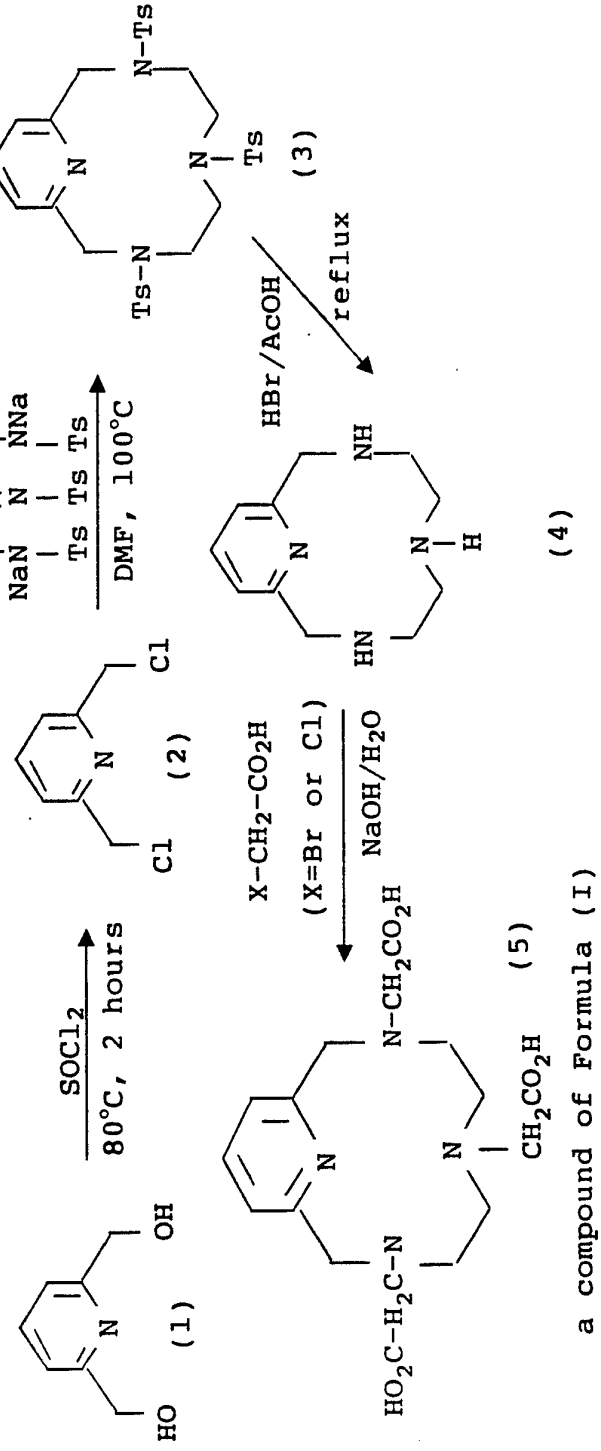
organic and inorganic sources include, for example, sulfuric, hydrochloric, phosphoric, acetic, succinic, citric, lactic, maleic, fumaric, palmitic, cholic, palmoic, mucic, glutamic, gluconic, d-camphoric, glutaric, glycolic, phthalic, tartaric, formic, lauric, steric, salicylic, methanesulfonic, benzenesulfonic, sorbic, picric, benzoic, cinnamic acids and other suitable acids. Also included are salts formed by standard reactions from both organic and inorganic sources such as ammonium or 1-deoxy-1-(methylamino)-D-glucitol, alkali metal ions, alkaline earth metal ions, and other similar ions. Particularly preferred are the salts of the complexes or conjugates of formula (I) where the salt is potassium, sodium or ammonium. Also included are mixtures of the above salts.

The complexes or conjugates of the present invention contain a ligand of Formula (I). The ligands are prepared by various processes. Typical general synthetic approaches to such processes are provided by the reaction schemes given below.

In Scheme 1, the compounds of Formula (I) are prepared wherein Q, A and Z = CH, and either one R = H and the other two R = the formula below or all three R =

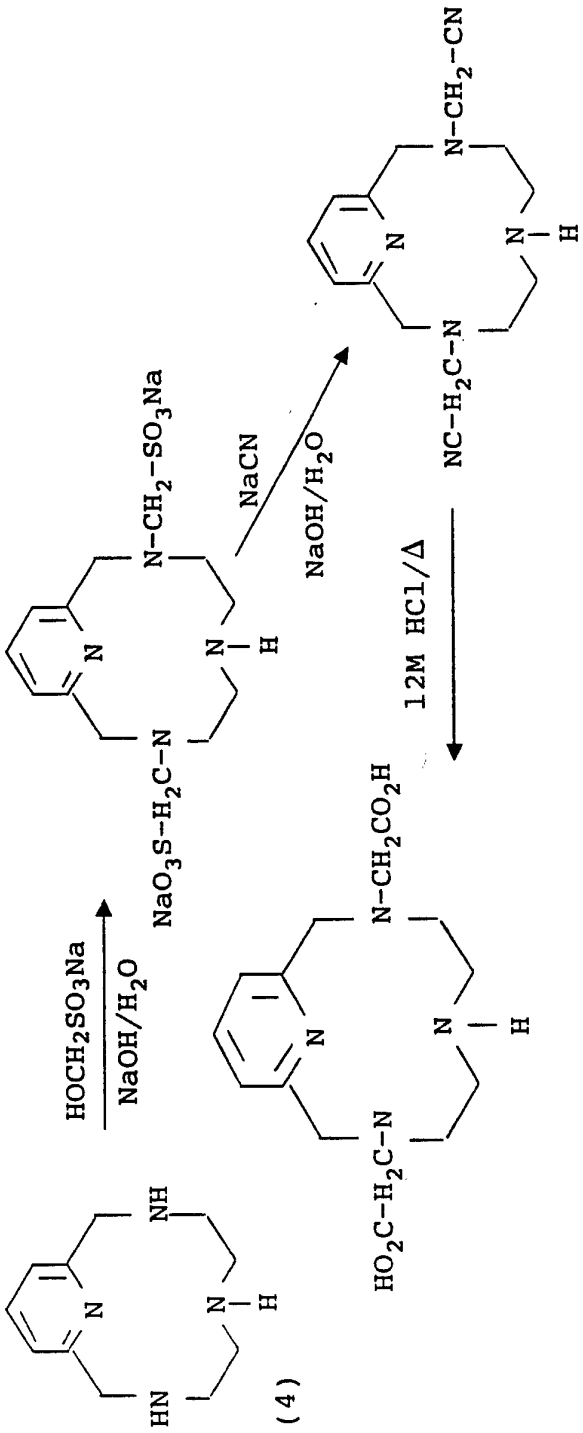


Scheme 1



a compound of Formula (I)

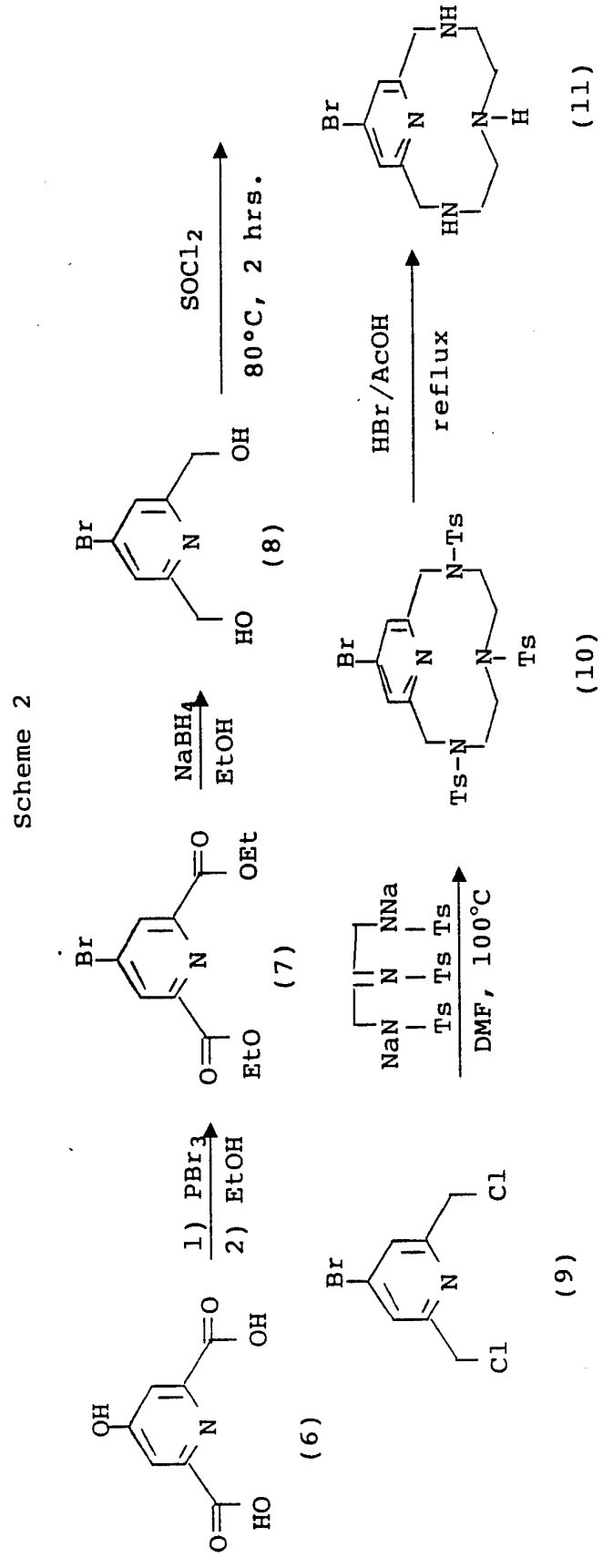
Scheme 1 Cont'd



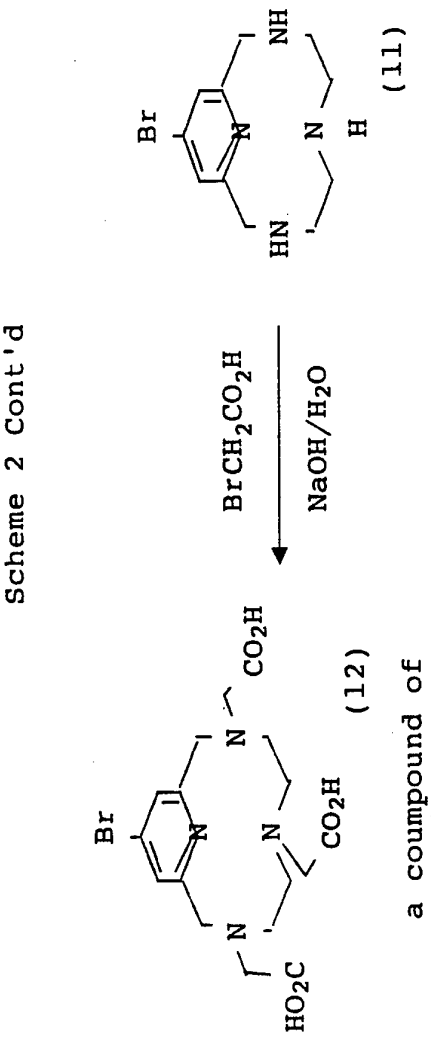
a compound of Formula (I)

Scheme 2 prepares the compounds of Formula (I) wherein A = C-Br, and Q and Z = CH.

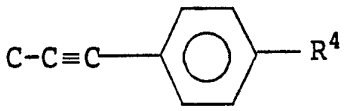
Scheme 2


Br
N
OH
HO
O
(6)
1) PBr3
2) EtOH
OEt
EtO
(7)
NaBH4
EtOH
(8)
SOCl2
80°C, 2 hrs.
Cl
(9)
NaN
NNa
Ts Ts Ts
DMF, 100°C
N-Ts
Ts-N
Ts
(10)
HBr/AcOH
reflux
NH
HN
H
(11)

Scheme 2 Cont'd



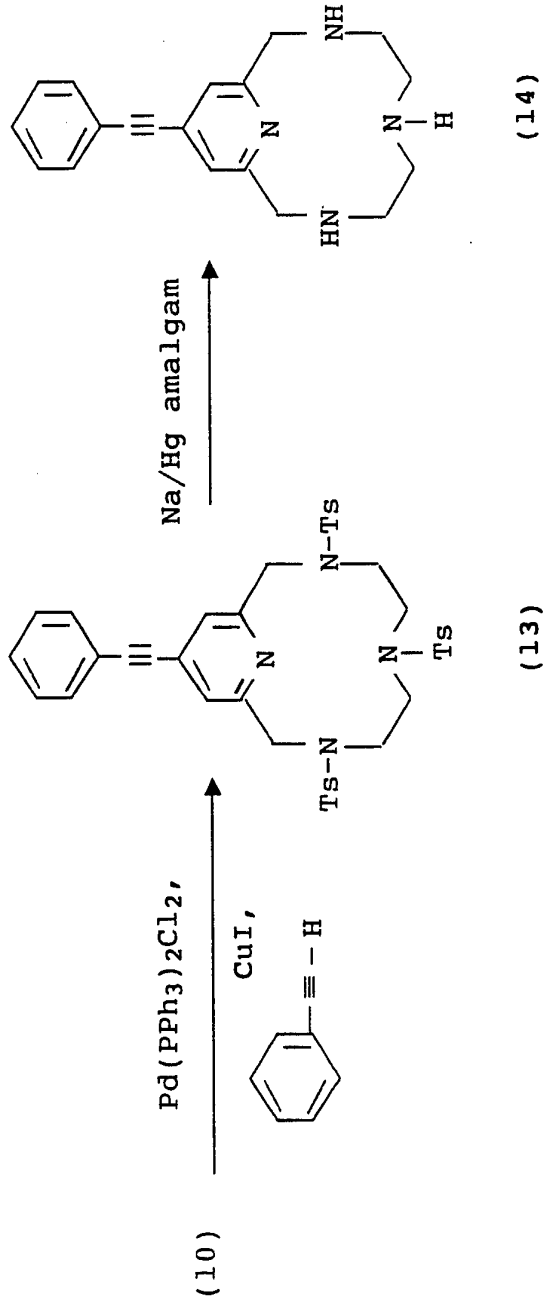
Scheme 3 prepares the compounds of Formula (I) wherein A =



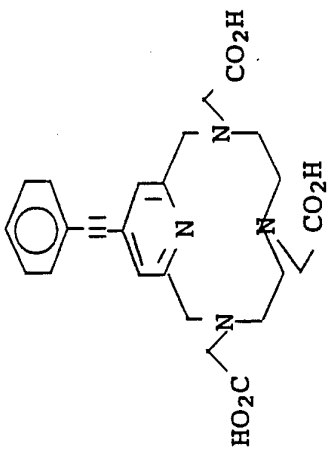
;

R^4 = H, NO_2, NH_2 or SCN; and Q and Z = CH.

Scheme 3



Scheme 3 Cont'd



(14) → (15)

$BrCH_2CO_2H$

$NaOH/H_2O$

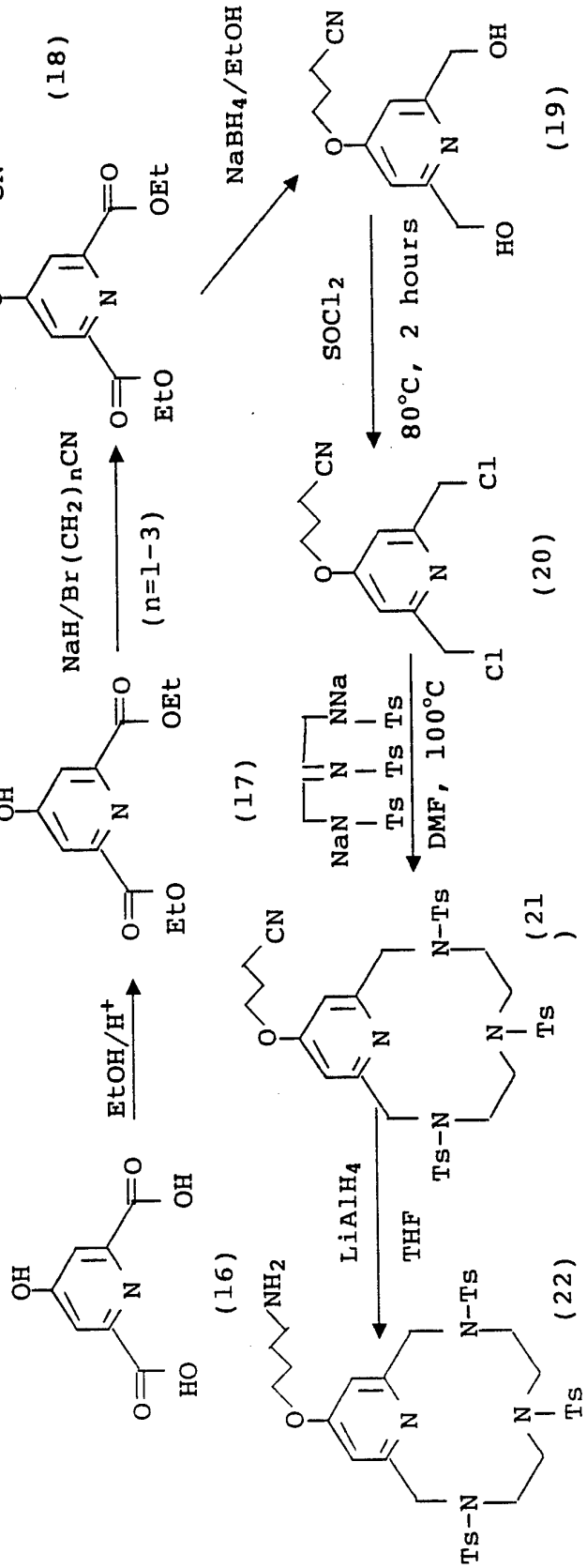
a compound of Formula (I)

Scheme 4 prepares the compounds of Formula (I) wherein A = C-OR^2,

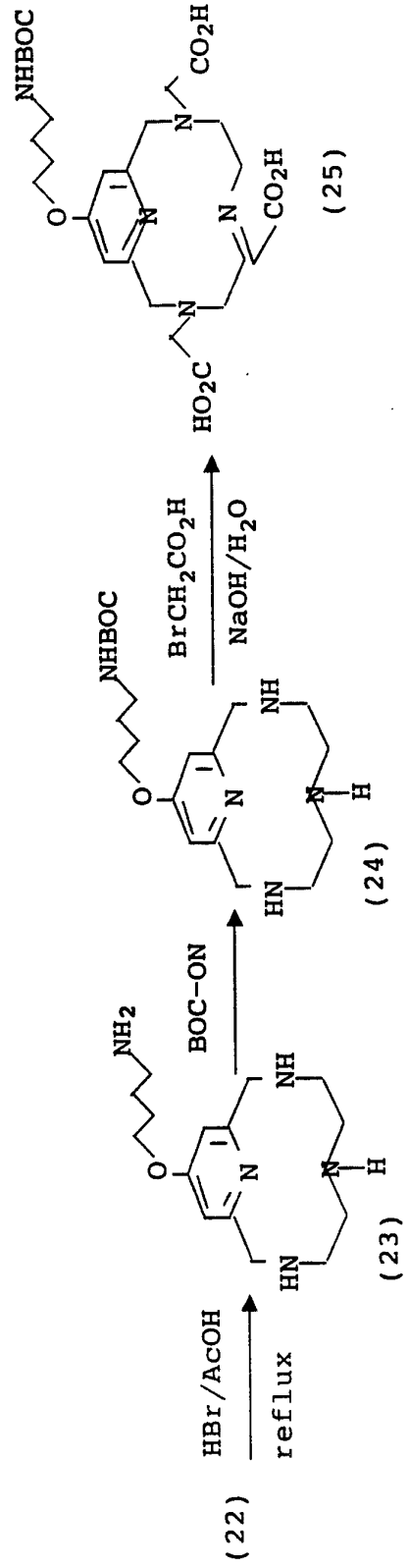
where R^2 = C_1-C_5 alkylamino; and

Q and Z = CH.

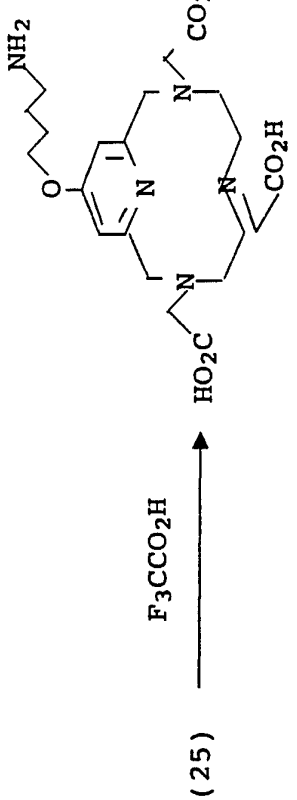
Scheme 4


(18)
(19)
(20)
(17)
(16)
(21)
(22)
NaBH4/EtOH
SOCl2
80°C, 2 hours
NaH/Br(CH2)nCN
(n=1-3)
EtOH/H+
DMF, 100°C
LiAlH4
THF
CN
OEt
EtO
OH
HO
Cl
NNa
NaN
Ts
N-Ts
Ts-N
NH2

Scheme 4 Cont'd



Scheme 4 Cont'd

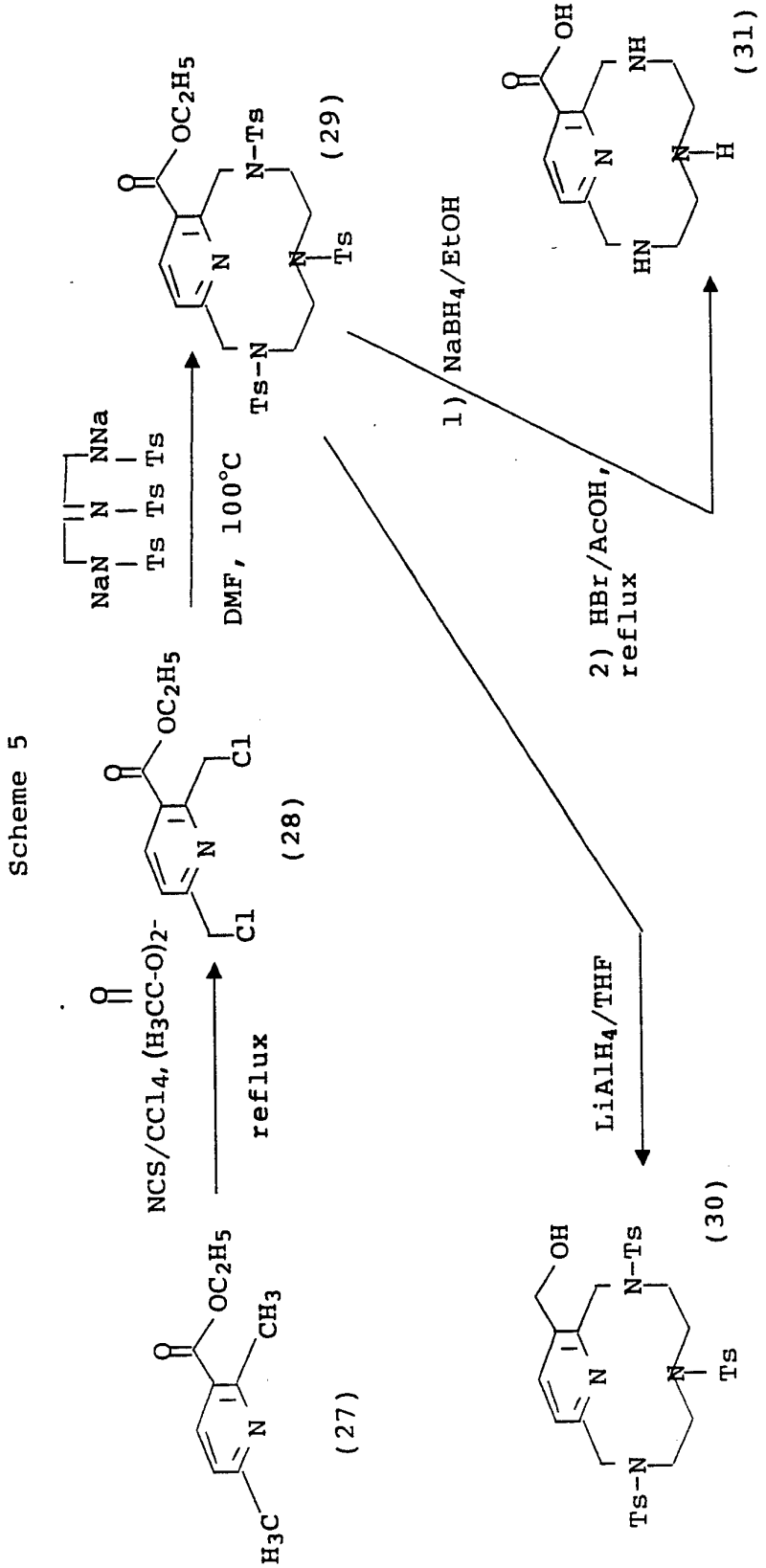


(25) (26)

a compound of Formula (I)

Scheme 5 prepares the compounds of Formula (I) wherein A = CH; and one of Q or Z = CH and the other Q or Z = C-C(O)-R^6 or C-CH_2-R^6, where R^6 is defined as before.

Scheme 5

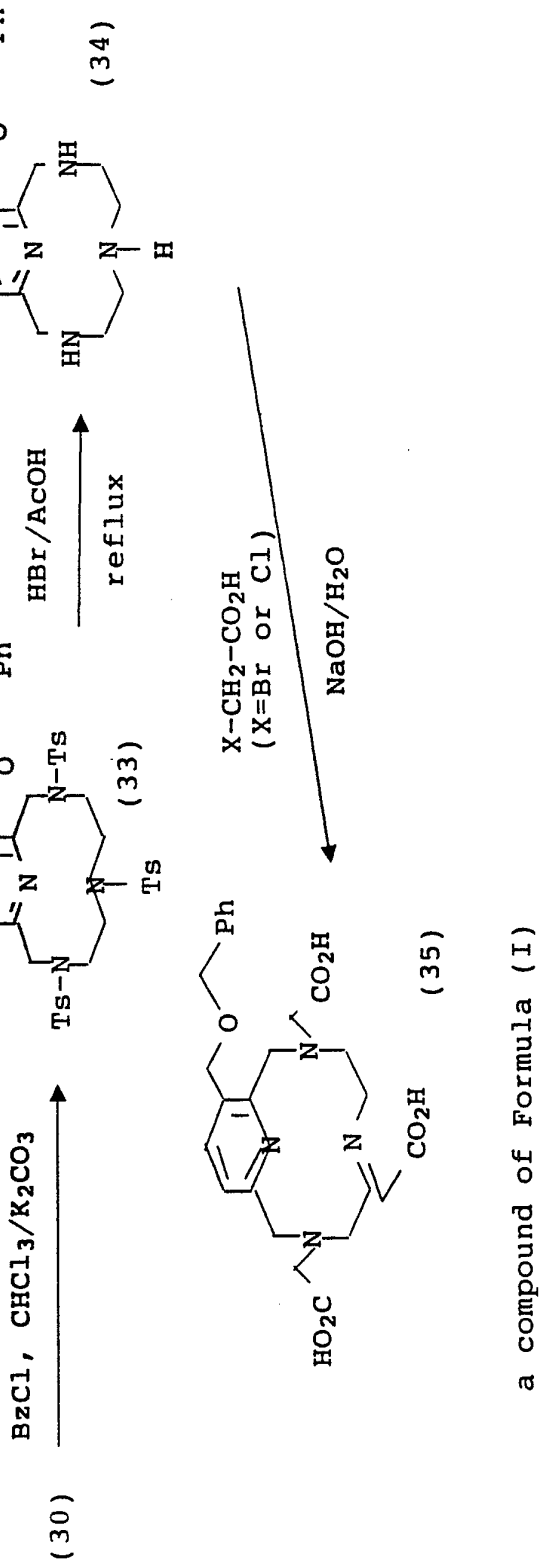

NCS/CCl4, (H3CC-O)2-
reflux
DMF, 100°C
LiAlH4/THF
1) NaBH4/EtOH
2) HBr/AcOH, reflux
(27)
(28)
(29)
(30)
(31)

Scheme 5 Cont'd

a compound of Formula (I)

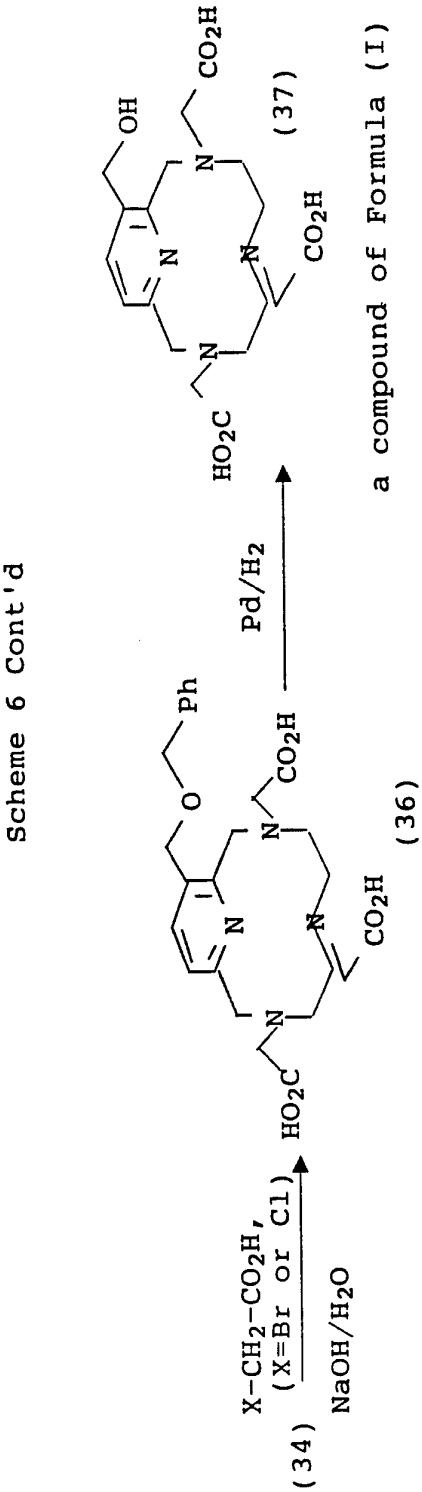
Scheme 6 prepares the compounds of Formula (I) wherein Z = C-CH_2-OBz or C-C(O)-R^5 where R^5 = -O-(C_1-C_3 alkyl), OH or NHR^6, where is defined as before; and Q and A = CH.

Scheme 6



a compound of Formula (I)

Scheme 6 Cont'd

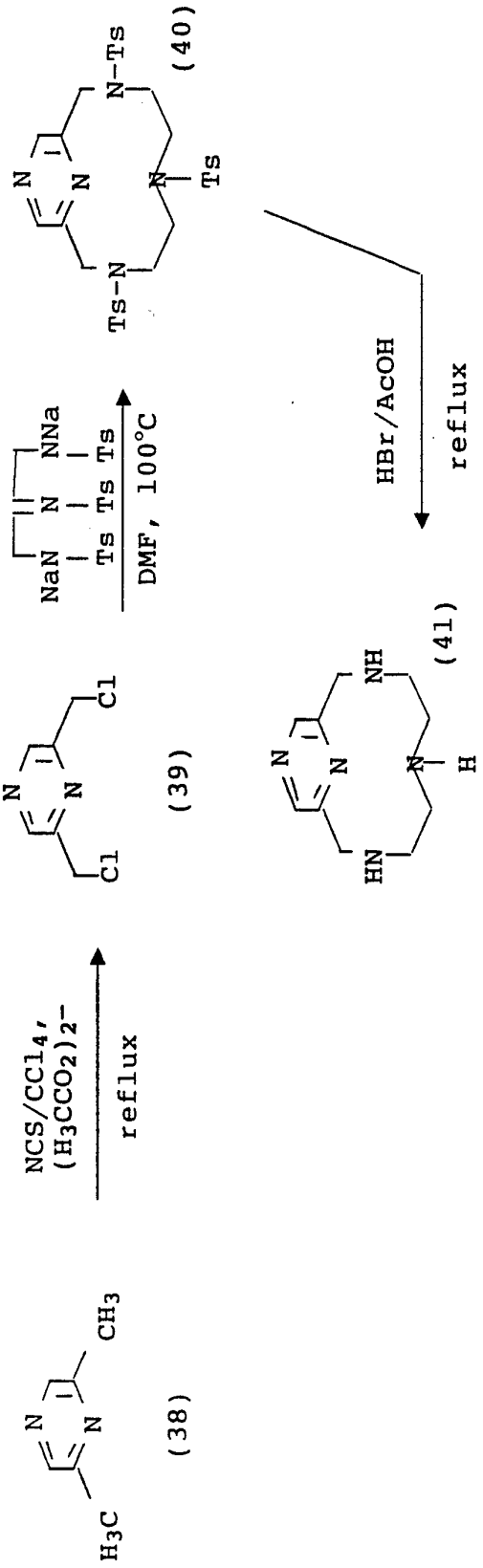


Scheme 7 prepares the compounds of Formula (I) wherein A = N or N^+-R^5

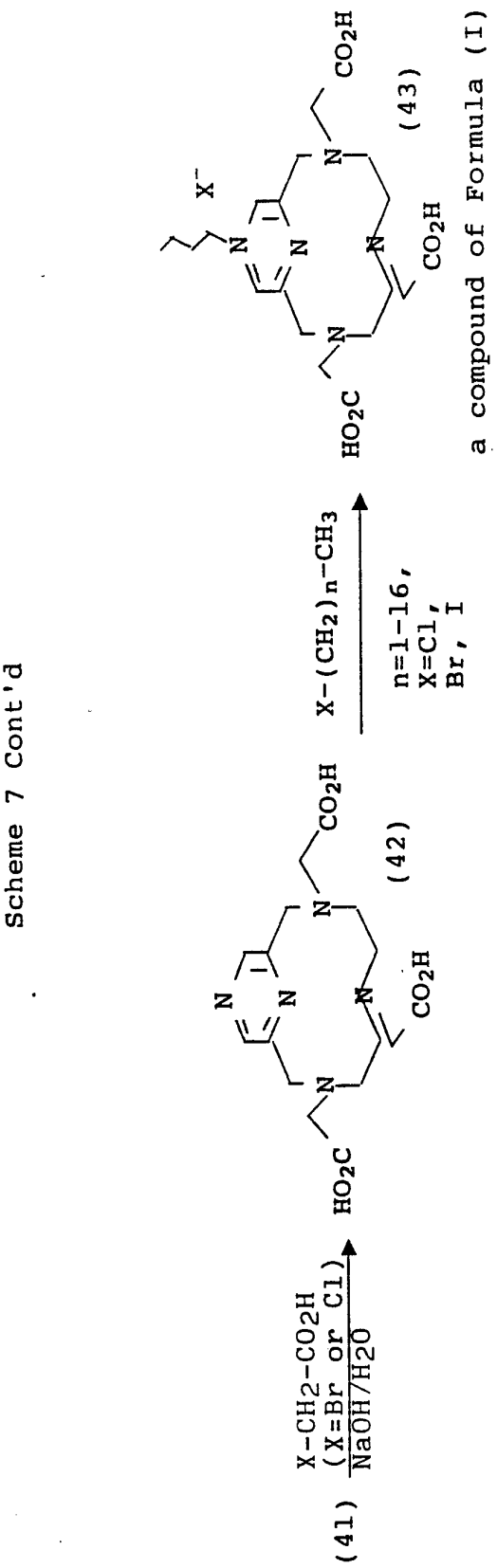
X^-; R^5 = C_1-C_{16} alkyl and is X^-halide; and

Q and Z = CH.

Scheme 7



Scheme 7 Cont'd

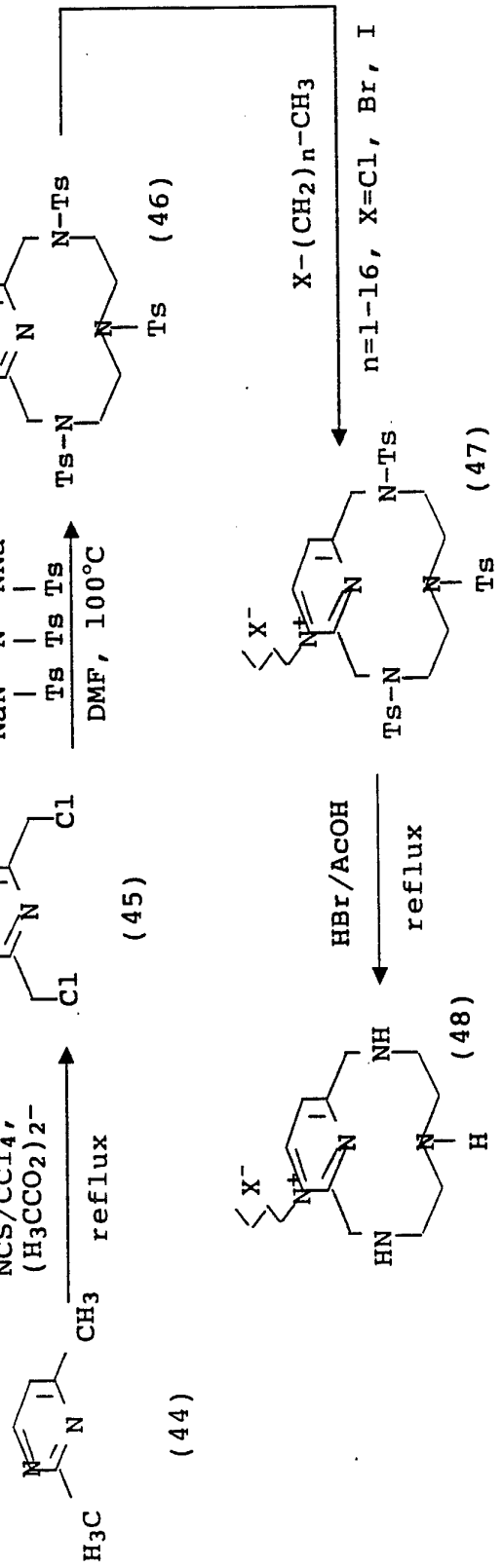


Scheme 8 prepares the compounds of Formula (I) wherein

Q = N^+-R^5 X^-, where R^5 = C_1-C_{16} alkyl and X^- = halide; and

A and Z = CH.

Scheme 8


NCS/CCl4,
(H3CCO2)2-
reflux
DMF, 100°C
HBr/AcOH
reflux
X-(CH2)n-CH3
n=1-16, X=Cl, Br, I
(44)
(45)
(46)
(47)
(48)

Scheme 8 Cont'd

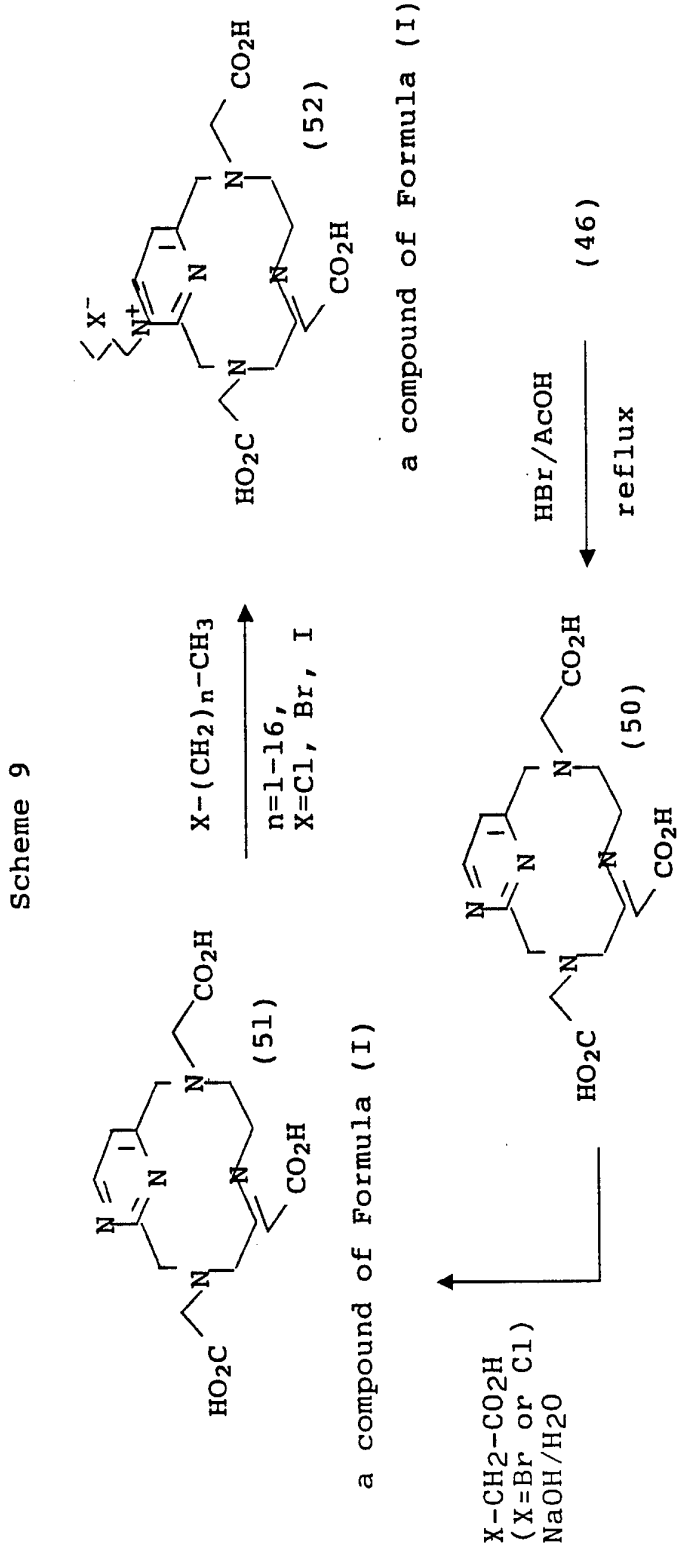
Scheme 9 prepares the compounds of Formula (I) wherein

Q = N or N+-R^5 X^-, where R^5 = C_1-C_{16} alkyl and

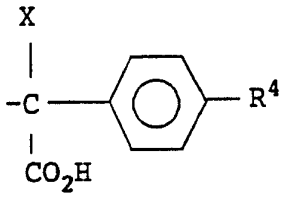
X^- = halide; and

A and Z = CH.

Scheme 9


a compound of Formula (I)
HBr/AcOH
reflux
(46)
(50)
X-CH2-CO2H
(X=Br or Cl)
NaOH/H2O
a compound of Formula (I)
X-(CH2)n-CH3
n=1-16,
X=Cl, Br, I
(51)
(52)

Scheme 10 prepares the compounds of Formula (I) wherein R term at the 6 position is

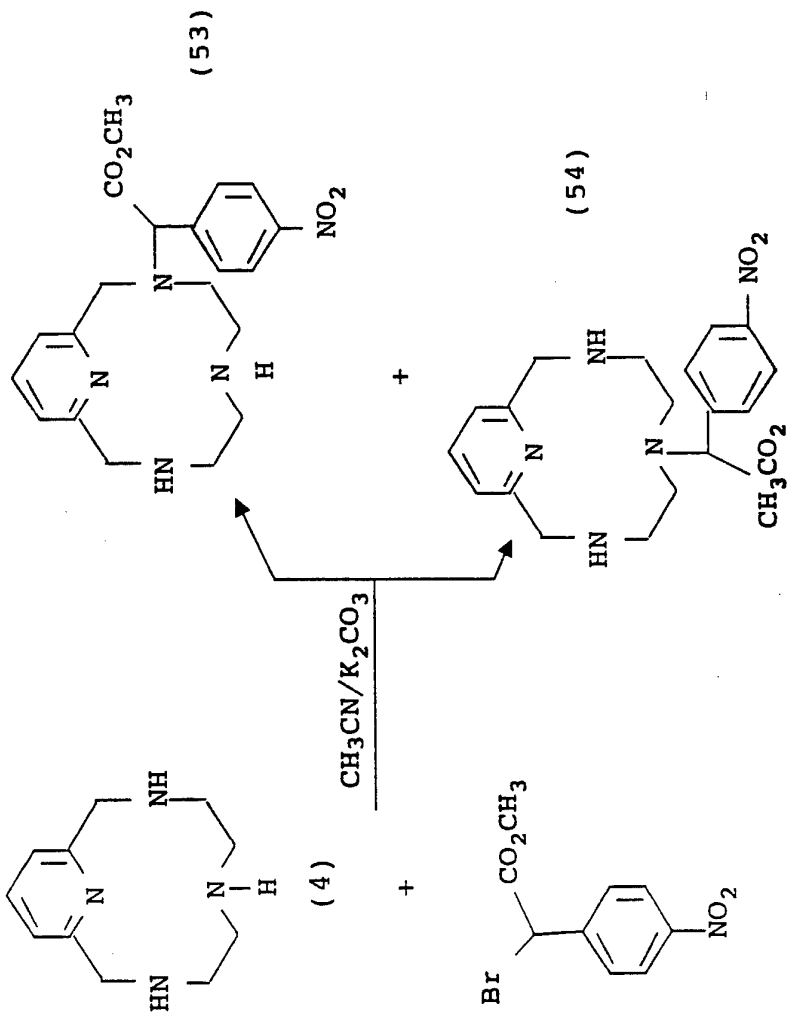


,

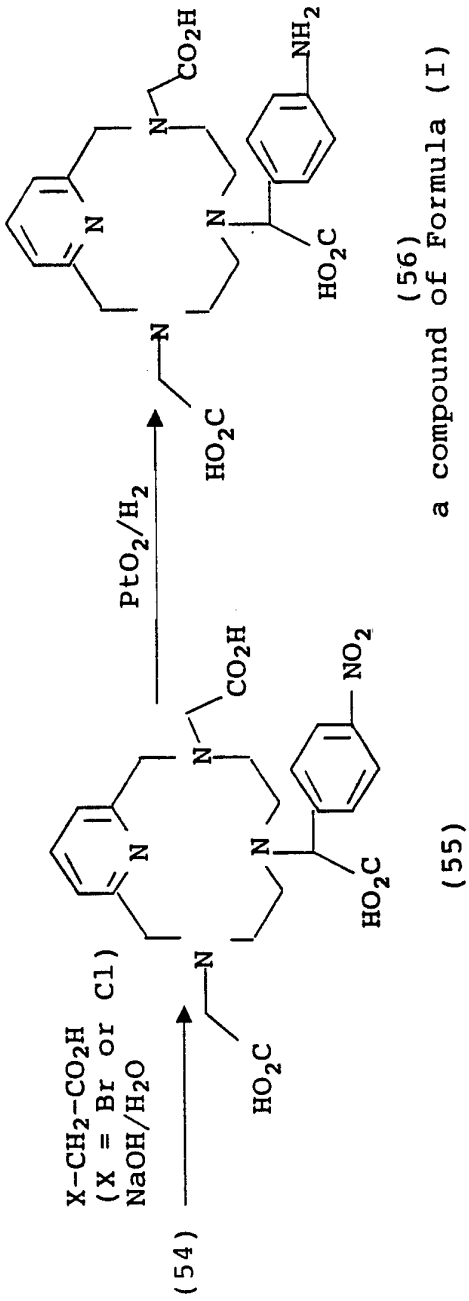
where R^4 = NO_2 or NH_2; and

A, Q and Z = CH.

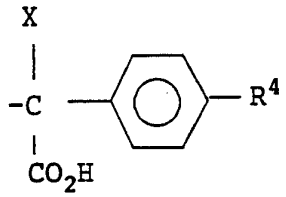
Scheme 10



Scheme 10 Cont'd

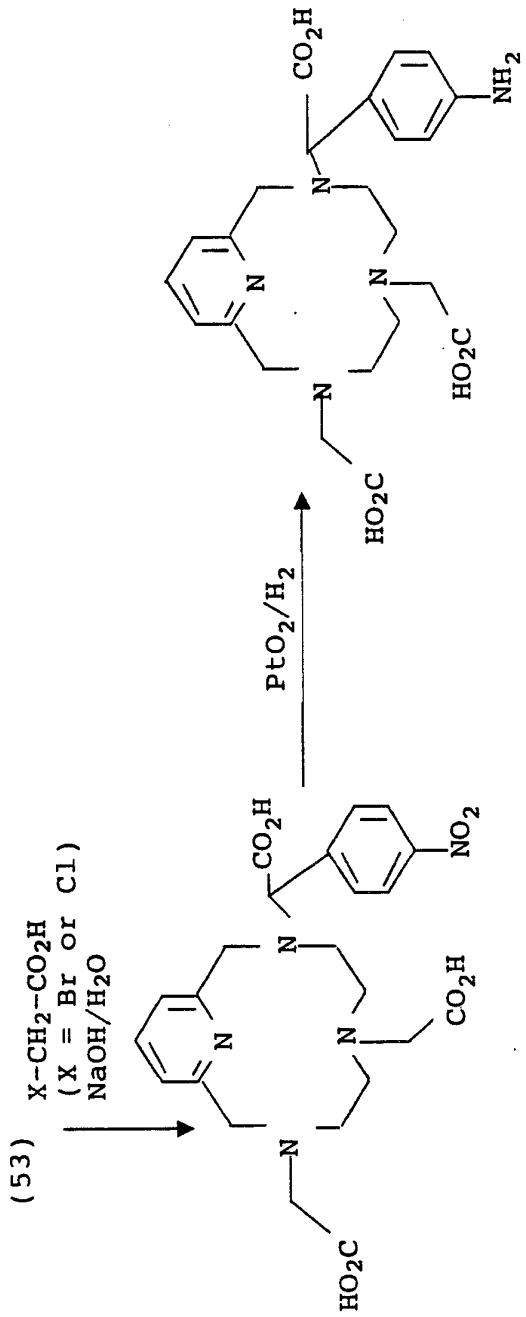


Scheme 11 prepares the compounds of Formula (I) wherein the R term at the 9 position is

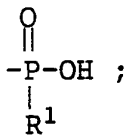


where R^4 = NO_2 or NH_2; and
A, Q and Z = CH.

Scheme 11

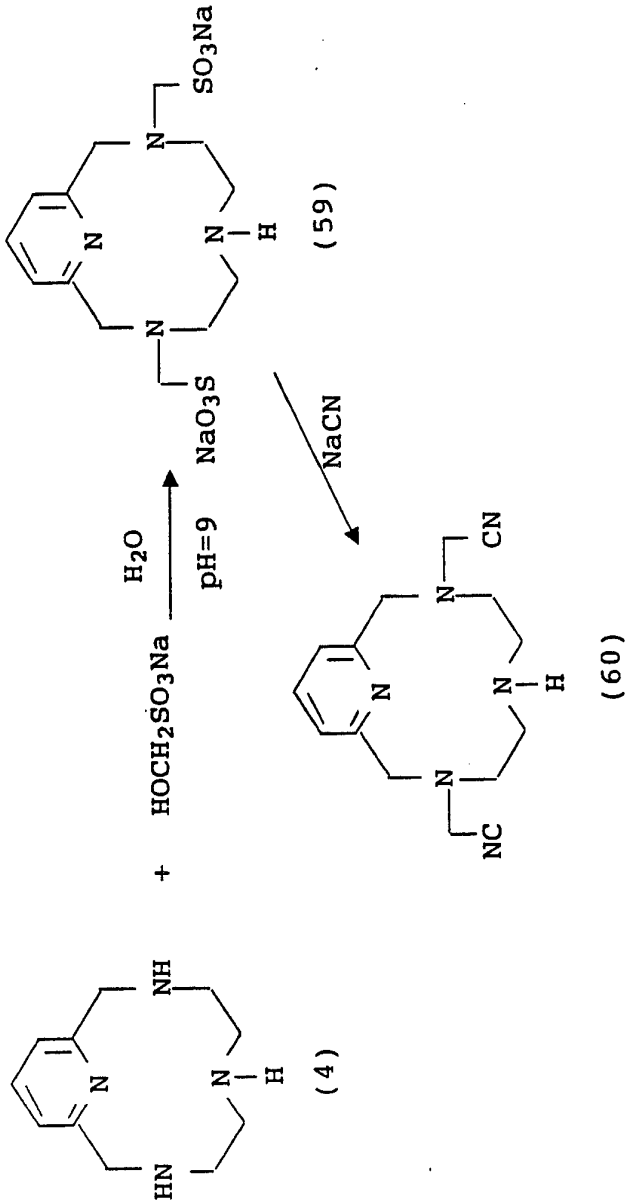

(53)
X-CH2-CO2H
(X = Br or Cl)
NaOH/H2O
PtO2/H2
CO2H
NO2
CO2H
HO2C
HO2C
(57)
a compound of Formula (I)
CO2H
NH2
HO2C
HO2C
(58)
a compound of Formula (I)

Scheme 12 prepares the compounds of Formula (I) wherein n = 1 (but would also apply if n = 2 or 3 with the corresponding change in the reagent), the R term at the 6 position has T =

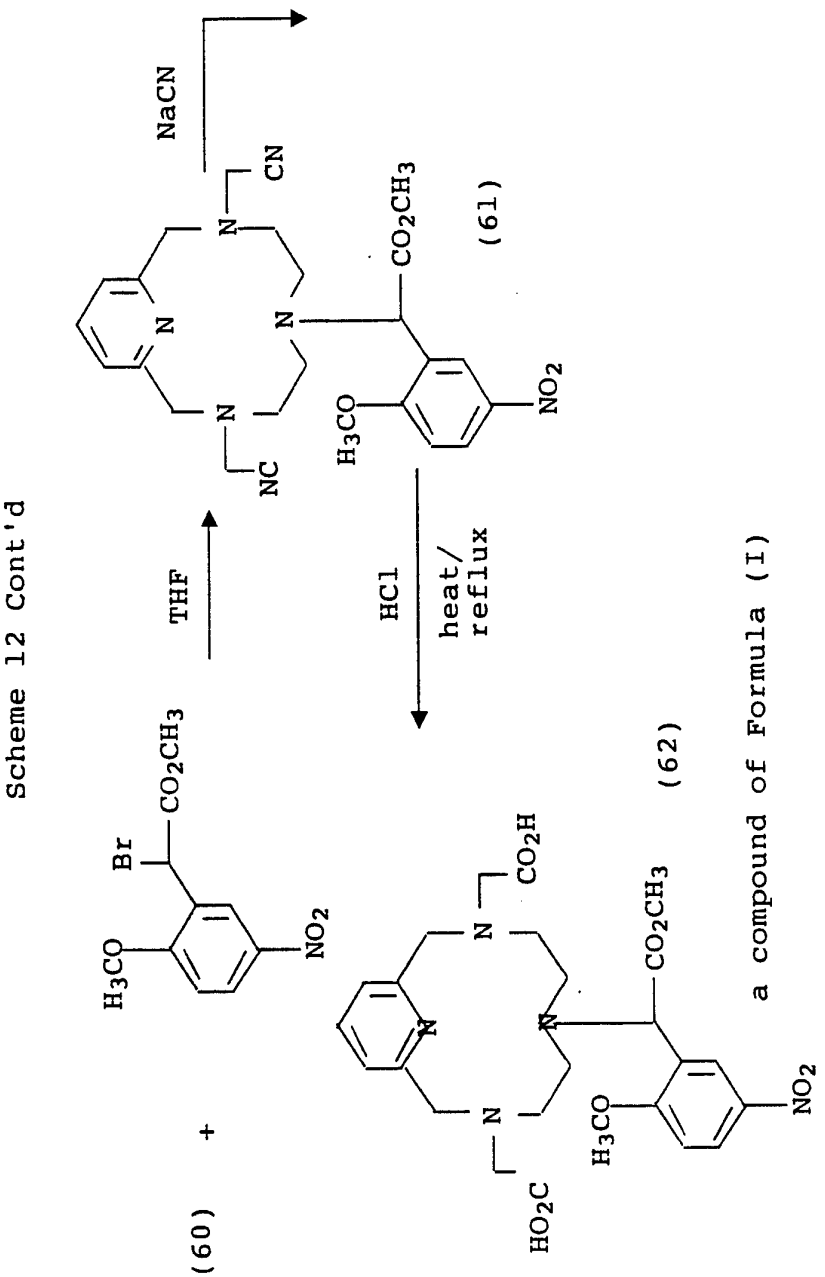


where R^1 = -OH; and X and Y = H;
the R term at the 3 and 9 positions have T = COOH; and
A, Q and Z = CH.

Scheme 12


SO3Na
N
N
H
(59)
N
N
NaO3S
NaCN
H2O
pH=9
HOCH2SO3Na
+
CN
N
N
H
(60)
N
N
NC
NH
N
N
H
(4)
HN

Scheme 12 Cont'd



In the above Schemes, the general process description illustrates specific steps that may be used to accomplish a desired reaction step. The general description of these process steps follows.

The synthetic Scheme 1 begins with a halogenation of commercially available bis-pyridyl alcohol (1) using thionyl chloride. Similar procedures for converting an alcohol to an electrophilic substrate, such as treatment with toluenesulfonyl chloride, HBr or HCl, should also result in a similarly reactive product which would work well in subsequent ring closure reactions. Macrocyclization procedures are numerous in the literature and the desired tetraazamacrocycle (3) was prepared according to the method of Stetter et al., *Tetrahedron* 37, 767-772 (1981). More general procedures have since been published which give good yields of similar macrocycles using milder conditions [A. D. Sherry et al., *J. Org. Chem.* 54, 2990-2992 (1989)]. Detosylation of the intermediate macrocycle [(3) to yield (4)] was accomplished under acidic conditions in good yield. Reductive detosylation procedures are also well known in the literature and can be adapted to the present reaction sequence.

Schemes 10, 11 and 12 delineate a synthetic approach which introduces an aromatic nitrobenzyl substituent at one of the macrocyclic nitrogen positions. Typically, the macrocyclic amine is mono-N-functionalized in an organic solvent such as acetonitrile or DMF at room temperature using a non-nucleophilic base such as potassium carbonate. Additional functionalization of the remaining nitrogen positions is then preformed by methods and conditions described in previous Schemes. After the introduction of the desired chelating moieties, the nitro group is reduced using platinum oxide and hydrogen in water. In this form, the chelating agent is compatible with conjugation techniques which will enable attachment to larger synthetic or natural molecules.

The metal ions used to form the complexes of this invention are Gd^{+3}, Mn^{+2}, Fe^{+3} and available commercially, e.g. from Aldrich Chemical Company. The anion present is halide, preferably chloride, or salt free (metal oxide).

A "paramagnetic nuclide" of this invention means a metal ion which displays spin angular momentum and/or orbital angular momentum. The two types of momentum combine to give the observed paramagnetic moment in a manner that depends largely on the atoms bearing the unpaired electron and, to a lesser extent, upon the environment of such atoms. The paramagnetic nuclides found to be useful in the practice of the invention are gadolinium (Gd^{+3}), iron (Fe^{+3}) and manganese (Mn^{+2}), with Gd^{+3} being preferred.

The complexes are prepared by methods well known in the art. Thus, for example, see Chelating Agents and Metal Chelates, Dwyer & Mellor, Academic Press (1964), Chapter 7. See also methods for making amino acids in Synthetic Production and Utilization of Amino Acids, (edited by Kameko, et al.) John Wiley & Sons (1974). An example of the preparation of a complex involves reacting a bicyclopolyazamacrocyclophosphonic acid with

the metal ion under aqueous conditions at a pH from 5 to 7. The complex formed is by a chemical bond and results in a stable paramagnetic nuclide composition, e.g. stable to the disassociation of the paramagnetic nuclide from the ligand.

The complexes of the present invention are administered at a ligand to metal molar ratio of at least about 1:1, preferably from 1:1 to 3:1, more preferably from 1:1 to 1.5:1. A large excess of ligand is undesirable since uncomplexed ligand may be toxic to the animal or may result in cardiac arrest or hypocalcemic convulsions.

The antibodies or antibody fragments which may be used in the conjugates described herein can be prepared by techniques well known in the art. Highly specific monoclonal antibodies can be produced by hybridization techniques well known in the art, see for example, Kohler and Milstein [*Nature*, 256, 495-497 (1975); and *Eur. J. Immunol.*, 6, 511-519 (1976)]. Such antibodies normally have a highly specific reactivity. In the antibody targeted conjugates, antibodies directed against any desired antigen or hapten may be used. Preferably the antibodies which are used in the conjugates are monoclonal antibodies, or fragments thereof having high specificity for a desired epitope(s). Antibodies used in the present invention may be directed against, for example, tumors, bacteria, fungi, viruses, parasites, mycoplasma, differentiation and other cell membrane antigens, pathogen surface antigens, toxins, enzymes, allergens, drugs and any biologically active molecules. Some examples of antibodies or antibody fragments are 1116-NS-19-9, 1116-NS-3d, 703D4, 704A1, CC49, CC83 and B72.3. All of these antibodies have been deposited in ATCC. A more complete list of antigens can be found in U.S. Patent 4,193,983. The conjugates of the present invention are particularly preferred for the diagnosis of various cancers.

This invention is used with a physiologically acceptable carrier, excipient or vehicle therefor. The methods for preparing such formulations are well known. The formulations may be in the form of a suspension, injectable solution or other suitable formulations. Physiologically acceptable suspending media, with or without adjuvants, may be used.

An "effective amount" of the formulation is used for diagnosis. The dose will vary depending on the disease and physical parameters of the animal, such as weight. *In vivo* diagnostics are also contemplated using formulations of this invention.

Other uses of some of the chelants of the present invention may include the removal of undesirable metals (i.e. iron) from the body, attachment to polymeric supports for various purposes, e.g. as diagnostic agents, and removal of metal ion by selective extraction. The ligands of Formula (I) having in at least two R terms T equal to $P(O)R^1OH$ may be used for metal ion control as scale inhibitors. It is likely that these ligands could be used in less than stoichiometric amounts. Similar uses are known for compounds described in U.S. Patents 2,609,390; 3,331,773; 3,336,221; and 3,434,969.

The invention will be further clarified by a consideration of the following examples, which are intended to be purely exemplary of the present invention.

Some terms used in the following examples are defined as follows:

LC = liquid chromatrography, purifications were carrier out at low pressure using Dionex 2010i system fitted with a hand-packed Q-Sepharose™ anion exchange column (23 x 2 cm).

DMF = dimethylformamide.

AcOH = acetic acid.

ICP = inductively coupled plasma.

g = gram(s).

mg = milligrams.

kg = kilogram(s).

mL = milliliter(s).

µL = microliter(s).

pH Stability General Procedure

A stock $^{159}GdCl_3$ or $^{153}SmCl_3$ solution was prepared by adding 2 µL of $3x10^{-4}M$ $^{159}GdCl_3$ in 0.1N HCl to 2 mL of a $3x10^{-4}M$ $GdCl_3$ carrier solution. Appropriate ligand solutions were then prepared in deionized water. The 1:1 ligand/metal complexes were then prepared by combining the ligands (dissolved in 100-500 µL of deionized water) with 2 mL of the stock $^{159}GdCl_3$ solution, followed by through mixing to give an acidic solution (pH = 2). The pH of the solution was then raised to 7.0 using 0.1N NaOH. The percent metal as a complex was then determined by passing a sample of the complex solution through a Sephadex™ G-50 column, eluting with 4:1 saline (85% $NaCl/NH_4OH$) and collecting 2 x 3 mL fractions. The amount of radioactivity in the combined elutions was then compared with that left on the resin (non-complexed metal is retained on the resin). The pH stability profile was generated by adjusting the pH of an aliquet of the complex solution using 1M NaOH or 1M HCl and determining the percent of the metal existing as a complex using the ion exchange method described above. The Sm results are known by expermintal comparison to be identical for complexation and biodistribution of the ligands of this invention.

STARTING MATERIALS

Example A

Preparation of 2,6-bis(chloromethyl)pyridine.

To 100 mL of thionyl chloride that was cooled (ice bath) was added 24 g (0.17 mol) of 2,6-bis(hydroxymethyl)pyridine. After 30 min, the reaction mixture was warmed to room temperature, then refluxed for 1.5 hrs. After cooling the reaction mixture to room temperature, the solid which formed was filtered, washed with benzene and dried *in vacuo*.

The solid was then neutralized with saturated $NaHCO_3$, filtered and dried to yield 23.1 g (71.5%) of the titled product as an off-white crystalline solid, mp 74.5-75.5°C, and further characterized by:

^1H NMR ($CDCl_3$)

δ 4.88 (s, 4H), 7.25-7.95 (m, 3H).

Example B

Preparation of 3,6,9-tris(*p*-tolylsulfonyl)-3,6,9,15-tetraazabicyclo[9.3.1]pentadeca-1(15),11,13-triene.

A DMF solution (92 mL) of 6.9 g (11.4 mmol) of 1,4,7-tris(*p*-tolylsulfonyl)diethylenetriamine disodium salt was stirred and heated to 100°C under nitrogen. To the solution was added dropwise over 45 min 2 g (11.4 mmol) of 2,6-bis(chloromethyl)pyridine (prepared by the procedure of Example A) in 37 mL of DMF. When the addition was completed the reaction mixture was stirred at 40°C for 12 hrs. To the reaction mixture was then added 50-75 mL of water, resulting in immediate dissolution NaCl, followed by precipitation of the title product. The resulting slurry was then filtered and the solid washed with water and dried *in vacuo*. The title product was obtained as a light-tan powder, 6.5 g (86%), mp 168-170°C dec. and further characterized by:

^1H NMR ($CDCl_3$)

δ 2.40 (s, 3H), 2.44 (s, 6H), 2.75 (m, 4H), 3.30 (m, 4H), 4.28 (s, 4H), 7.27 (d, 2H), 7.34 (d, 4H), 7.43 (d, 2H), 7.65 (d, 4H), 7.75 (t, 1H); and

^{13}C NMR

δ 21.48, 47.29, 50.37, 54.86, 124.19, 127.00, 127.11, 129.73, 135.04, 135.74, 138.95, 143.42, 143.73, 155.15.

Example C

Preparation of 3,6,9,15-tetraazabicyclo[9.3.1]pentadeca-1(15),11,13-triene.

A solution of HBr and AcOH was prepared by mixing 48% HBr and glacial AcOH in a 64:35 ratio. To 112 mL of the HBr/AcOH mixture was added 5.5 g (8.2 mmol) of 3,6,9-tris(*p*-tolylsulfonyl)-3,6,9,15-tetraazabicyclo[9.3.1]pentadeca-1(15),11,13-triene (prepared by the procedure of Example B) and the reaction mixture was heated at mild reflux with constant stirring for 72 hrs. The reaction mixture was then cooled to room temperature and concentrated to approximately 1/10 of the original volume. The remaining solution was stirred vigorously and 15-20 mL of diethyl ether was added. A off-white solid formed which was filtered, washed with diethyl ether, and dried *in vacuo*. The dry tetrahydrobromide salt was then dissolved in 10 mL of water, adjusted to pH 9.5 with NaOH (50% w/w) and continuously extracted with chloroform for 4 hrs. After drying over anhydrous sodium sulfate, the chloroform was evaporated to give a light-tan oil which gradually crystallized upon standing at room temperature to yield 1.2 g (71%) of the title product, mp 86-88°C and further characterized by:

^{1}H NMR ($CDCl_3$)

δ 2.21 (m, 4H), 2.59 (m, 4H), 3.06 (s, 3H), 3.85 (s, 4H), 6.89 (d, 2H), 7.44 (t, 1H); and

^{13}C NMR

δ 48.73, 49.01, 53.63, 119.67, 136.29, 159.54.

Example D

Preparation of 3,6,9,15-tetraazabicyclo[9.3.1]pentadeca-1(15),11,13-triene-3,6,9-triacetic acid (PCTA).

An aqueous solution (15 mL) of 2.1 g (15 mmol) of bromoacetic acid was added to 0.8 g (3.8 mmol) of 3,6,9,15-tetraazabicyclo[9.3.1]pentadeca-1(15),11,13-triene (prepared by the procedure of Example C) with stirring at room temperature. After complete dissolution, the reaction mixture was cooled with an ice bath and the pH adjusted to 9 by the slow addition of NaOH (50%w/w). The pH was held constant at 9 throughout the reaction by adding small aliquots of NaOH. After 1.5 hrs the reaction mixture was warmed to 60°C with continued monitoring of pH. When no further drop in pH could be detected, the reaction was cooled to room temperature and the aqueous solution freeze-dried to give a white solid. The solid was then dissolved in a minimum of hot water and allowed to stand at room temperature for 12 hrs. The resulting crystals were filtered and dried *in vacuo* to give 1.2 g (70%) of the title product as the trisodium salt, mp 378-380°C dec. and further characterized by:

^{1}H NMR (D_2O)

δ 2.76 (m, 4H), 3.36 (m, 4H), 3.47 (s, 2H), 4.10 (s, 4H), 7.31 (d, 2H), 7.84 (t, 1H); and

^{13}C NMR

δ 53.83, 57.31, 57.40, 59.48, 62.36, 125.47, 143.72, 152.67, 172.15, 177.41.

Example E

Preparation of 3,9-bis(sodium methylenesulfonate)-3,6,9,15-tetraazabicyclo[9.3.1]pentadeca-1(15),11,13-triene (PC2S).

A solution of 10 mL of an aqueous solution of 1.03 g (5.0 mmol) of 3,6,9,15-tetraazabicyclo[9.3.1]pentadeca-1(15),11,13-triene (prepared by the procedure of Example C) and 0.5 mL of concentrated HCl was stirred for 10 min at room temperature. The solution had a pH of 8.6. To the solution was then added 1.37 g (10.2 mmol) of $HOCH_2SO_3Na$ and 5 mL of deionized water. The solution was then heated at 60°C for 10 min and the pH was 5.6. After cooling, the pH was adjusted to 9.0 with 1M NaOH, followed by freeze-drying to give the desired product as a white solid (quantitative yield), and further characterized by:

^{1}H NMR (D_2O)

δ 2.87 (t, 4H), 3.18 (t, 4H), 3.85 (s, 4H), 4.11 (s, 4H), 7.03 (d, 2H), 7.55 (t, 1H); and

^{13}C NMR (D_2O)

δ 48.52, 54.04, 58.92, 75.09, 123.90, 141.37, 161.89.

Example F

Preparation of 3,9-bis(methylenenitrile)-3,6,9,15-tetraazabicyclo[9.3.1]pentadeca-1(15),11,13-triene.

To an aqueous solution of 10 mL of 3,9-bis(sodium methylenesulfonate)-3,6,9,15-tetraazabicyclo[9.3.1]pentadeca-1(15),11,13-triene (prepared by the procedure of Example E) was added 10 mL of 0.06 g (12.24 mmol) of NaCN. The reaction mixture was stirred for 3 hrs at room temperature. The solution had a pH of about 10. Upon adjustment of the pH to greater than 13 by with concentrated NaOH, the product precipitated, was extracted with chloroform (3 x 20 mL), dried over magnesium sulfate, and filtered. Upon removal of the solvent and concentration *in vacuo*, the desired product was isolated as a waxy white powder, 1.00 g (71%), and further characterized by:

^{1}H NMR ($CDCl_3$)

δ 2.03 (s br, 4H), 2.64 (m, 4H), 3.82 (s, 4H), 3.90 (s, 4H), 7.14 (d, 2H), 7.62 (t, 1H); and

^{13}C NMR ($CDCl_3$)

δ 46.64, 52.89, 60.78, 115.31, 122.02, 137.57, 157.33.

Example G

Preparation of 3,6,9,15-tetraazabicyclo[9.3.1]pentadeca-1(15),11,13-triene-3,9-dimethylenenitrile-6-(2-methoxy-5-nitrophenyl)methyl acetate.

To 7 mL of a THF solution of 200 mg (0.73 mmol) of 3,6,9,15-tetraazabicyclo[9.3.1]pentadeca-1(15),11,13-triene-3,9-dimethylenenitrile (prepared by the procedure of Example F) was added 223 mg (0.73 mmol) of bromo-(2-methoxy-5-nitrophenyl)methyl acetate. The resulting solution was stirred at room temperature for 12 hrs. To the reaction mixture was added 100 mg of K_2CO_3 and the mixture stirred for an additional 2 hrs. The reaction mixture was then filtered and the filtrate concentrated *in vacuo*. The resulting crude product was then purified by column chromatography (silica gel, 5% $CH_3OH/CHCl_3$).

Example H

Preparation of 3,6,9,15-tetraazabicyclo[9.3.1]pentadeca-1(15),11,13-triene-3,9-acetic acid-6-(2-methoxy-5-nitrophenyl)acetic acid.

3,6,9,15-Tetraazabicyclo[9.3.1]pentadeca-1(15),11,13-triene-3,9-dimethylenenitrile-6-(2-methoxy-5-nitrophenyl)methyl acetate (prepared by the procedure of Example G) was stirred for 12 hrs at reflux in 6N HCl. The solution was then cooled and concentrated *in vacuo*. The residue was then dissolved in water and lyophilized to give the desired product.

Example I

Preparation of 3,9-diacetic acid-3,6,9,15-tetraazabicyclo[9.3.1]pentadeca-1(15),11,13-triene (PC2A).

A concentrated aqueous solution of 30 mL of HCl (37%) and mg (2.5 mmol) of 3,9-bis(methylenenitrile)-3,6,9,15-tetraazabicyclo[9.3.1]pentadeca-1(15),11,13-triene(prepared by the procedure of Example F) was heated at reflux for 2 hrs. After cooling, the aqueous solution was evaporated to dryness, followed by coevaporation with deionized water (2 x 10 mL) to eliminate excess HCl. The pH of the reaction mixture was adjusted to 7 with concentrated NaOH. The resulting nutral solution chromatographed on cation exchange (SP-Sepharose™) column (1.5 x 50 cm), elutin with first deionized water, then with 1M HCl. The acidic fraction containing product was evaporated to dryness, followed by coevaporation with deionized water (3 x 10 mL) to eliminate excess HCl. The final product was isolated as a white solid upon freeze drying of the concentrated aqueous solution, and characterized by:

^{1}H NMR (D_2O)

δ 2.84 (s br, 4H), 3.18 (m, 4H), 3.77 (s, 4H), 4.35 (s, 4H), 7.63 (d, 2H), 8.23 (t, 1H); and

^{13}C NMR (D_2O)

δ 47.45, 54.33, 59.73, 60.36, 127.20, 149.31, 155.60, 177.74.

FINAL PRODUCTS

Example 1

Preparation of the complex of ^{153}Sm-3,6,9,15-tetraazabicyclo[9.3.1]pentadeca-1(15),11,13-triene-3,6,9-trimethylenecarboxylic acid (^{153}Sm-PCTA)

A solution of the ligand of Example D was prepared by dissolving 3.8 mg of ligand/0.517 mL of deionized water (pH = 2). A 1:1 ligand/metal complex was then prepared by combining 40 µL of the ligand solution with 2 mL of aqueous $SmCl_3 \cdot H_2O$ ($3x10^{-4}$M in 0.01N HCl) containing tracer $^{153}SmCl_3$. After thorough mixing, the percent metal as a complex was determined by passing a sample of the complex solution through a Sephadex™ column, eluting with 4:1 saline (0.85% NaCl/NH_4OH), and collecting 2 x 3 mL fractions. The amount of radioactivity in the combined elutions was then compared with that left on the resin. Under these conditions, complex was removed with the eluent and non-complexed metal is retained on the resin. By this method complexation was determined to be 92%. A sample of the solution that was passed through the resin was used for pH studies. The pH stability was then determined using the General Procedure above.

Complexation for the title product after passing through the resin was determined to be greater than 98% at the 1:1 ligand to metal ratio.

BIODISTRIBUTION

General Procedure

Sprague Dawley rats were allowed to acclimate for five days then injected with 100 µL of the complex solution via a tail vein. The rats weighed between 150 and 200 g at the time of injection. After 30 min. the rats were killed by cervical dislocation and dissected. The amount of radioactivity in each tissue was determined by counting in a NaI scintillation counter

coupled to a multichannel analyzer. The counts were compared to the counts in 100 µL standards in order to determine the percentage of the dose in each tissue or organ.

The percent dose in blood was estimated assuming blood to be 7% of the body weight. The percent dose in bone was estimated by multipuling the percent dose in the femur by 25. The percent dose in muscle was estimated assuming muscle to be 43% of the body weight.

In addition to organ biodistribution, chelates of the compounds of Formula (I) were evaluated for efficiency of bone localization since phosphonates are known for their ability to bind to hydroxyapatite.

EXAMPLE I

The percent of the injected dose of complex of of Example 1 (^{153}Sm-PCTA) in several tissues are given in Table I. The numbers represent the average of 5 rats per data point.

TABLE I
% INJECTED DOSE IN SEVERAL TISSUES FOR Sm-PCTA

Tissue	Average
Bone	2.77
Liver	0.80
Kidney	1.50
Spleen	0.12
Muscle	0.87
Blood	0.39

The bone to blood ratio (% dose) was 7. The bone to liver ratio was 3.5. The bone to muscle ratio was 4.8.

IMAGING EXPERIMENTS

General Procedure

Injectable solutions were first prepared (0.5M) by dissolving the appropriate amount of each complex in 2 mL of deionized water. The pH of the solutions were then adjusted to 7.4 using 1M HCl or NaOH as needed. The total Gd content of each solution was then determined by ICP analysis.

An anesthetized Sprague Dawley rat was injected intramuscularly with one of the metal solutions described above at a dose of 0.05-0.1 mmol Gd/kg body weight. Images were then taken at various time intervals and compared with a non-injected control at time 0.

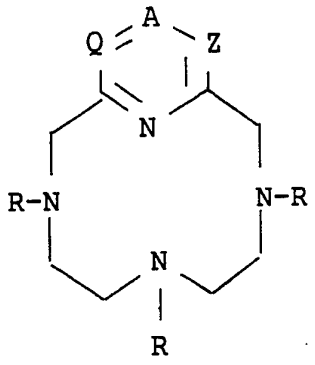
Example II

The Gd-PCTA complex (prepared in Example 1) was rapidly taken up by the renal system with brilliant enhancement of the kidney cortex as well as peripheral kidney tissue.

Other embodiments of the invention will be apparent to those skilled in the art from a consideration of this specification or practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with the true scope and spirit of the invention being indicated by the following claims.

WHAT IS CLAIMED IS:

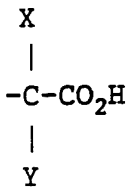
1. A complex which comprises a bicyclopolyazamacrocyclocarboxylic acid compound of the formula



(I)

wherein:

R is hydrogen,



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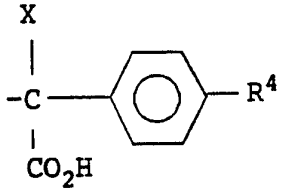
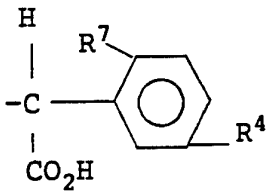


or



;

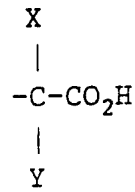
where:

X and Y are independently H, OH, C_1-C_3 alkyl or COOH;

R^7 is H or OH; and

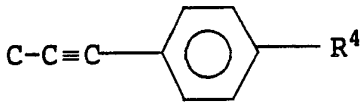
R^4 is H, NO_2, NH_2, isothiocyanato, semicarbazido, thiosemicarbazido, maleimido, bromoacetamido or carboxyl;

with the proviso that at least two R terms must be



;

A = CH, N, C-Br, C-Cl, C-OR^1, C-OR^2, N^+-R^3 X^-, or



where: R^1 = H, C_1-C_5 alkyl, benzyl, or benzyl substituted with at least one R^4;

R^2 is C_1-C_{16} alkylamino;

R^3 is C_1-C_{16} alkyl, benzyl, or benzyl substituted with at least one R^4;

R^4 is defined as before;

X^- is Cl^-, Br^-, I^- or $H_3CCO_2^-$;

Q and Z independently are CH, N, N^+-R^3 X^-, C-CH_2-OR^1 or C-C(O)-R^5;

R^1 and R^3 are defined as above;

R^5 is -O-(C_1-C_3 alkyl), OH or NHR^6;

R^6 is C_1-C_5 alkyl or a biologically active material;

X^- is defined as above; and

with the proviso that:

a) when Q, A or Z is N or N^+-R^3X^-, then the other two groups must be CH;

b) when A is C-Br, C-Cl, C-OR^1 or C-OR^2, then both Q and Z must be CH;

c) the sum of the R^2, R^4 and R^6 terms, when present, may not exceed one; and

d) only one of Q or Z can be C-C(O)-R^5 and when one of Q or Z is C-C(O)-R^5, then A must be CH; and

complexed with a metal ion selected from Gd^{+3}, Mn^{+2} or Fe^{+3}; or

pharmaceutically-acceptable salts thereof.

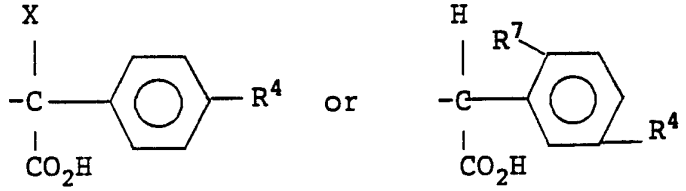
2. A complex of Claim 1 wherein the metal is Gd^{+3}.

3. A complex of Claim 1 wherein A, Q and Z are CH; and X and Y are H.

4. A complex of Claim 1 wherein X and Y are H.

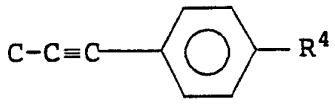
5. A complex of Claim 1 wherein A, Q and Z are CH.

6. A complex of Claim 1 wherein Q, A and Z are CH; and one R term is



where: X, Y, R^2 and R^4 are defined as in Claim 1.

7. A complex of Claim 1 wherein A is C-OR^1, C-OR^2, where R^1 and R^2 are defined as in Claim 1 or

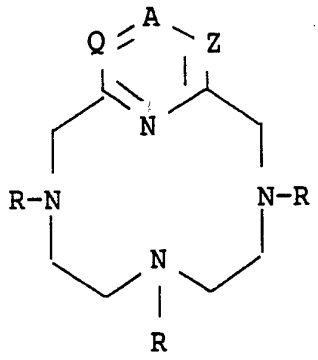


where R^4 is defined as in Claim 1.

8. A complex of Claim 1 wherein A is CH, and one of Q or Z is CH and the other is C-C(O)-R^5 or C-CH_2-OR^1, where R^1 and R^5 are defined as in Claim 1.

9. A complex of Claim 8 wherein R^5 is NHR^6, where R^6 is a biologically active material.

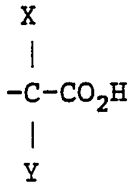
10. A conjugate comprising a bicyclopolyazamacrocyclocarboxylic acid compound of the formula



(I)

wherein:

R is hydrogen,



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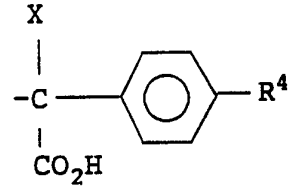
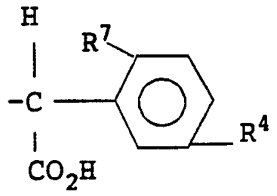


or



;

where:

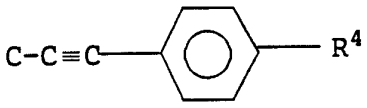
X and Y are independently H, OH, C_1-C_3 alkyl or COOH;

R^7 is H or OH; and

R^4 is H, NO_2, NH_2, isothiocyanato, semicarbazido, thiosemicarbazido, maleimido, bromoacetamido or carboxyl;

with the proviso that at least two R terms have a CO_2H group present

A = CH, N, C-Br, C-Cl, C-OR^1, C-OR^2, N^+-R^3 X^-, or



;

R^1 = H, C_1-C_5 alkyl, benzyl, or benzyl substituted with at least one R^4;

R^2 is C_1-C_{16} alkylamino;

R^3 is C_1-C_{16} alkyl, benzyl, or benzyl substituted with at least one R^4;

R^4 is defined as before;

X^- is Cl^-, Br^-, I^- or $H_3CCO_2^-$;

Q and Z independently are CH, N, N^+-R^3 X^-, C-CH_2-OR^1 or C-C(O)-R^5;

R^1 and R^3 are defined as above;

R^5 is -O-(C_1-C_3 alkyl), OH or NHR^6;

R^6 is C_1-C_5 alkyl or a biologically active material;

X is defined as above; and

with the proviso that:

a) when Q, A or Z is N or N^+-R^3 X^-, then the other two groups must be CH;

b) when A is C-Br, C-Cl, C-OR^1 or C-OR^2, then both Q and Z must be CH;

c) the sum of the R^2, R^4 and R^6 terms, when present, may not exceed one; and

d) only one of Q or Z can be C-C(O)-R^5 and when one of Q or Z is C-C(O)-R^5, then A must be CH;

complexed with a metal ion selected from Gd^{+3}, Mn^{+2} or Fe^{+3}; and

covalently attached to a biologically active material.

11. A conjugate of Claim 10 wherein the biologically active material is a dextran, a peptide, a molecule that has specific affinity for a receptor, or an antibody or antibody fragment.

12. A conjugate of Claim 11 wherein the antibody or antibody fragment is a monoclonal antibody or fragment thereof.

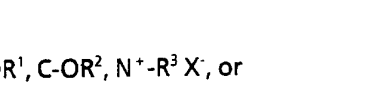
13. A conjugate of Claim 12 wherein the antibody or antibody fragment is B72.3.

14. A conjugate as claimed in any one of Claims 10-13 wherein the metal ion is Gd^{+3}.

15. A conjugate of Claim 10 wherein X and Y are H.

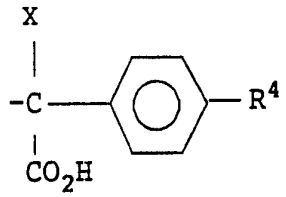
16. A conjugate of Claim 10 wherein A, Q and Z are CH.

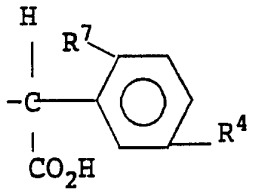
17. A conjugate of Claim 10 wherein Q, A and Z are CH; and one R term is



where: X and R^4 are defined as in Claim 10.

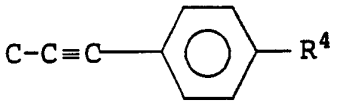
18. A conjugate of Claim 10 wherein Q, A and Z are CH; and one R term is





where: R^4 and R^7 are defined as in Claim 10.

19. A conjugate of Claim 10 wherein A is C-OR^1, C-OR^2, where R^1 and R^2 are defined as in Claim 10, or



where R^4 is defined as in Claim 10.

20. A conjugate of Claim 10 wherein A is CH, and one of Q or Z is CH and the other is C-C(O)-R^6, where R^6 is defined as in Claim 10.

21. A conjugate of Claim 20 wherein R^6 is NHR^7, where R^7 is a biologically active material.

22. A pharmaceutical formulation comprising a complex as claimed in any one of Claims 1-9 with a pharmaceutically-acceptable carrier.

23. A pharmaceutical formulation comprising a conjugate as claimed in any one of Claims 10-21 with a pharmaceutically-acceptable carrier.

24. A method for the diagnosis of a disease state in an animal which comprises administering to said animal an effective amount of the formulation of Claim 22.

25. A method for the diagnosis of a disease state in an animal which comprises administering to said animal an effective amount of the formulation of Claim 23.

26. The complex as claimed in any one of Claims 1-9 for use as a pharmaceutical.

27. The conjugate as claimed in any one of Claims 10-21 for use as a pharmaceutical.

28. A kit for use as a diagnostic agent having as an ingredient a ligand as claimed in any one of Claims 1-9.

29. A process for preparing a complex as claimed in Claim 1 which comprises reacting a bicyclopolyazamacrocyclocarboxylic acid compound as claimed in Claim 1 with a metal ion selected from Gd^{+3}, Mn^{+2} or Fe^{+3} under aqueous conditions at a pH from 5 to 7.

30. The process of Claim 29 wherein the bicyclopolyazamacrocyclocarboxylic acid compound is 3,6,9,15-tetraazabicyclo[9.3.1]pentadeca-1(15),11,13-triene-3,6,9-trimethylenecarboxylic acid.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 93/04322

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 A61K49/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 A61K C07F C07C

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,Y	EP,A,0 391 766 (GUERBET S.A.) 10 October 1990 see page 2, line 3; claims ---	1-30
Y	WO,A,91 10669 (COCKBAIN J. R.) 25 July 1991 see page 10; claims 1,2; figures IK,IN,IS,IQ ---	1-30
X,Y	WO,A,91 10645 (SALUTAR INC.) 25 July 1991 see page 4 see page 8; claims; figure ID ---	1-30
X,Y	EP,A,0 438 206 (SCHERING AG.) 24 July 1991 see page 1 - page 2; claims ---	1-30
X,Y	EP,A,0 430 863 (SCHERING AG.) 5 June 1991 see claims; figure IC ---	1-30
	-/--	

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

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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

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

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

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

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

1

Date of the actual completion of the international search	Date of mailing of the international search report
20 January 1994	01.02.94
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	**Authorized officer** Berte, M

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP,A,0 352 218 (SCHERING AG.) 24 January 1990 see claims	1-30
X,Y	JOURNAL OF HETEROCYCLIC CHEMISTRY vol. 27 , 1990 , PROVO US pages 167 - 169 H. TAKALO ET AL. 'PREPARATION OF NEW MACROCYCLIC POLYAMINES CONTAINING 4-(PHENYLETHYNYL)PYRIDINE SUBUNIT.' see figure 6	1-30
X	TETRAHEDRON vol. 37 , 1981 , OXFORD GB pages 767 - 772 H. STETTER ET AL. 'DARSTELLUNG UND KOMPLEXBILDUNG VON POLYAZACYCLOALKAN-N-ESSIGSÄUREN.' see figure 19	1-8, 22-26, 29,30

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 93/ 04322

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [X] Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
REMARK: Although claims 24, 25 are directed to a method of treatment of (diagnostic method practised on) the human/animal body the search has been carried out and based on the alleged effects of the compound/composition.

2. [X] Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
In view of the large number of compounds which are designed by the general formulas of claim 1 the search has to be restricted for economic reasons. The search was limited to the compounds for which pharmacological data was given and/or mentioned in the examples. (guidelines, Part B, Chapter III, PARAGRAPH 3.6) PARTIALLY SEARCHED CLAIMS: 1-30

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. [ ] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. [ ] As all searchable claims could be searches without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest.

[ ] No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US 93/04322

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
EP-A-0391766	10-10-90	FR-A-	2644785	28-09-90
		WO-A-	9011282	04-10-90
		FR-A-	2660977	18-10-91
		JP-T-	4506955	03-12-92
WO-A-9110669	25-07-91	AU-A-	7146391	05-08-91
		EP-A-	0511275	04-11-92
		JP-T-	5503519	10-06-93
WO-A-9110645	25-07-91	AU-A-	7060291	05-08-91
		EP-A-	0527131	17-02-93
EP-A-0438206	24-07-91	DE-A-	4001655	25-07-91
		AU-A-	6981291	22-08-91
		JP-A-	5112567	07-05-93
EP-A-0430863	05-06-91	DE-A-	3938992	23-05-91
		AU-A-	6685990	30-05-91
		CA-A-	2030472	22-05-91
		JP-A-	3246234	01-11-91
EP-A-0352218	24-01-90	DE-A-	3825040	25-01-90
		AU-B-	637052	20-05-93
		AU-A-	3827589	01-02-90
		JP-A-	2104588	17-04-90