

α -PHOSPHONOSULFONATE SQUALENE SYNTHETASE
INHIBITORS AND METHOD

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The present invention relates to new α -
10 phosphonosulfonate compounds which are useful in
inhibiting cholesterol biosynthesis by inhibiting
de novo squalene production, to hypocholesterolemic
and antiatherosclerotic compositions containing
such compounds and to a method of using such
15 compounds for inhibiting cholesterol biosynthesis
and atherosclerosis.

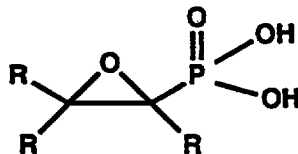
Squalene synthetase is a microsomal enzyme
which catalyzes the reductive dimerization of two
20 molecules of farnesyl pyrophosphate (FPP) in the
presence of nicotinamide adenine dinucleotide
phosphate (reduced form) (NADPH) to form squalene
(Poulter, C.D.; Rilling, H.C., in "Biosynthesis of
Isoprenoid Compounds", Vol. I, Chapter 8, pp. 413-
25 441, J. Wiley and Sons, 1981, and references
therein). This enzyme is the first committed step
of the de novo cholesterol biosynthetic pathway.
The selective inhibition of this step should allow

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the essential pathways to isopentenyl tRNA, ubiquinone, and dolichol to proceed unimpeded. Squalene synthetase along with HMG-CoA reductase have been shown to be down-regulated by receptor mediated LDL uptake (Faust, J.R.; Goldstein, J.L.; Brown, M.S. Proc. Nat. Acad. Sci. U.S.A. 1979, 76, 5018-5022), lending credence to the proposal that inhibiting squalene synthetase will lead to an up-regulation of LDL receptor levels, as has been demonstrated for HMG-CoA reductase, and thus ultimately should be useful for the treatment and prevention of hypercholesterolemia and atherosclerosis.

U.S. Patent No. 3,657,282 (Merck) (Division U.S. Patent No. 3,822,296) discloses antibiotics of the structure

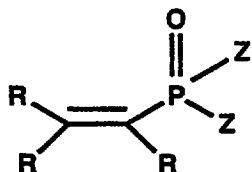


wherein R = SO₃H, SO₂R*, H, hydrocarbyl other than alkyl (eg. alkenyl, alkynyl, phenyl and naphthyl), substituted hydrocarbyl, CO₂H, CO₂R*, SO₃NR₂, heterocycle*, amino*, OH, OR, SH, SR, CHO, halogen, NO₂, CN, PO₃H₂, AsO₃H₂, acyl, -CHR¹R³ where R¹ = H, Me; R³ = R as above, preferably at least one R not = H, R preferably contains 1-10 carbons. * = optionally substituted.

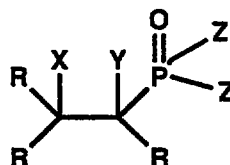
Starting materials employed to prepare the above antibiotics include

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via epoxidation



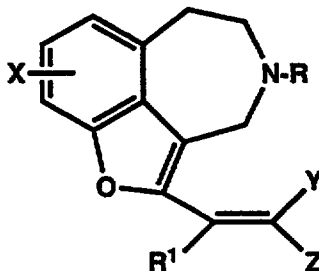
via ring closure

wherein R can be SO₃H, and X and Y are hydroxy or functional equivalent precursor to epoxide: eg.

- 5 OH, halo, azide, RCO₂-, RSO₂O-, R₂S⁺-, R₃N⁺-, ArO-, R₂PO₂-, RSO₂NR¹-. One of X and Y must be an oxygen radical.

EP 89/0-344-980 (Smith Kline) discloses α - antagonists of the structure

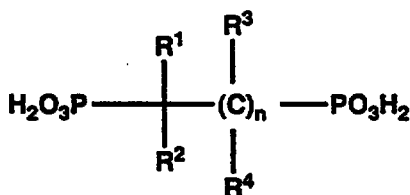
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wherein Y or Z may be -SO₂R, -P(R)O(OR), -PR₂O, -PO(OR)₂, and amides.

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WO 88/00061 (Amersham) discloses Technetium-99 complexes for bone scanning having the structure



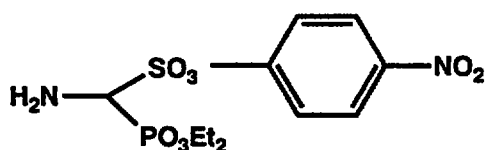
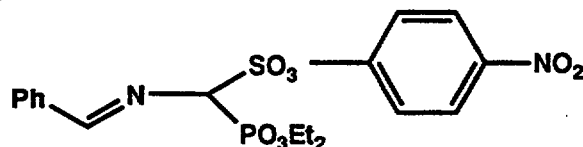
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wherein R¹ and R³ = H, SO₃H or alkyl substituted with SO₃H and optionally one or more heteroatoms; R⁴ can also be SO₃H or OH, NH₂, NHMe, NMe₂, lower alkyl substituted with a polar group;

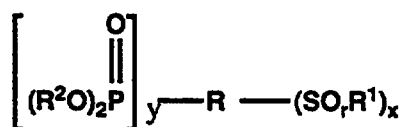


R^2 = same as R^4 except not SO_3H and
 $n = 0, 1$.

U.S. Patent No. 4,032,521 (Merck) discloses
 inter-mediate, in cephalosporin synthesis, of the
 5 structures



WO 90/07513 (Gas Research Institute)
 discloses electrolytes for fuel cells of the
 10 structure



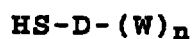
wherein R = organic radicals with 1 or more F
 15 atoms;

R^1 = H, alkali metal, Zn, Cd;

R^2 = H, lower alkyl;

$r = 2, 3$; and $x, y = 1, 2, 3$.

U.S. Patent No. 4,254,215 (Ciba Geigy AG)
 20 discloses a process for photographic developers
 wherein one component of a developer solution is:



wherein $n = 1$ to 4.

D = optionally substituted, saturated or
 25 unsaturated aliphatic radical (< 40 carbons), can

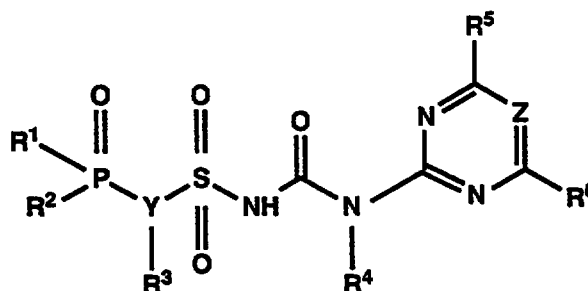
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be interrupted by heteroatoms such as O, SO₂, NH, NR.

W = PO₃R₂, SO₃R, SO₂R, -NY-SO₃R, -SO₂NR₂, -SSO₃R, CO₂R, OH, NR₃⁺, NR₂, CONR₂.

- 5 DE 89/3739691-A (Hoechst) (Derwent # 89-173507/24) discloses herbicides and plant growth regulators of the structure



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wherein Y = CH, N; X = O, S; Z=CH, N;

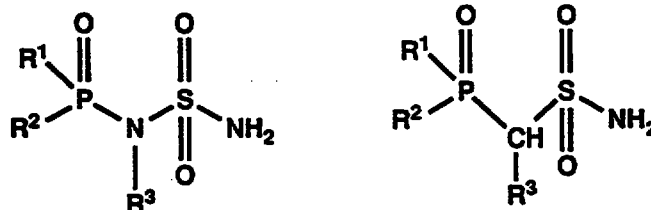
R¹, R² = C1-C6 alkyl or alkoxy;

R³ = H, C1-C6 alkyl or alkoxy, C2-C6 alkenyl, alkynyl, alkenyloxy, alkynyloxy; all optionally

- 15 substituted with one or more halogens; and
R⁴ = H, C1-C4 alkyl or physiologically acceptable cation.

New intermediates are disclosed of the structures

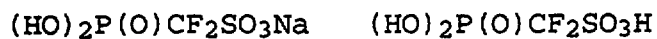
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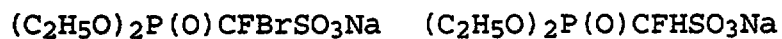
- Burton, D.J., J. Am. Chem. Soc. 1989, 111, 1773-1776 discloses electrolytes and chelators of
25 the structures

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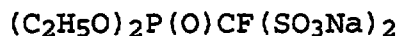
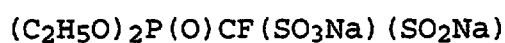




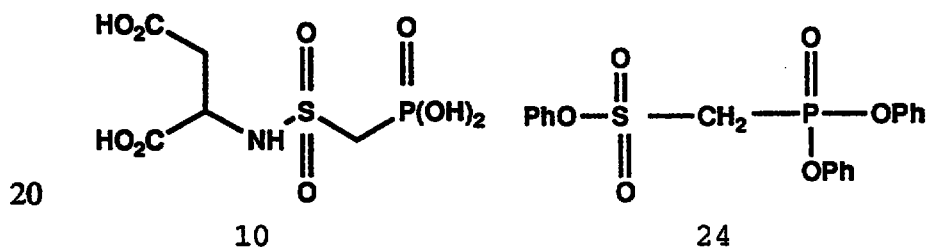
Su, D.; Cen. W.; Kirchmeier, R.L.; Shreeve,
J. M., Can. J. Chem. 1989, 67, 1795-1799, disclose
5 electrolytes and chelators of the structures



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Farrington, G.K.; Kumar, A.; Wedler, F.C.,
15 J. Med. Chem. 1985, 28, 1668-1673 discloses
compound 10 as an inhibitor of aspartate
transcarbamylase. Compound 24 is a synthetic
intermediate.

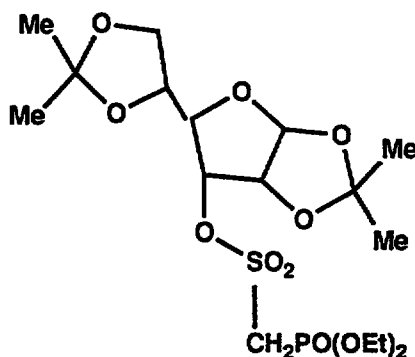


Musicki, B.; Widlanski, T.S. Tetrahedron
Lett. 1991, 32, 1267-1270 discloses compound 4 as a
synthetic intermediate.

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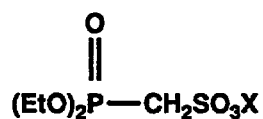




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Carretero, J.C.; Demillequand, M.; Ghosez, L., Tetrahedron 1987, 43, 5125-5134 discloses

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1a X = Et

1b X = i-Pr

2a X = Li

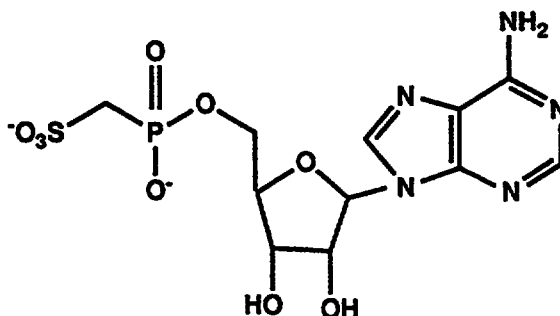
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2b X = n-Bu₄N

for use in the synthesis of vinyl phosphonates via a Horner-Emmons reaction.

Callahan, L.; Ng, K.; Geller, D.H.; Agarwal, K.; Schwartz, N.B., Analytical

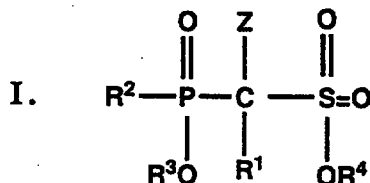
15 Biochemistry 1989, 177, 67-71 discloses an analog of ADP (adenosine diphosphate) of the structure



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In accordance with the present invention, there is provided α -phosphonosulfonate compounds which inhibit cholesterol biosynthesis, and thus
 5 are useful as hypocholesterolemic and antiatherosclerotic agents and have the following structure I.



10 wherein R^2 is OR^5 or R^{5a} , R^3 and R^5 are the same or different and are H, alkyl, arylalkyl, aryl, cycloalkyl, a metal ion or other pharmaceutically acceptable cations as defined below, or a prodrug ester;

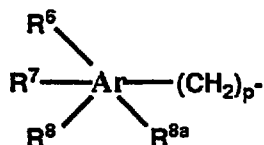
15 R^{5a} is H, alkyl, arylalkyl or aryl;

R^4 is H, alkyl, cycloalkyl, aryl, arylalkyl, metal ion or other pharmaceutically acceptable cations as defined below, or a prodrug ester;

20 Z is H, halogen, lower alkyl or lower alkenyl;

R^1 a lipophilic group containing at least 7 carbons and is alkyl containing 7 to 25 carbons in the chain; alkenyl containing from 7 to 25 carbon
 25 atoms in the chain and from 1 to 6 double bonds; alkynyl containing 1 to 6 triple bonds; mixed alkenyl-alkynyl containing 1 to 5 double bonds and 1 to 5 triple bonds; and where in the above groups alkenyl and/or alkynyl may be substituted or
 30 unsubstituted; cycloalkyl; cycloheteroalkyl linked through a carbon on the ring or a heteroatom; aryl; heteroaryl; heteroarylalkyl; cycloalkylalkyl; cycloheteroalkylalkyl; or a group of the structure





- wherein Ar is aryl (such as phenyl or naphthyl), heteroaryl (5 or 6 membered) and may include
- 5 one to three additional rings fused to Ar (such as aryl, cycloalkyl, heteroaryl or cyclo-heteroalkyl) and wherein $(CH_2)_p$ contains from 1 to 15 carbons, preferably 2 to 12 carbons, in the chain and may include 0, 1, 2 or 3 double
- 10 bonds and/or 0, 1, 2 or 3 triple bonds in the normal chain, and may contain an ether or amino function in the chain, and/or may include 0, 1, 2 or 3 substituents as defined below for R^6 ; and R^6 , R^7 , R^8 and R^{8a} are the same or different and are H,
- 15 alkyl containing 1 to 40 carbons, preferably from 3 to 25 carbons, alkoxy containing 1 to 40 carbons, preferably from 3 to 25 carbons, alkenyl containing 2 to 40 carbons, preferably from 3 to 25 carbons, alkenyloxy containing 2 to 40 carbons, preferably
- 20 from 3 to 25 carbons, alkynyl containing 2 to 40 carbons, preferably from 3 to 25 carbons, alkynyl-oxy containing 2 to 40 carbons, preferably from 3 to 25 carbons, cycloheteroalkyl, cycloheteroalkylalkyl, heteroaryl, cycloalkyl,
- 25 cycloalkylalkyl, Ar-alkyl, (such as arylalkyl), ArO (such as aryloxy), Ar-amino (such as arylamino), hydroxy, halogen, nitro, Ar (such as aryl), amino, substituted amino wherein the amino includes 1 or 2 substituents (which are alkyl, alkenyl, aryl or any
- 30 of the Ar groups mentioned above), thiol, alkylthio, Ar-thio (such as arylthio), alkyl-sulfinyl, Ar-sulfinyl (such as arylsulfinyl),

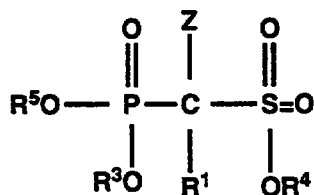


alkylsulfonyl, Ar-sulfonyl (such as arylsulfonyl),
 carboxy, cyano, alkoxycarbonyl, aminocarbonyl,
 alkylcarbonyloxy, Ar-carbonyloxy (such as
 arylcarbonyloxy), Ar-carbonylamino (such as
 5 arylcarbonylamino) or alkylcarbonylamino, as well
 as any of the Ar groups as defined above, and
 preferably wherein the total number of carbons in
 the substituted Ar-(CH₂)_p- group exceeds 10
 carbons; including pharmaceutically acceptable
 10 salts thereof such as alkali metal salts such as
 lithium, sodium or potassium, alkaline earth metal
 salts such as calcium or magnesium, as well as zinc
 or aluminum and other FDA approved cations such as
 ammonium, choline, diethanolamine, ethylenediamine,
 15 and salts of naturally occurring amino acids such as
 arginine, lysine, alanine and the like.

The (CH₂)_p group may contain 1, 2, 3 or more
 alkyl, alkoxy, alkenyl, alkynyl, hydroxy and/or
 halogen substituents as well as any of the
 20 substituents defined for R⁶.

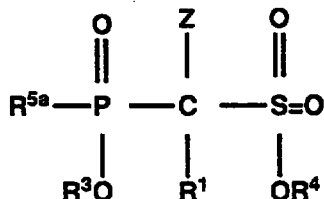
Thus, the compounds of the invention
 include the following sub-genuses:

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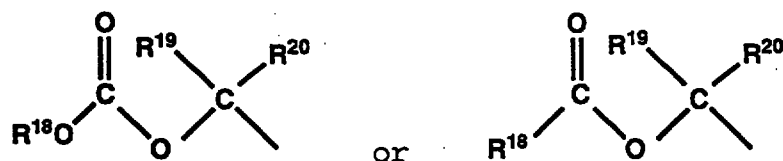
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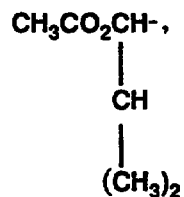
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The term "prodrug esters" as employed herein includes prodrug esters which are known in the art for both phosphorus and carboxylic acids. Examples include the following groups: (1-
 5 alkanoyloxy)alkyl such as,



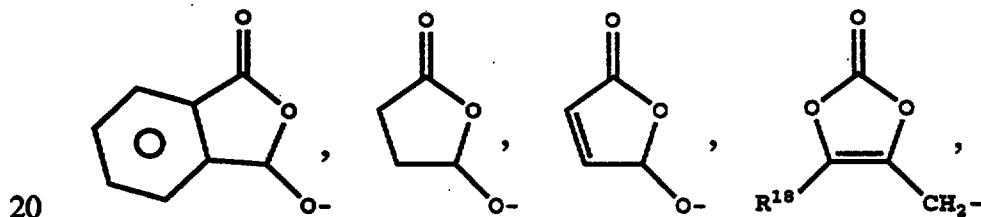
wherein R^{18} , R^{19} and R^{20} are H, alkyl, aryl or aryl-
 10 alkyl; however R^{18}O cannot be HO. Examples of such prodrug esters include $\text{CH}_3\text{CO}_2\text{CH}_2-$,

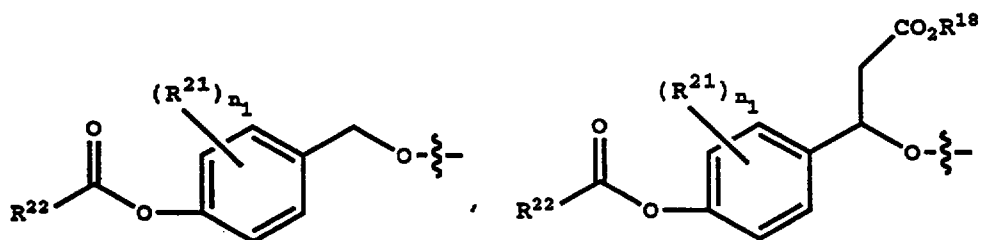


$t\text{-C}_4\text{H}_9\text{CO}_2\text{CH}_2-$, or
 15 (preferred)

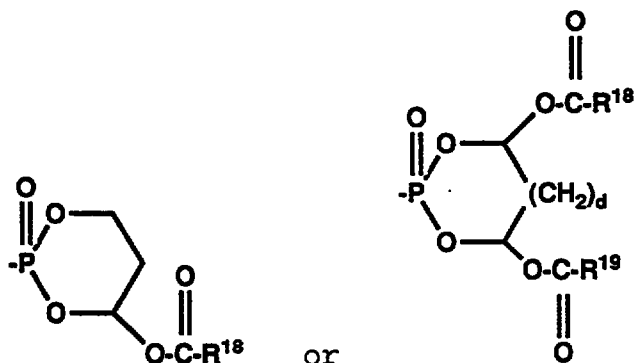


Other examples of suitable prodrug esters include





wherein R^{18} can be H, alkyl (such as methyl or t-butyl), arylalkyl (such as benzyl) or aryl (such as phenyl); R^{21} is H, alkyl, halogen or alkoxy, R^{22} is
 5 alkyl, aryl, arylalkyl or alkoxyl, and n_1 is 0, 1 or 2; or R^3 and R^5 can be linked together as in



or

(d is 0 to 3).

10

Unless otherwise indicated, the term "lower alkyl" or "alkyl" as employed herein alone or as
 15 part of another group includes both straight and branched chain hydrocarbons, containing 1 to 40 carbons, preferably 1 to 20 carbons, in the normal chain, more preferably 1 to 12 carbons, such as methyl, ethyl, propyl, isopropyl, butyl, t-butyl,
 20 isobutyl, pentyl, hexyl, isohexyl, heptyl, 4,4-dimethylpentyl, octyl, 2,2,4-trimethylpentyl, nonyl, decyl, undecyl, dodecyl, the various branched chain isomers thereof, and the like as

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well as such groups including 1 to 4 substituents such as F, Br, Cl or I or CF₃, alkoxy, aryl, arylalkyl, alkenyl, cycloalkyl, amino, hydroxy, alkylamido, alkanoylamino, arylcarbonylamino, 5 nitro, cyano, thiol and/or alkylthio, as well as any of the other substituents as defined for R⁶.

Unless otherwise indicated, the term "cycloalkyl" as employed herein alone or as part of another group includes saturated or partially 10 unsaturated cyclic hydrocarbon groups containing 3 to 12 carbons, preferably 3 to 8 carbons, which include cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, cycloheptyl, cyclooctyl, cyclodecyl and cyclododecyl, cyclohexenyl, any of which groups may 15 be substituted with 1 to 4 substituents such as halogen, alkyl, alkoxy, hydroxy, aryl, arylalkyl, cycloalkyl, alkylamido, alkanoylamino, arylcarbonylamino, amino, nitro, cyano, thiol and/or alkylthio, as well as any of the other 20 substituents as defined for R⁶.

Unless otherwise indicated, the term "aryl" as employed herein refers to monocyclic or bicyclic aromatic groups containing from 6 to 10 carbons in the ring portion, such as phenyl, naphthyl, or 25 phenyl or naphthyl substituted with 1 to 4 substituents such as alkyl, halogen (Cl, Br or F), alkoxy, hydroxy, amino, alkanoylamino, arylcarbonylamino, aryl, arylalkyl, cycloalkyl, alkylamido, nitro, cyano, thiol and/or alkylthio, 30 as well as any of the other substituents as defined for R⁶.

The term "aralkyl", "aryl-alkyl" or "aryl-lower alkyl" as used herein alone or as part of another group refers to alkyl groups as discussed

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above having an aryl substituent, such as benzyl or phenethyl, or naphthylpropyl.

The term "lower alkoxy", "alkoxy", "aryloxy" or "aralkoxy" as employed herein alone or
5 as part of another group includes any of the above alkyl, aralkyl or aryl groups linked to an oxygen atom.

The term "lower alkylthio", "alkylthio", "arylthio" or "aralkylthio" as employed herein
10 alone or as part of another group includes any of the above alkyl, alkyl, aralkyl or aryl groups linked to a sulfur atom.

The term "lower alkylamino", "alkylamino", "arylamino", or "arylalkylamino" as employed herein
15 alone or as part of another group includes any of the above alkyl, aryl or arylalkyl groups linked to a nitrogen atom.

The term "alkanoyl" as used herein alone or as part of another group refers to alkyl linked to
20 a carbonyl group.

Unless otherwise indicated, the term "lower alkenyl" or "alkenyl" as used herein by itself or as part of another group refers to straight or branched chain radicals of 2 to 40 carbons, preferably 3 to 30 carbons in the normal chain, which
25 include one to six double bonds in the normal chain, such as vinyl, 2-propenyl, 3-butenyl, 2-butenyl, 4-pentenyl, 3-pentenyl, 2-hexenyl, 3-hexenyl, 2-heptenyl, 3-heptenyl, 4-heptenyl, 3-octenyl, 3-nonenyl, 4-decenyl, 3-undecenyl, 4-dodecenyl, 4,8,12-tetradecatrienyl, and the like,
30 and which may be optionally substituted with 1 to 4 substituents, namely, halogen, alkyl, alkoxy, alkenyl, alkynyl, aryl, arylalkyl, cycloalkyl,

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amino, hydroxy, alkanoylamino, alkylamido, arylcarbonylamino, nitro, cyano, thiol and/or alkylthio, as well as any of the other substituents as defined for R⁶.

5 Unless otherwise indicated, the term "lower alkynyl" or "alkynyl" as used herein by itself or as part of another group refers to straight or branched chain radicals of 2 to 40 carbons, preferably 2 to 20 carbons in the normal chain,
 10 which include one triple bond in the normal chain, such as 2-propynyl, 3-butynyl, 2-butynyl, 4-pentynyl, 3-pentynyl, 2-hexynyl, 3-hexynyl, 2-heptynyl, 3-heptynyl, 4-heptynyl, 3-octynyl, 3-nonyl, 4-decynyl, 3-undecynyl, 4-dodecynyl and the
 15 like, and which may be optionally substituted with 1 to 4 substituents, namely, halogen, alkyl, alkoxy, alkenyl, alkynyl, aryl, arylalkyl, cycloalkyl, amino, hydroxy, alkanoylamino, alkyl-amido, arylcarbonylamino, nitro, cyano, thiol,
 20 and/or alkylthio, as well as any of the other substituents as defined for R⁶.

Examples of suitable (CH₂)_p groups include

25 $-\text{CH}=\text{CH}-\text{CH}_2-$, $-\text{CH}_2\text{CH}=\text{CH}-$, $-\text{C}\equiv\text{C}-\text{CH}_2-$,

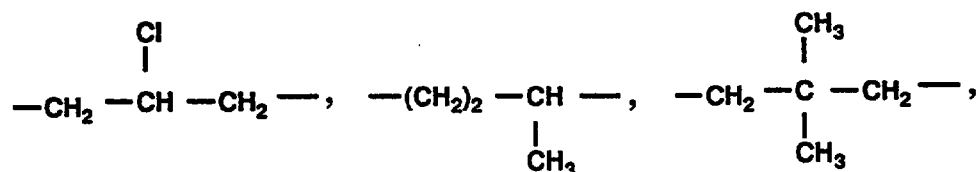
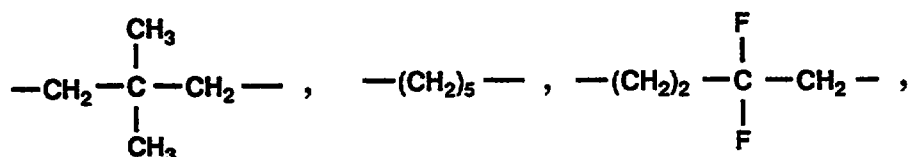
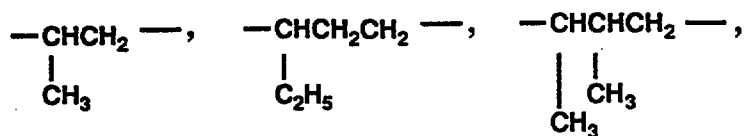
$-\text{CH}_2\text{C}\equiv\text{CCH}_2-$, $-\overset{\text{CH}_3}{\underset{|}{\text{C}}}=\text{CH}-\text{CH}_2-$,

$-(\text{CH}_2)_2-$, $-(\text{CH}_2)_3-$, $-(\text{CH}_2)_4-$,

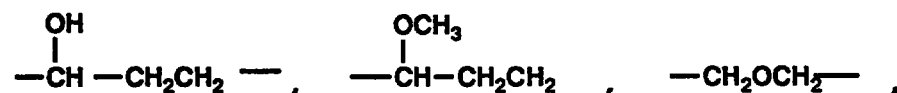
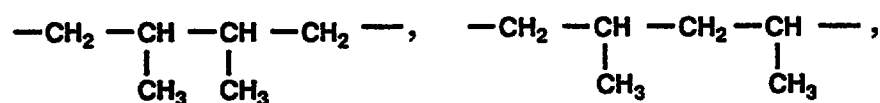
30 $-(\text{CH}_2)_2-\overset{\text{CH}_3}{\underset{|}{\text{C}}}-\text{CH}_2\text{CH}_2-$, $-\text{CH}_2\overset{\text{CH}_3}{\underset{|}{\text{CH}}}-$, $-\text{CH}_2\overset{\text{C}_2\text{H}_5}{\underset{|}{\text{CH}}}\text{CH}_2-$,

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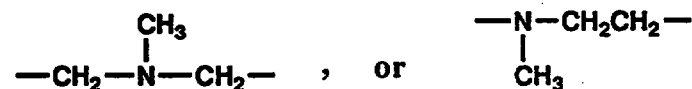




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15 The term "halogen" or "halo" as used herein refers to chlorine, bromine, fluorine, and iodine as well as CF₃, with chlorine or fluorine being preferred.

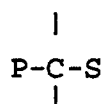
20 The term "amino" as used herein refers to unsubstituted amino as well as monosubstituted amino or disubstituted amino wherein the substituents may be alkyl and/or aryl.

25 The term "metal ion" refers to alkali metal ions such as sodium, potassium or lithium and alkaline earth metal ions such as magnesium and calcium, as well as zinc and aluminum.

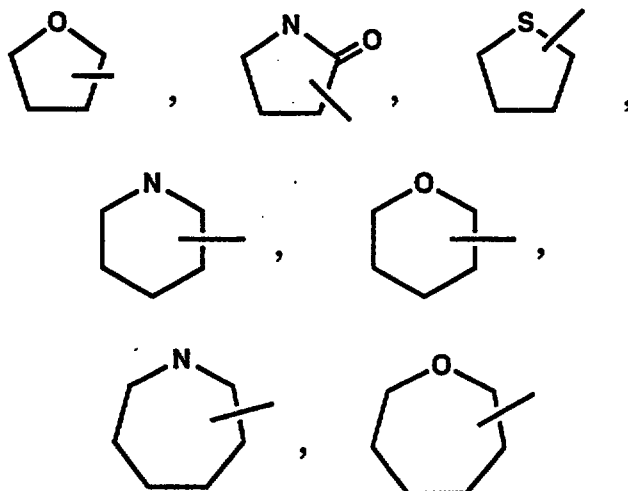
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The term "cycloheteroalkyl" as used herein as an R^1 substituent refers to a 5-, 6- or 7-membered saturated ring which includes 1 to 2 hetero atoms such as nitrogen, oxygen and/or sulfur, linked to the carbon "C" of



through a carbon atom or a heteroatom, where possible, optionally via the linker $(CH_2)_p$ (which is defined above), such as



20 and the like. The above groups may include 1 to 3 substituents such as any of the R^6 groups as defined above. In addition, any of the above rings can be fused to a cycloalkyl, aryl, heteroaryl or cycloheteroalkyl ring.

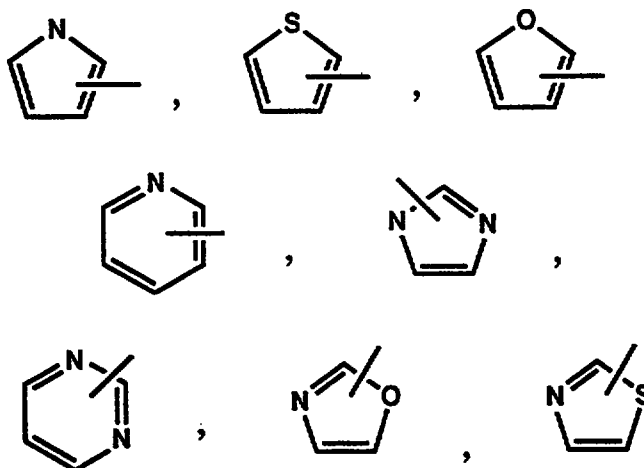
25 The term "heteroaryl" as an R^1 substituent refers to a 5- or 6- membered aromatic ring which includes 1, 2, 3 or 4 hetero atoms such as nitrogen, oxygen or sulfur, which is linked to the carbon "C" of

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|
P-C-S, through a carbon atom or a heteroatom, where
|

possible, optionally via the linker $(CH_2)_p$ (which
5 is defined above), such as



10

and the like. The above groups may include 1 to 3
substituents such as any of the R^6 groups as
15 defined above. In addition, any of the above rings
can be fused to a cycloalkyl, aryl, heteroaryl or
cycloheteroalkyl ring.

The term "cycloheteroalkylalkyl" as defined
by R^1 refers to cycloheteroalkyl groups as defined
20 above linked through a C atom or heteroatom to the
"C" of

|
P-C-S group through a $(CH_2)_p$ chain wherein p is
|

25 preferably 1 to 8.

The term "heteroarylalkyl" as defined by R^1
refers to a heteroaryl group as defined above
linked through a C atom or heteroatom to the

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"C" of P-C-S through a $-(CH_2)_p-$ chain

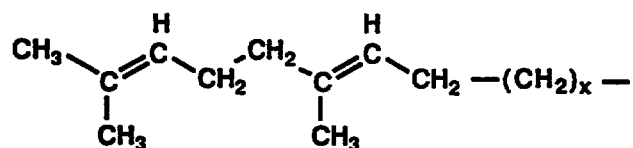
as defined above, where p is preferably 1 to 8.

- 5 Preferred are compounds of formula I and IA wherein R^2 is OR^5 and R^5 is a metal ion such as Na or K, or H or a pharmaceutically acceptable salt or more preferably a prodrug ester;

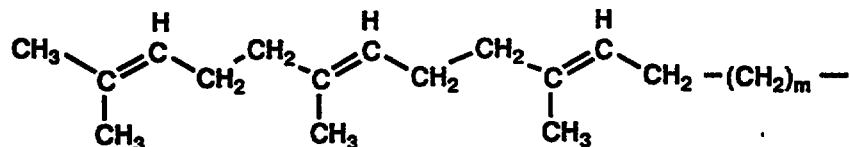
R^3 is H, a metal ion such as Na or K;

- 10 R^4 is a metal ion such as Na or K;

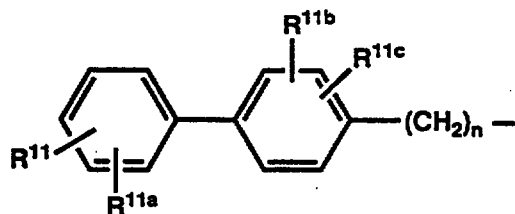
R^1 is alkenyl such as



- 15 wherein $(CH_2)_x$ is defined as $(CH_2)_p$ above and x is preferably 2 to 8,



- 20 m is 1 to 5;

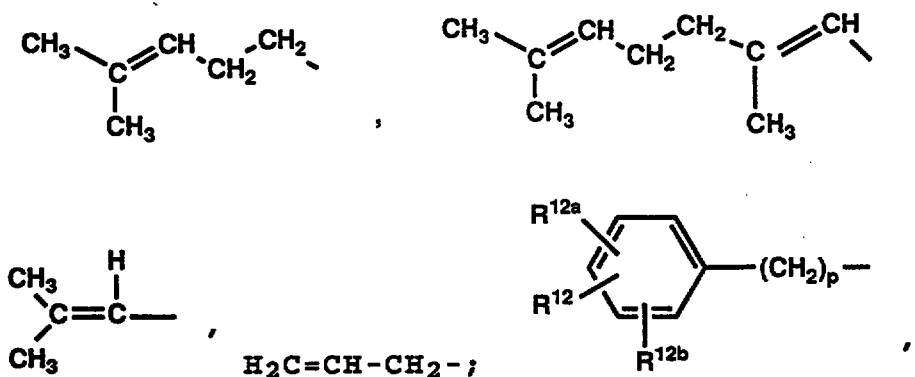


$n = 1$ to 15;

- 25 R^{11} , R^{11a} , R^{11b} , and R^{11c} are independently selected from H, alkyl such as propyl, alkoxy, such as methoxy or propyloxy, alkenyl such as

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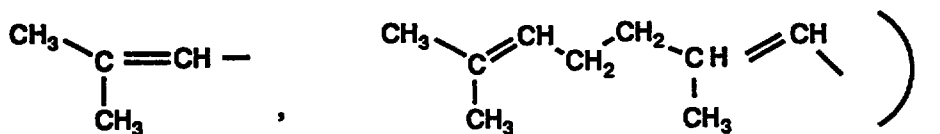




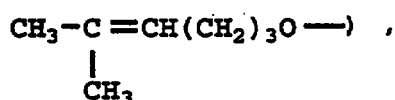
5

wherein R¹², R^{12a} and R^{12b} are independently selected from H, aryl (such as phenyl or naphthyl), alkylphenyl (such as p-propylphenyl, p-pentylphenyl), alkyl containing 1 to 20 carbons (such as p-heptyl), halo, alkoxy (such as methoxy or propyloxy), alkenyl (such as

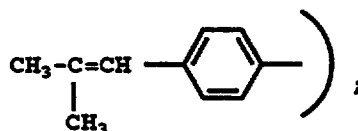
10



15 arylalkyloxy (such as phenethyloxy), alkenyloxy (such as

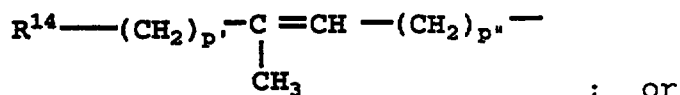


20 aryloxy (such as phenoxy), phenylalkyl (such as benzyl, phenylpropyl), alkylphenoxy (such as ortho-butylphenoxy), alkenylphenyl (such as

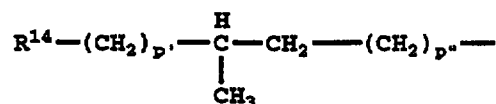


25



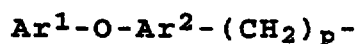


; or



- 5 wherein R^{14} is aryl, heteroaryl, aryloxy, heteroaryloxy, cycloalkyl, heterocycloalkyl, and $(CH_2)_{p'}$ and $(CH_2)_{p''}$ are as defined above for $-(CH_2)_{p'}$. Preferred p' and p'' are independently 1 to 4;

10



- wherein Ar^1 and Ar^2 are independently selected from any of the Ar groups defined hereinbefore, and
- 15 $(CH_2)_p$ is as defined hereinbefore.

The compounds of the invention may be prepared according to the following reaction sequences.

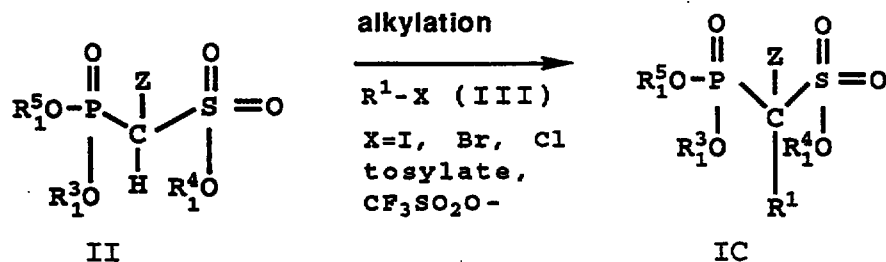
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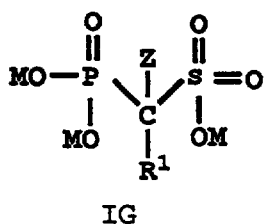
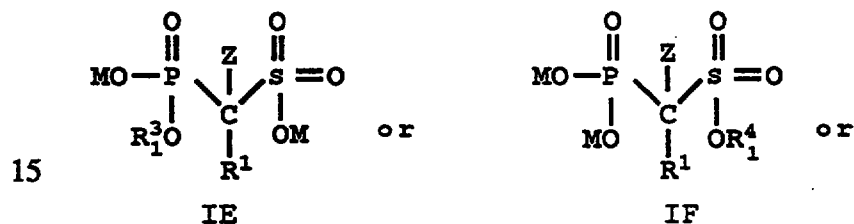
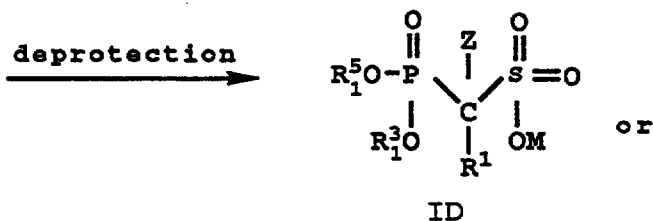
Schemes I, IA and II
General Schemes for the Preparation of
 α -Phosphonosulfonates

Scheme I

5



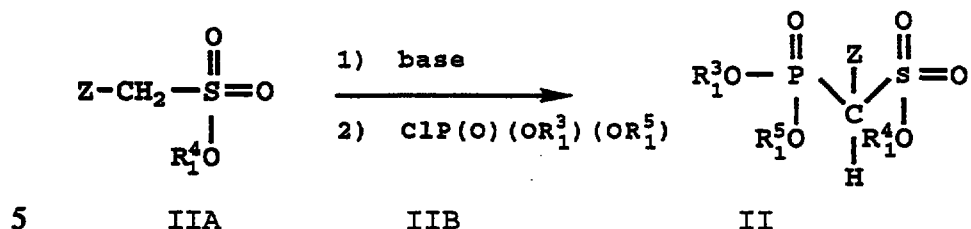
(R^3 , R^4 , R^5 are independently alkyl, aryl,
10 arylalkyl or cycloalkyl)



20 M=H, metal ion, or other pharmaceutically acceptable cation.

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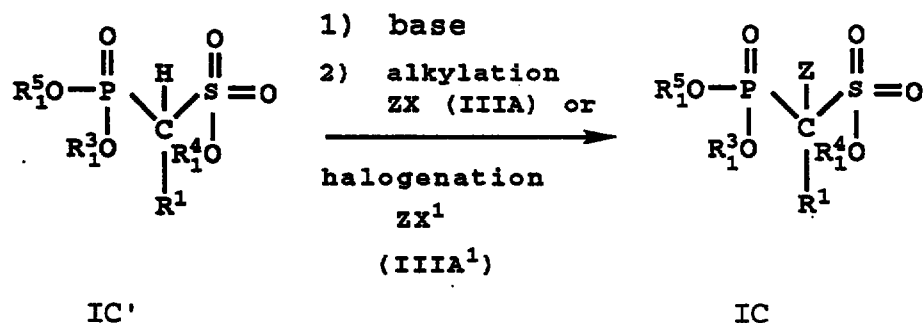


Scheme IAPreparation of Starting Phosphonosulfonate II

Procedure employed is similar to that described by Carretero, J.C.; Demillequand, M.; Ghosez, L., Tetrahedron, Vol. 43, 1987, pp 5125-5134.

Scheme II

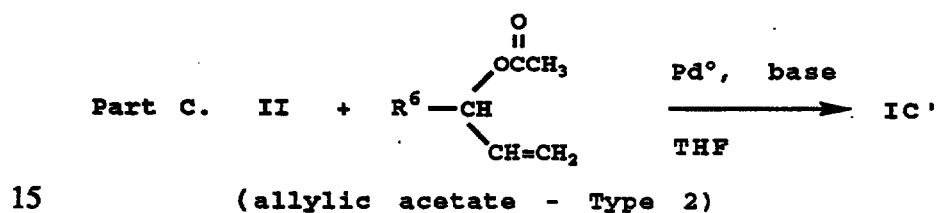
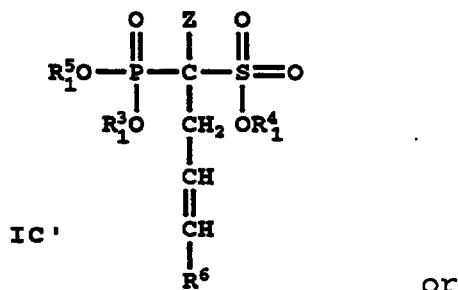
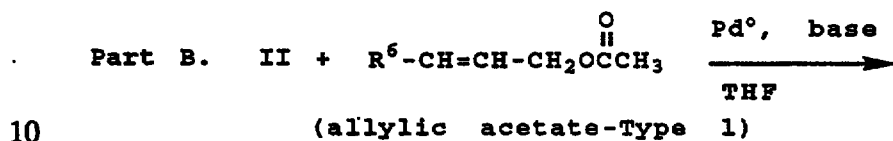
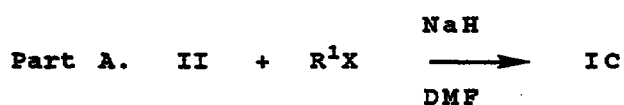
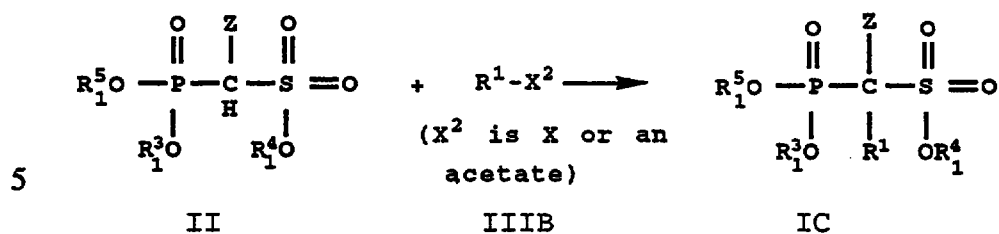
Alternatively, Z can be added after R¹ (where Z = lower alkyl or halogen).



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Scheme III - Alkylation Reaction of Electrophiles
III with Phosphonosulfonates II to Yield Triesters
IC

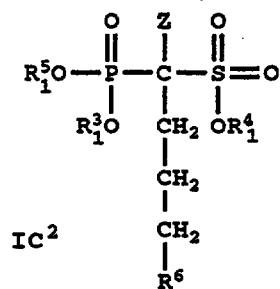


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Part D. IC' $\xrightarrow{\text{Hydrogenation}}$

(where R¹ is R⁶-CH=CH-CH₂-)



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$$\text{A. } \begin{array}{c} \text{O} \quad \text{Z} \quad \text{O} \\ || \quad | \quad || \\ \text{R}_1^5\text{O}-\text{P}-\text{C}-\text{S}=\text{O} \\ | \quad | \quad | \\ \text{R}_3^1\text{O} \quad \text{H} \quad \text{R}_4^1\text{O} \end{array} + \text{R}'\text{I} \xrightarrow[\text{DMF}]{\text{Base}} \begin{array}{c} \text{O} \quad \text{Z} \quad \text{O} \\ || \quad | \quad || \\ \text{R}_1^5\text{O}-\text{P}-\text{C}-\text{S}=\text{O} \\ | \quad | \quad | \\ \text{R}_3^1\text{O} \quad \text{R}^1 \quad \text{OM} \end{array}$$

II IIIA ID

$$\text{B. } \text{R}_1^5\text{O} - \text{P} \begin{array}{c} \text{O} \\ \parallel \\ \text{R}_3^3\text{O} \end{array} - \text{C} \begin{array}{c} \text{Z} \\ | \\ \text{R}^1 \end{array} - \text{S} \begin{array}{c} \text{O} \\ \parallel \\ \text{OR}_4^4 \end{array} = \text{O}$$

10

IC

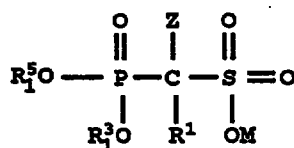
Part B(1) R_1^4 = alkyl,
cycloalkyl,
arylalkyl
(ICa)

_____ ID

1) a) $\text{NH}_3/\text{CH}_3\text{OH}$, or
b) MHCO_3 or
pyridine, or MOAc
in CH_3OH or
 $\text{CF}_3\text{CH}_2\text{OH}$, opt. H_2O
or
c) MI , DMF or
d) MI , 18-crown-6, THF
2) MOH (optional),
room temp.

15

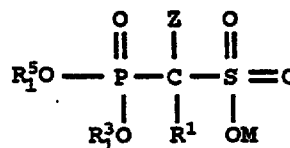
20



ID

Part B(2)
R₁⁴=aryl
(ICb)

MOH
R.T. to 80°C



ID

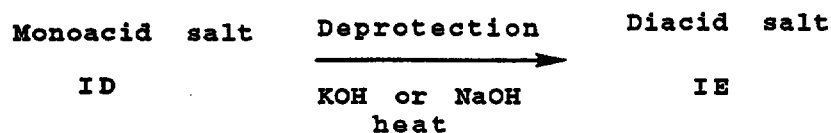
25

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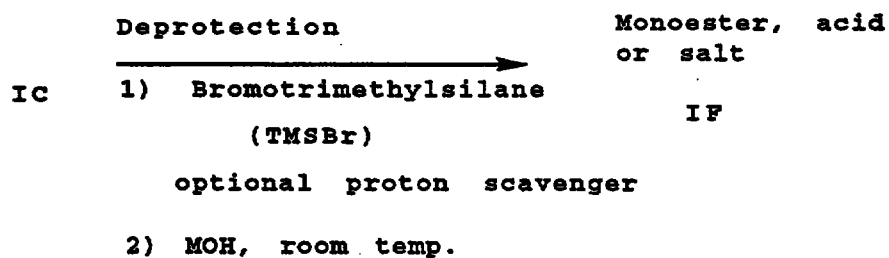


Scheme V - Preparation of (Hydroxyalkoxyphosphinyl)methanesulfonic Diacid Salts IE

5



10 Scheme VI - Preparation of (Dihydroxyphosphinyl)-methanesulfonic Acid Monoesters IF

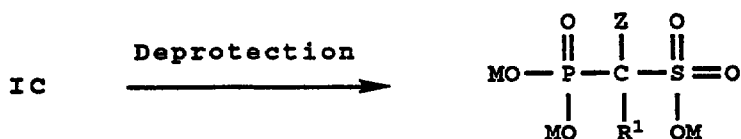


R_1^5, R_1^3 = alkyl, cycloalkyl, arylalkyl

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Scheme VII - Preparation of (Dihydroxyphosphinyl)-
methanesulfonic Acids IG



IG

5

- 1) Trimethylsilyliodide (TMSI) or
TMSI and a proton scavenger

Part A. IC

- 2) MOH

 $\text{R}^4 \neq \text{aryl}$

IG

- 1) Conversion to ID as described in
Part B(1) or B(2) Scheme IV

- 2) TMSBr or
TMSBr and a proton scavenger

- 3) MOH

Part B. IC

IG

- 1) TMSBr or TMSBr and a
proton scavenger

- 2) KI, 18-crown-6, THF

Part C. IC

- 3) MOH

 $\text{R}_1^4 \neq \text{aryl}$

IG

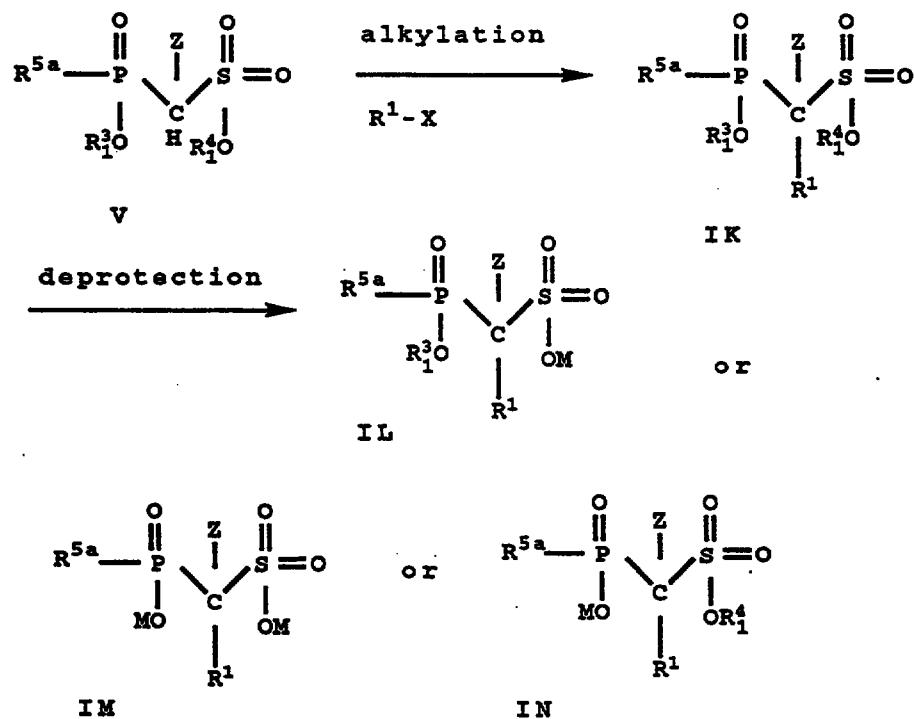
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Schemes VIII, IX, IXA and X - General Schemes for
the Preparation of α -(Alkyl-or Aryl-hydroxy-
phosphinyl)sulfonates

5 Scheme VIII



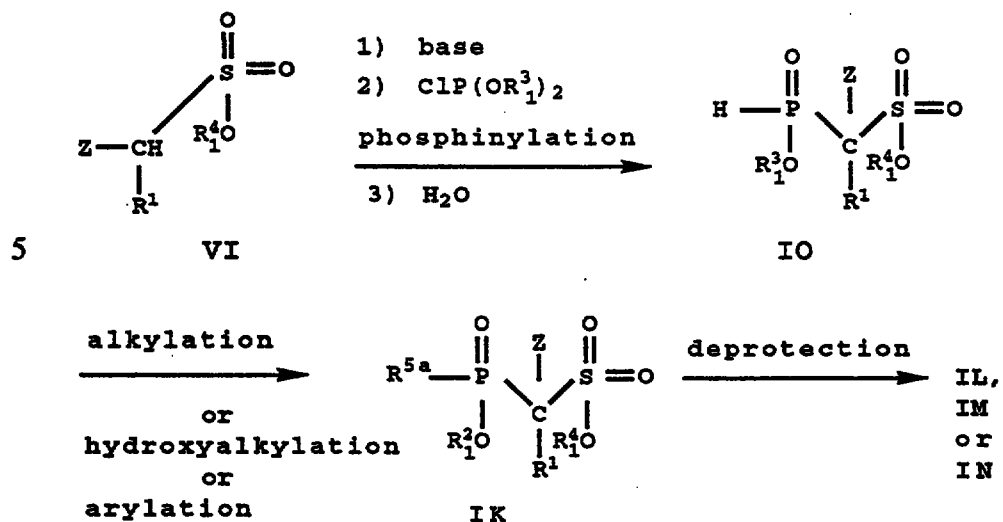
10

R^3, R^4 = alkyl, aryl, arylalkyl, cycloalkyl

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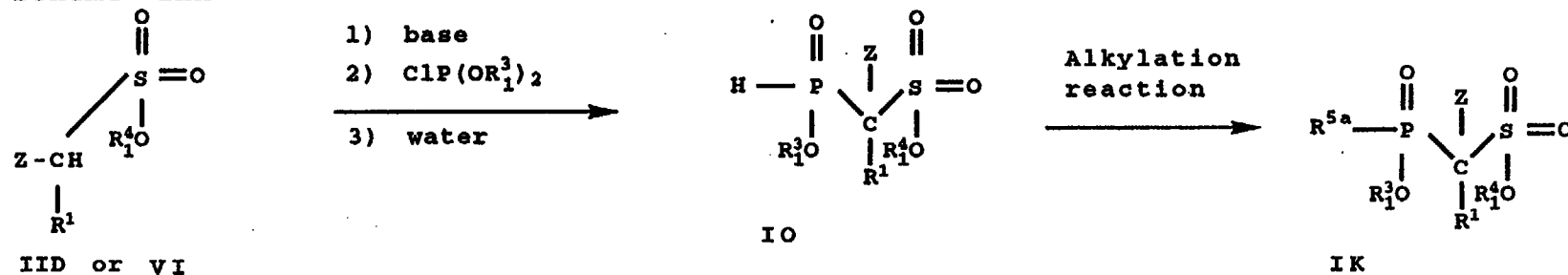
Scheme IX



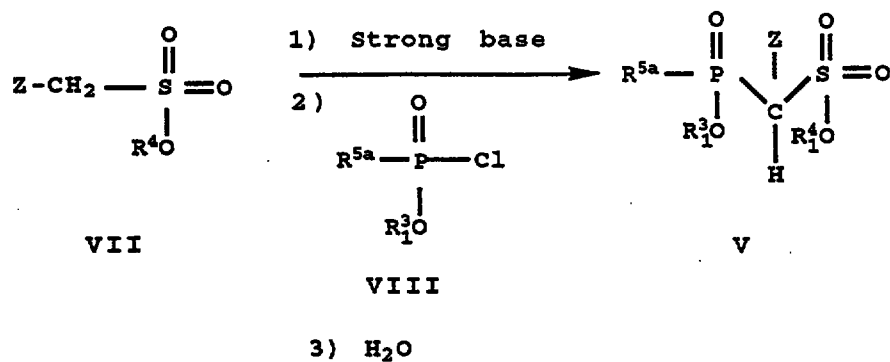
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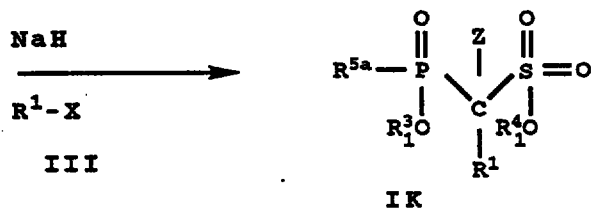
Scheme IXA



Alkylation Reaction Methodology		product IK
A.	A. 1) ≥ 1 eq. of base 2) $\text{R}^{5a}\text{-Hal}$ (Hal=I or Br) VIB	$\text{R}^{5a} \neq \text{Aryl}$
B.	B. 1) Chlortrimethylsilane (TMSCl) Et ₃ N 2) $\text{R}^{5a}\text{-Hal}$ VIB	$\text{R}^{5a} \neq \text{Aryl}$
C.	C. 1) base 2) aldehyde or 1) TMSCl, $(\text{C}_2\text{H}_5)_3\text{N}$ 2) aldehyde	$\text{R}^{5a} = \text{R}^7\text{CHOH}$ $\text{R}^7 = \text{aryl, alkyl or H}$
D.	D. 1) base 2) aryl halide, $\text{Pd}[\text{P}(\text{C}_6\text{H}_5)_3]_4$ or $\text{Ni}[\text{P}(\text{C}_6\text{H}_5)_3]_4$	$\text{R}^{5a} = \text{aryl}$

Scheme X

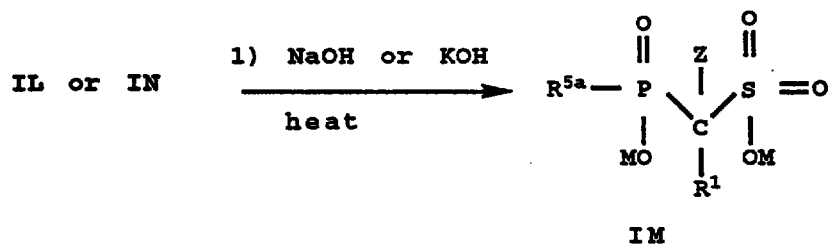
5



10 Scheme XI - Preparation of (Hydroxyphosphinyl)-methanesulfonic Acids

The diesters IL or IM are deprotected by treatment with aqueous alkali as shown below to yield the product IM.

15

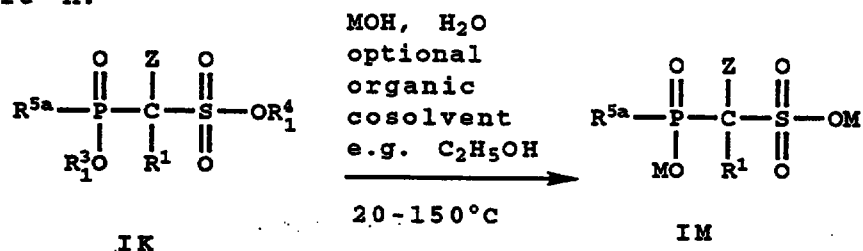


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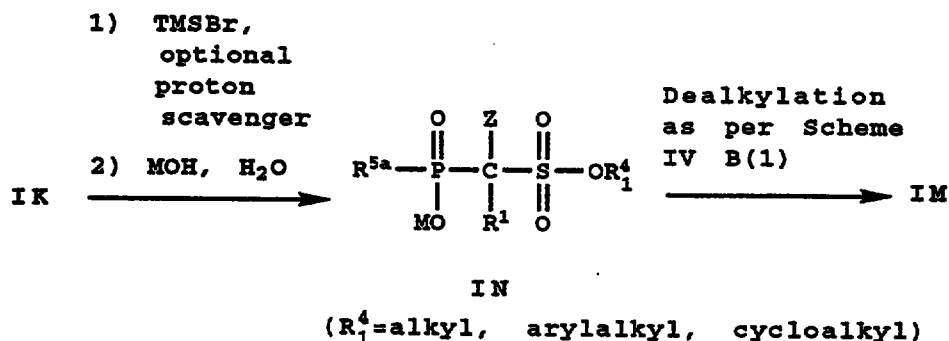
Scheme XIA - Preparation of (Hydroxyphosphinyl)-methanesulfonic Acids.

Part A.

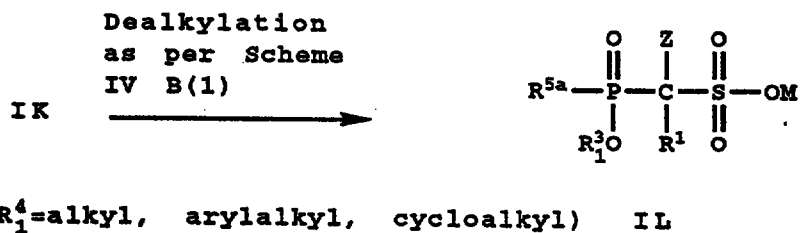


5

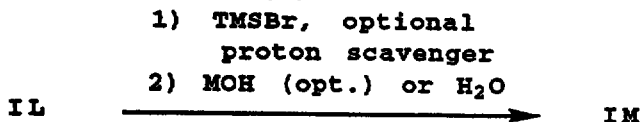
Part B.



Part C.



Method (1)



or

Method (2)

MOH, H₂O
optional organic
cosolvent
20-150°C

10

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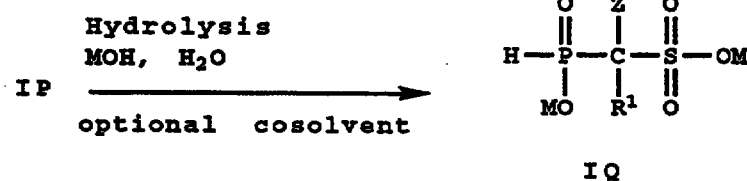
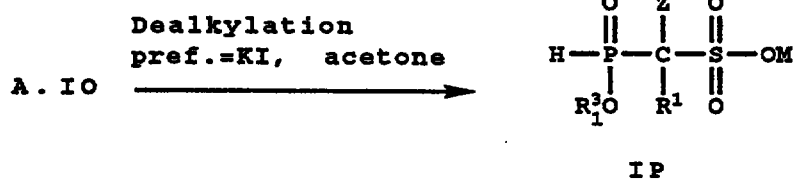
Part D.

As in Scheme
VII

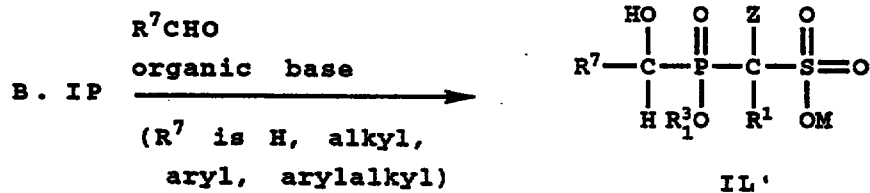
Part C

(R₁⁴=alkyl, aryl, arylalkyl)

5 Scheme XII - Preparation of α-Hydroxyphosphinyl
methanesulfonic Acids (phosphonous acids)

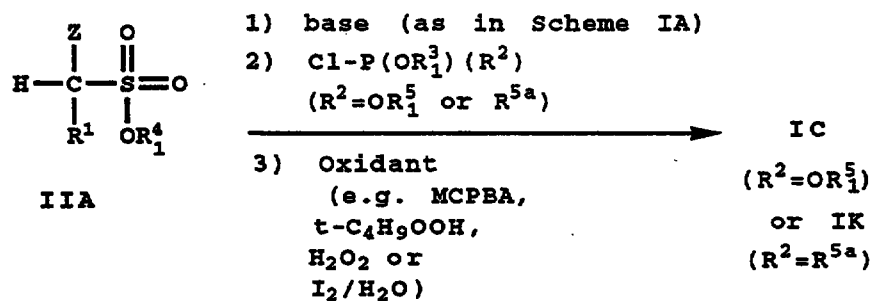
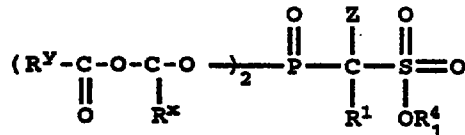
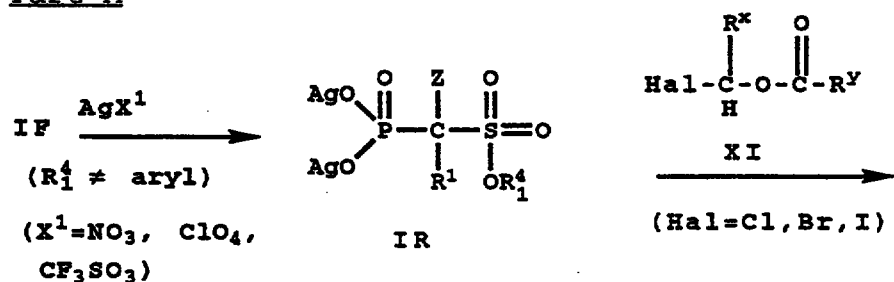


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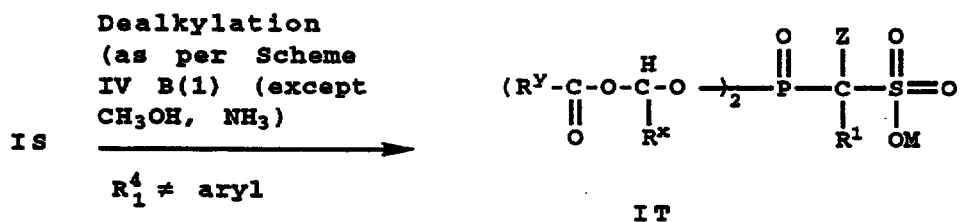
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Scheme XIII - Alternative Route to IC or IK5 Scheme XIV - Preparation of ProdrugsPart A

IS

10

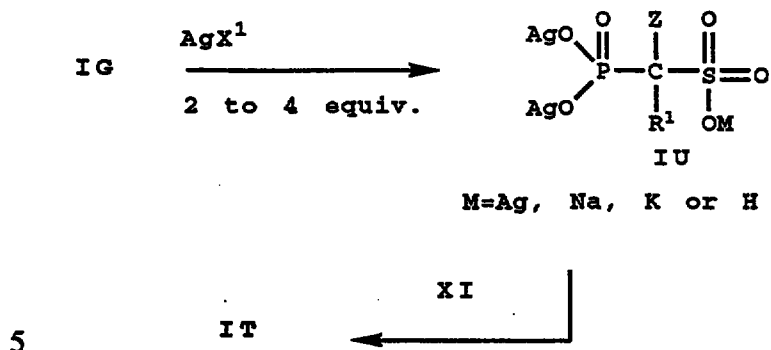
(R^y = aryl, aralkyl, alkyl or alkoxy)(R^x = aryl, aralkyl, alkyl or H)

15

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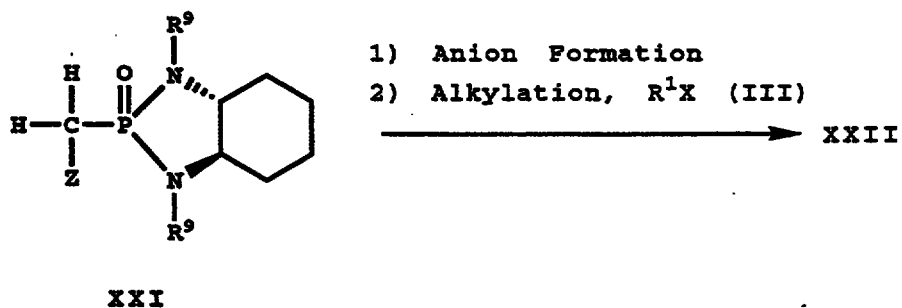
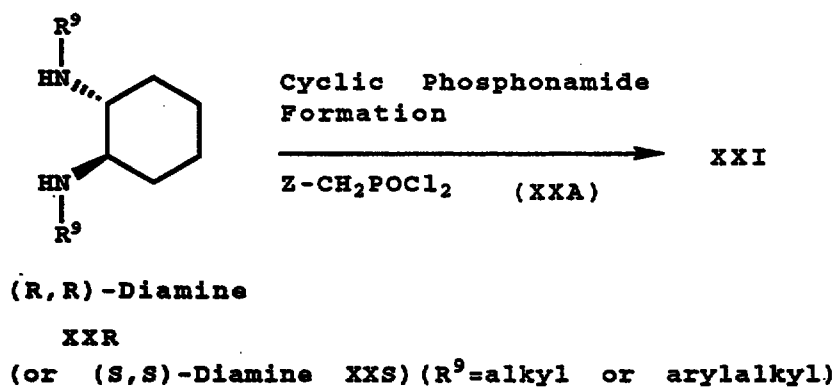


Part B



Scheme XV - Preparation of Individual Enantiomers of Formula I Compounds

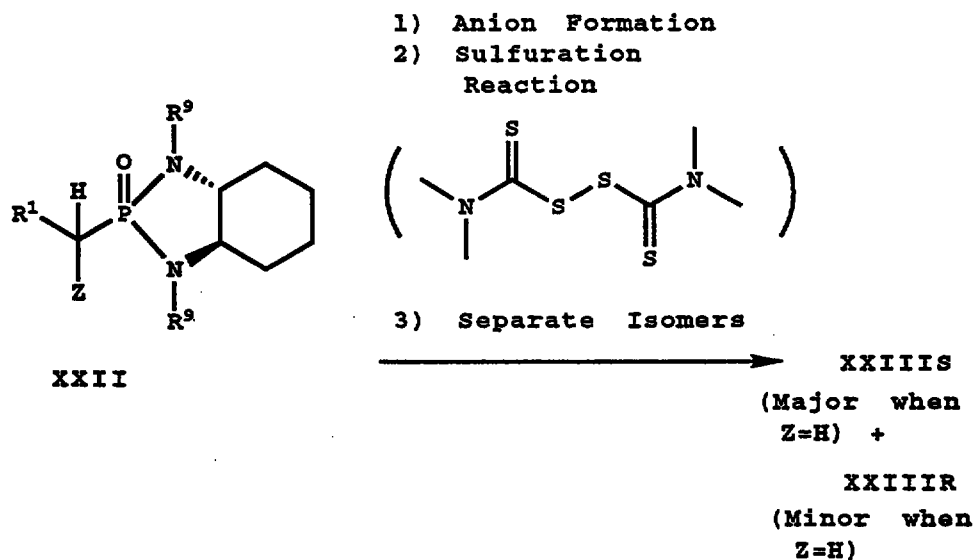
10 Part A



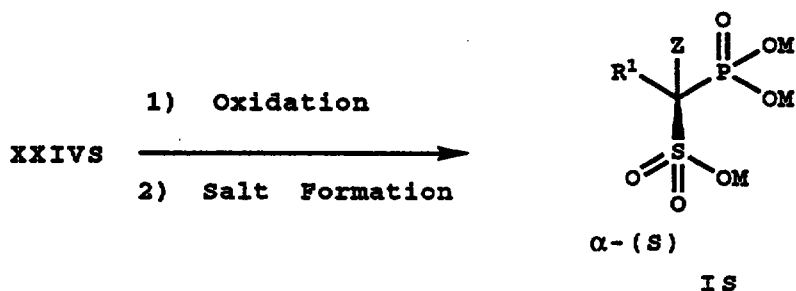
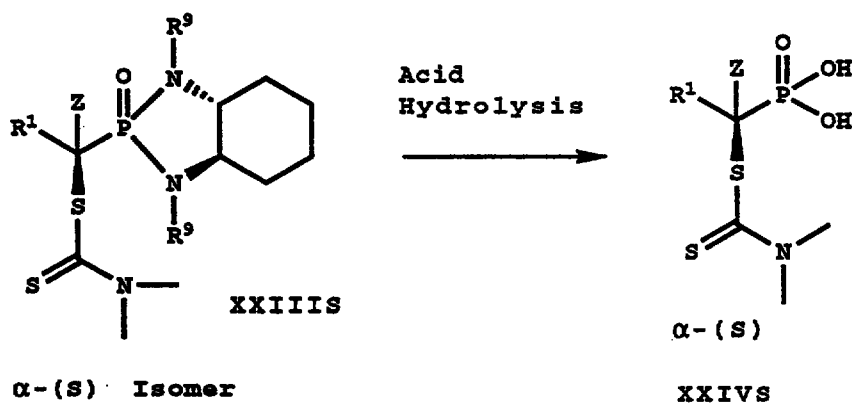
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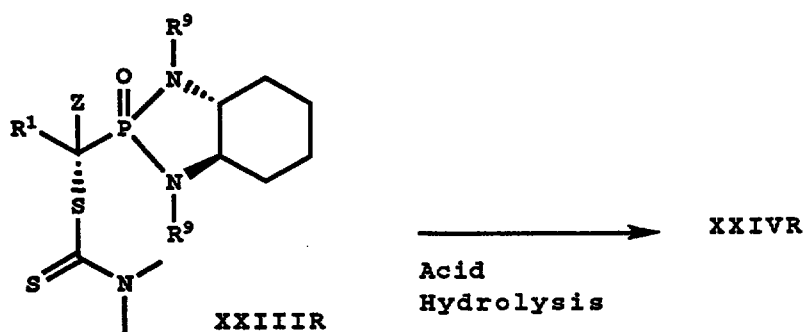
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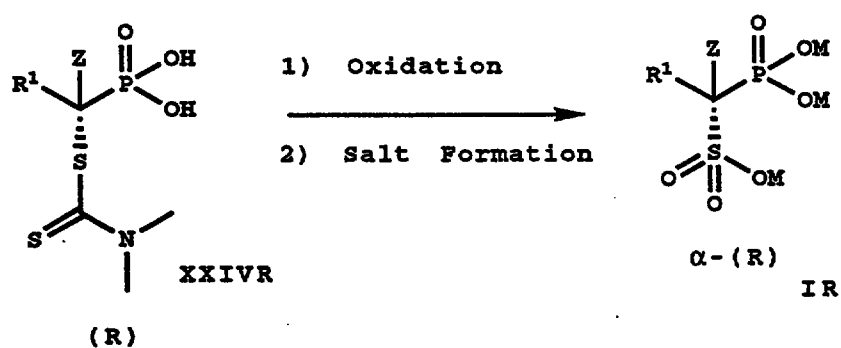


When (S,S)-Diamine XXS is used as starting material, α -(R) is Major Isomer where (Z=H) and
5 α -(S) is Minor Isomer (Z=H)





α -(R) Isomer



5 References on asymmetric reaction of chiral phosphonates:

Hanessian, S., Delorme, D., Beaudoin, S., LeBlanc (1984) *Chemica Scripta* 25, 5-11.

Hanessian, S., Bennani, Y.L., Delorme, D. (1990)

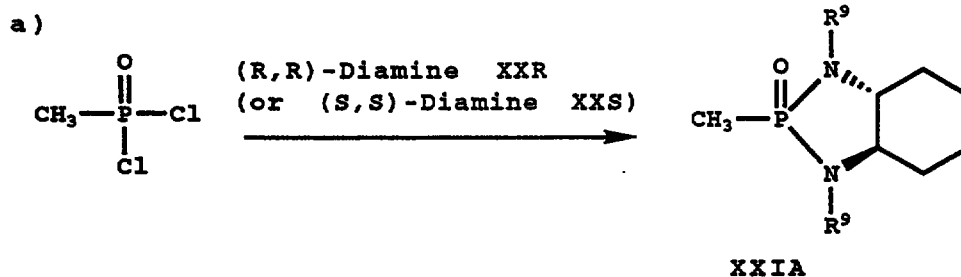
10 *Tetrahedron Lett.* 45, 6461-6464.

Hanessian, S., Bennani, Y.L. (1990) *Tetrahedron Lett.* 45, 6465-6468.

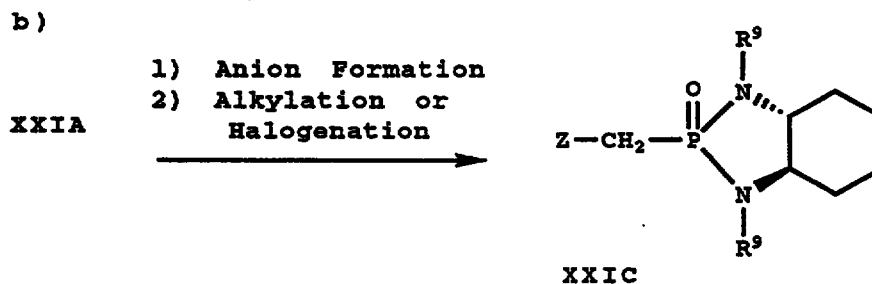
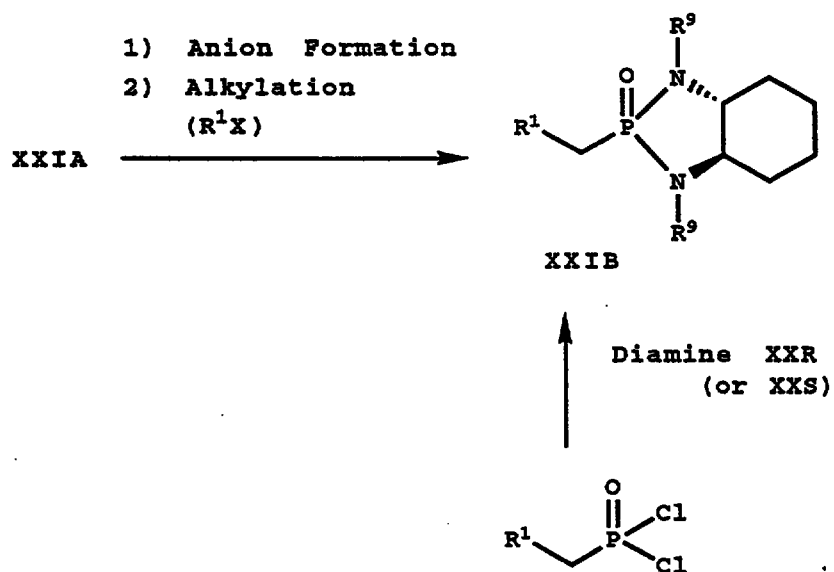
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Scheme XV Part A(1) - Alternate Routes to XXII
(Used in Scheme XV, Part A)

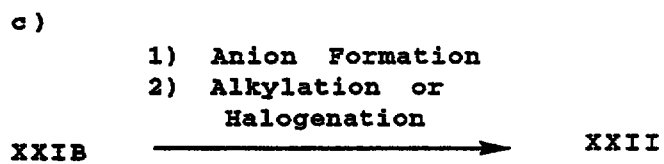
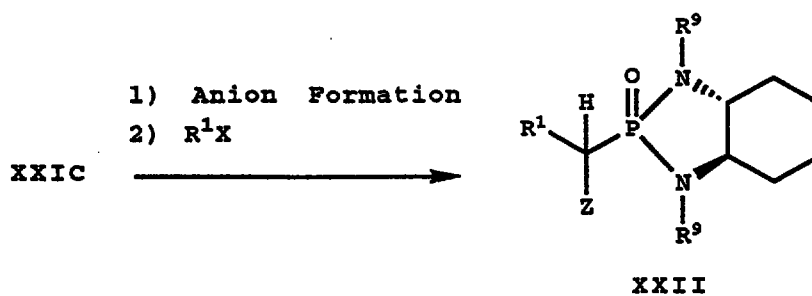


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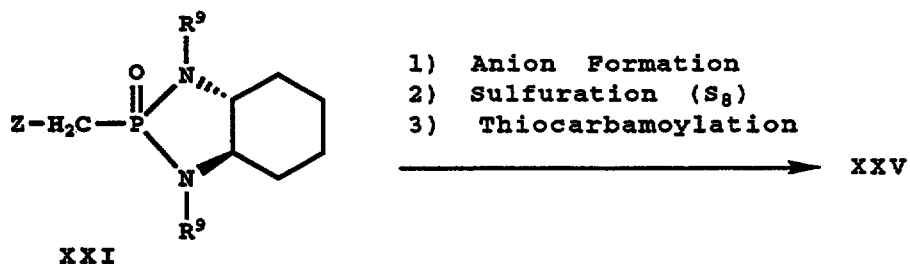




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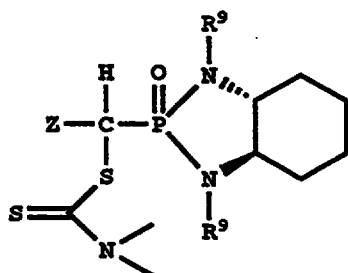
Scheme XV Part B



- 1) Anion Formation
- 2) Sulfuration (S_8)
- 3) Thiocarbamylation

XXV

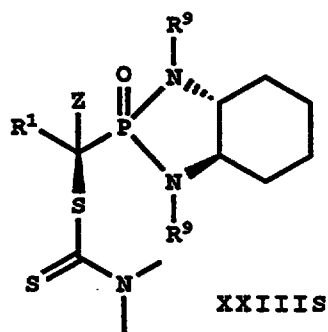
(from (R,R)-Diamine XXR)



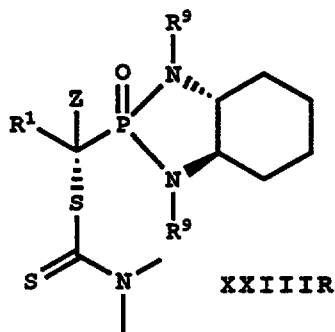
XXV

- 1) anion formation
- 2) alkylation
 $R^1\text{Hal}$

5 XXV



(Minor Isomer
 α -(S) when Z=H)



(Major Isomer
 α -(R) when Z=H)

When (S,S)-Diamine XXS is the starting material,
the α -(S) isomer XXIIIS is obtained as the major
10 product when Z=H.

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XXIIIS

Continue as in Scheme XV Part A

IS

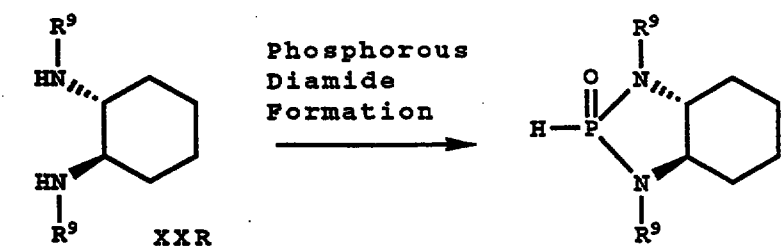
XXIIIR



IR

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Scheme XV Part C



(R,R)-Diamine

XXVII

(or (S,S)-Diamine (XXS))

- 1) Condensation
Reaction

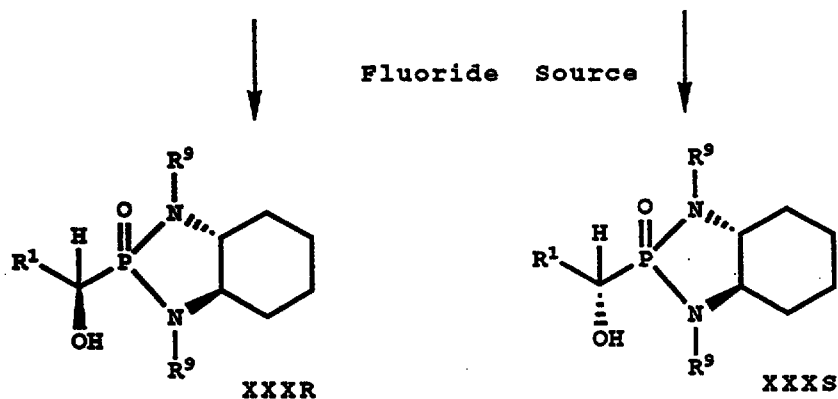
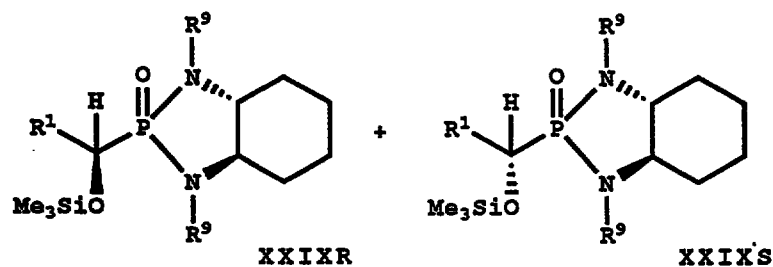
 R^1CHO (XXVIII)

Silylating Agent



5

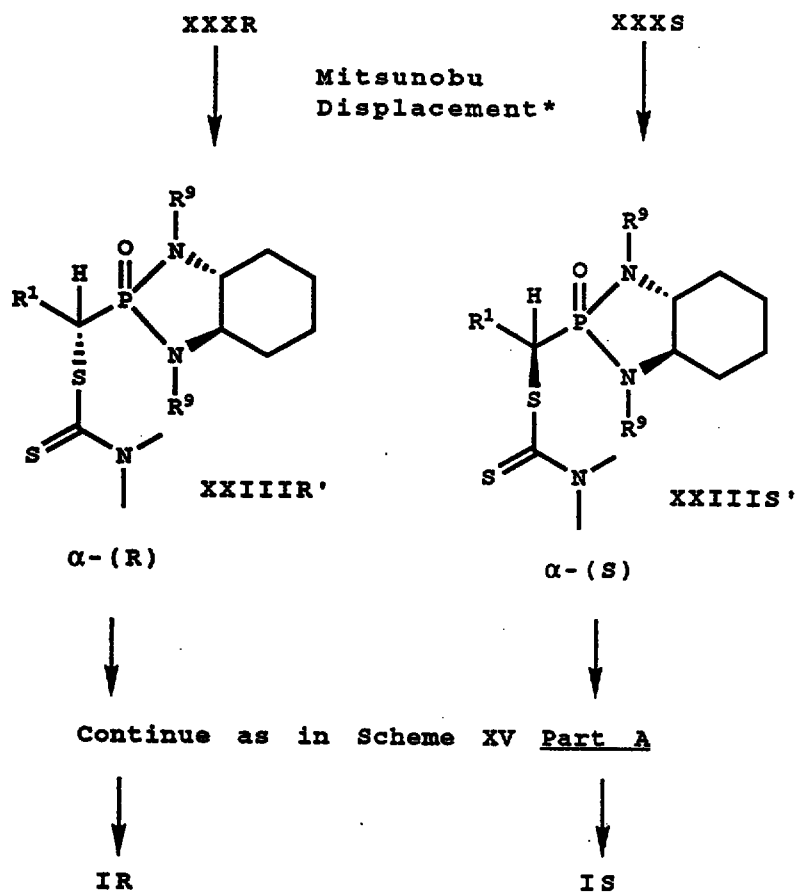
- 2) Separate Isomers



Alternatively, isomers can be separated at the alcohol stage, that is, XXXR and XXXS.

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*P. Rollin, Tetrahedron Lett. 1986, 27, 4169-4170

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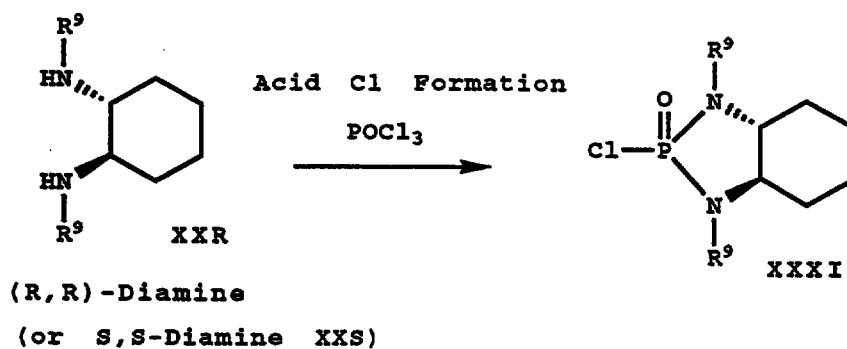
Part C (1)

- 1) Condensation
Reaction
R¹CHO (XXVIII)
Various Bases
including Fluoride
XXVII $\xrightarrow{\hspace{2cm}}$ XXXR + XXXS
- 2) Separate Isomers

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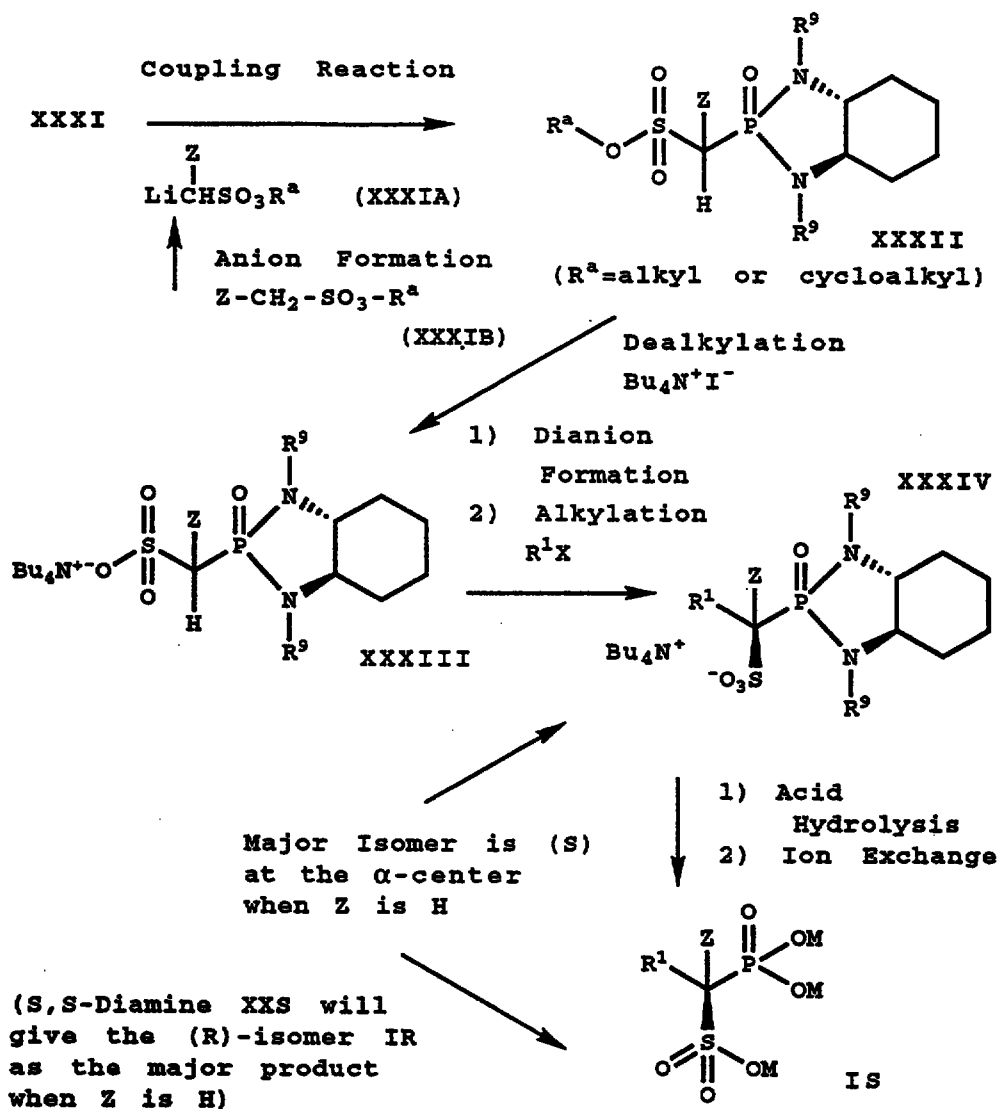
Scheme XVI - Alternate Preparation of Individual Enantiomers of Formula I Compounds



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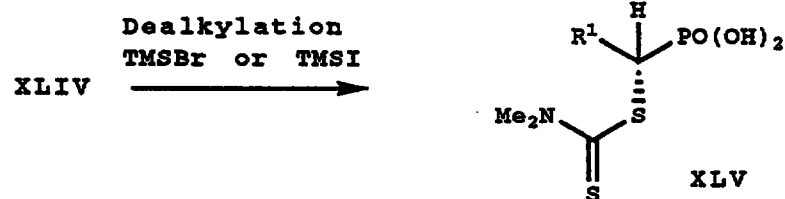
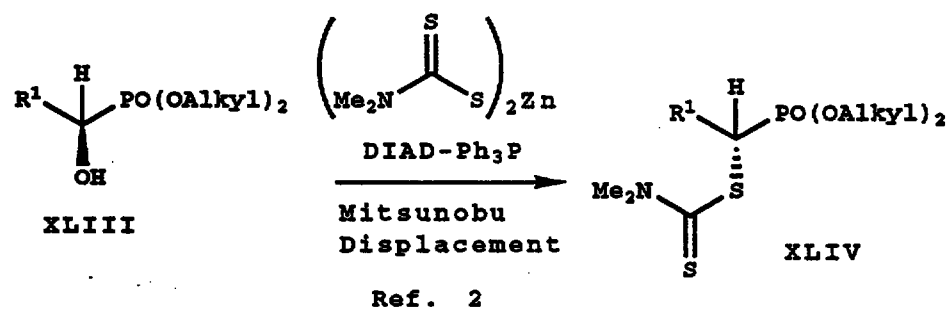
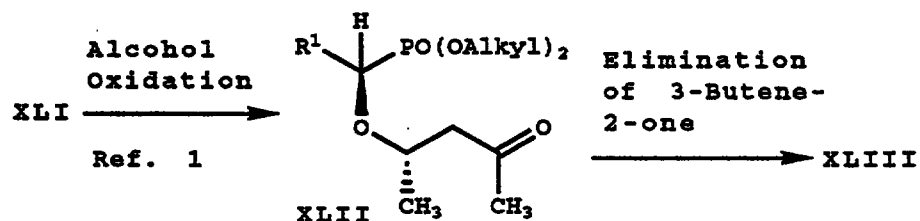
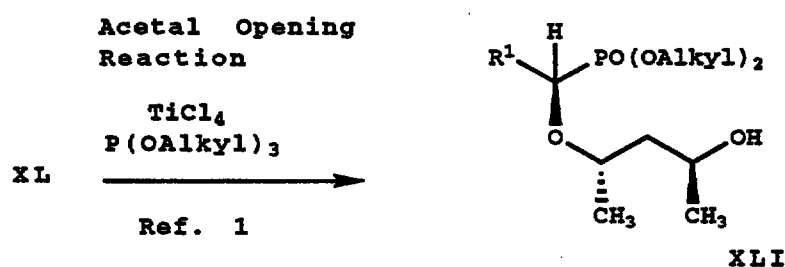
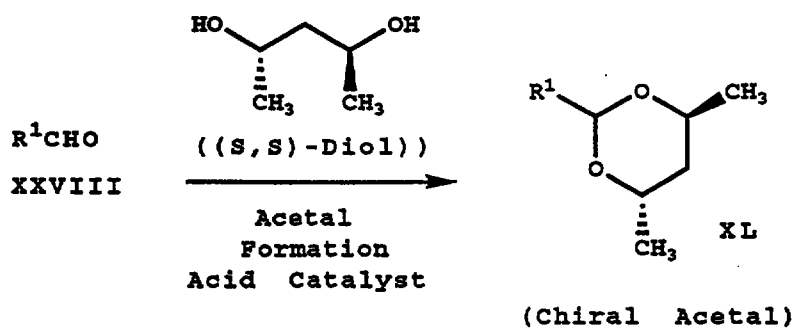
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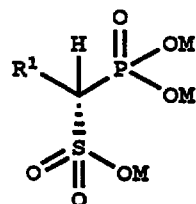
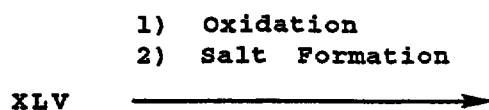
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Scheme XVII - Preparation of Individual Enantiomer

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(R)-enantiomer (IR)

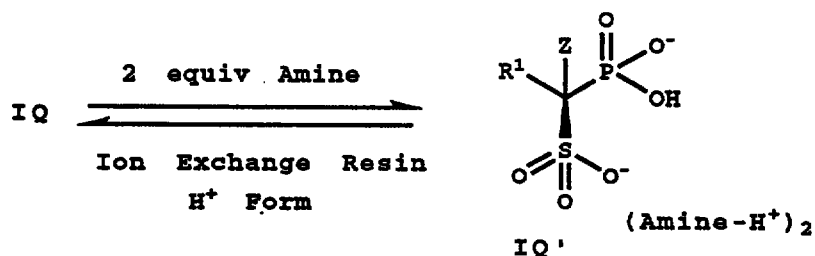
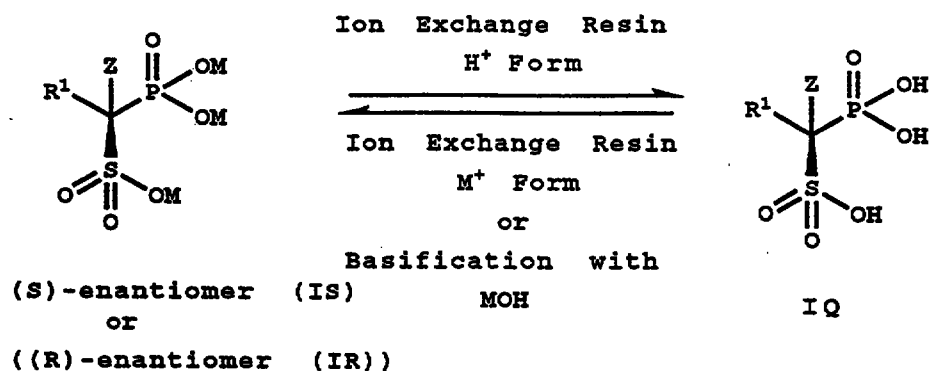
Use (R,R)-diol to obtain (S)-enantiomer (IS)

References:

- 5 (1) Yokomatsu T.; Shibuya, S., *Tetrahedron Asymmetry* 1992, 3, 377-378
(2) P. Rollin, *Tetrahedron Lett.* 1986, 27, 4169-4170

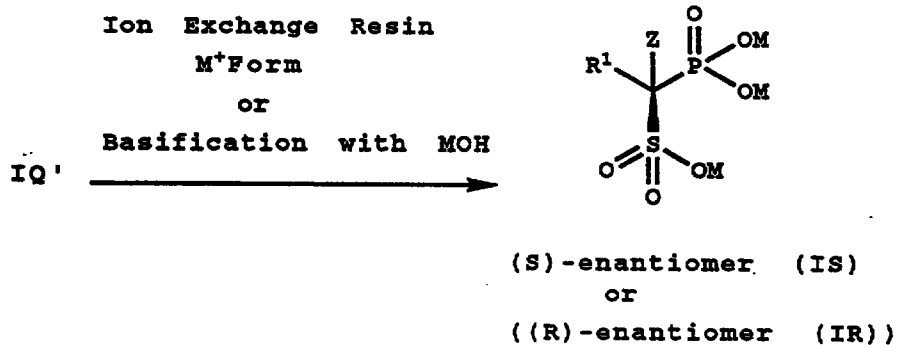
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Scheme XVIII - Purification of Desired Enantiomer

Diamine Salts (IQ') are useful for purification and improvement of enantiomeric excess, especially by recrystallization

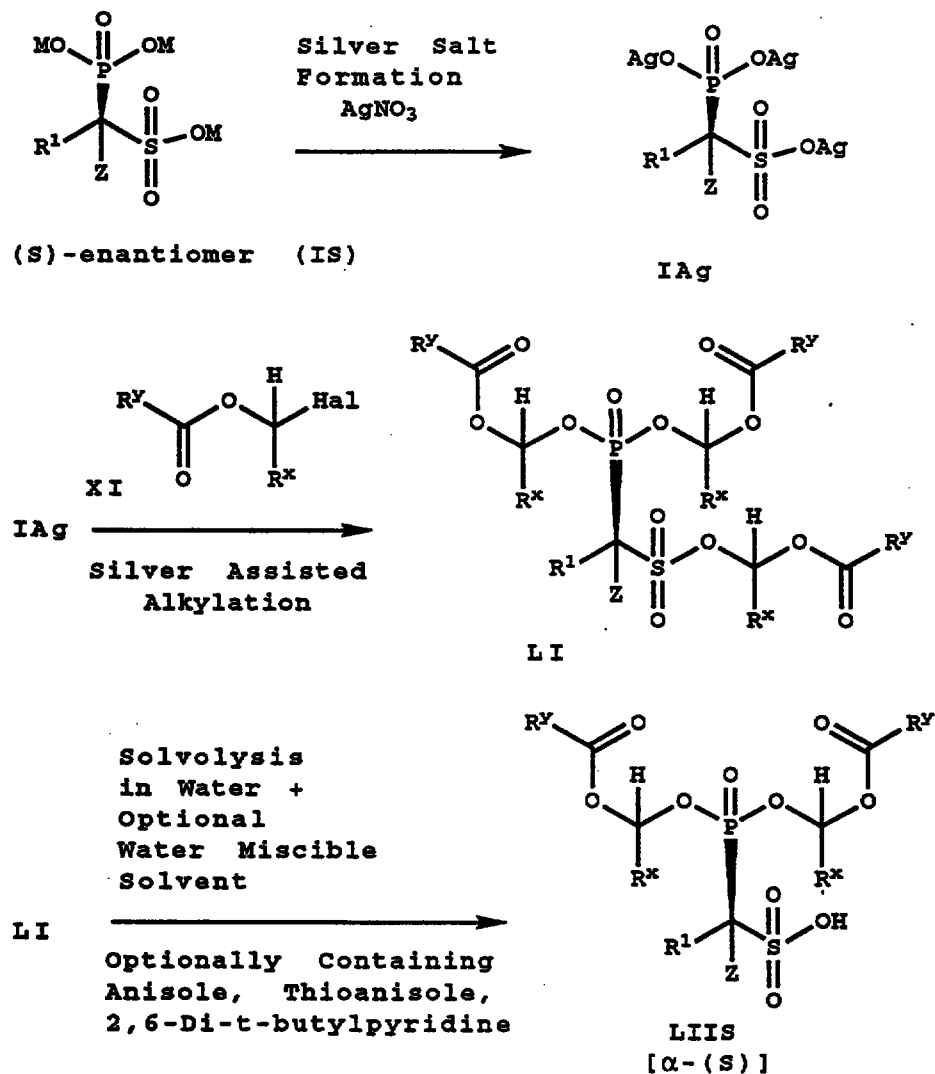
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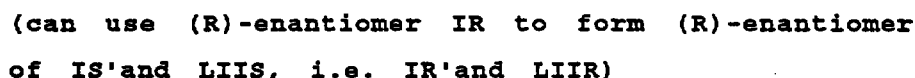


Scheme XIX - Preparation of Prodrugs of Desired Enantiomer



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Referring to "General Reaction" Scheme I, compounds of the invention IC may be prepared by alkylating the phosphonosulfonate II by reacting II with compound III in the presence of an appropriate base and an inert organic solvent under an inert atmosphere to form IC, followed by deprotection to the various acid forms ID, IE, IF and IG.

In carrying out the above reaction, the phosphonosulfonate II is employed in a molar ratio to compound III of within the range of from about 5:1 to about 0.8:1, and preferably from about 3:1 to about 1.2:1. The reaction is carried out under an inert atmosphere, such as argon, initially preferably at a reduced temperature of within the range of from about -78 to about 80°C, and more preferably from about 0 to about 50°C, although the reaction may be completed at room temperature.

Examples of inert organic solvents suitable for use herein include, but are not limited to dimethylformamide (DMF), tetrahydrofuran (THF), dimethylsulfoxide (DMSO), hexamethylphosphoramide (HMPA) or diethyl ether (Et₂O), or mixtures thereof.



Examples of bases suitable for use in carrying out the above reaction include, but are not limited to, alkali metal hydrides, such as sodium hydride (which is preferred), potassium
5 hydride, lithium-, sodium- or potassium bis(tri-methylsilyl)amide, lithium diisopropylamide or butyllithium.

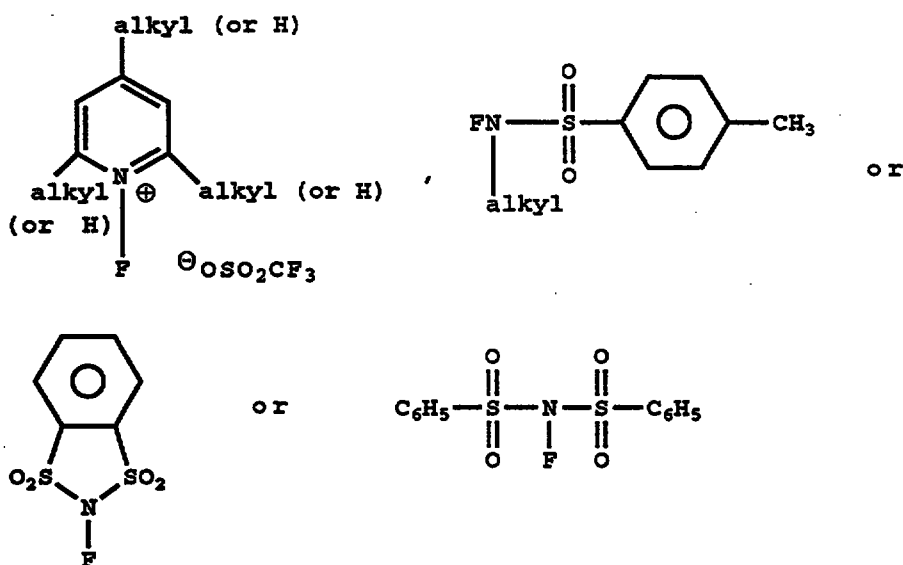
Referring to Scheme IA, starting compounds of formula IIC wherein R_1^2 , R_1^3 , and R_1^4 of II as
10 defined in Scheme I may be prepared by reacting starting sulfonate IIA with a strong base such as any of those used in Scheme I, in the presence of or followed by chlorophosphate IIB, and an inert organic solvent such as used in Scheme I, to form
15 IIC.

In carrying out the reaction of Scheme IA, chlorophosphate IIB will be employed in a molar ratio to sulfonate IIA of within the range of from about 3:1 to about 1:2, and preferably from about
20 2.0:1 to about 1:1. The reaction is carried out at a temperature of within the range of from about -100° to about 30°C, and preferably from about -90° to about 0°C.

Referring to Scheme II, compounds of the
25 invention IC may be prepared by alkylating the phosphonosulfonate IC' with an alkylhalide, ZX (IIIA) (Z is alkyl and X is as defined in Scheme I), or with a halogenating agent ZX^1 (where Z is halogen except F and X^1 is succinimido, Cl, Br or
30 I, or OH; when Z is F, ZX^1 is XeF_2),

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5 The above reactions are carried out in the presence of appropriate inert organic solvent as described above, under an inert atmosphere, to form IC.

10 In carrying out the above reaction, the phosphonosulfonate IC' is employed in a molar ratio to compound IIIA or IIIA' of within the range of from about 2:1 to about 0.2:1, and preferably from about 1.5:1 to about 0.7:1. The reaction is carried out under an inert atmosphere, such as

15 argon, initially preferably at a reduced temperature of within the range of from about -78° to about 80°C, and more preferably from about 0°C to about 50°C, although the reaction may be completed at room temperature. Bases and solvents

20 appropriate for this reaction are as described for Scheme I.

25 Referring to Scheme III Part A, compounds of the invention IC may be prepared by alkylating the phosphonosulfonate II with compound III in the presence of an appropriate base and an inert

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organic solvent (as described hereinbefore with respect to Scheme I) preferably dimethylformamide (DMF), under an inert atmosphere to form IC.

In carrying out the above reaction, the
5 phosphonosulfonate II is employed in a molar ratio to compound III of within the range of from about 5:1 to about 0.8:1, and preferably from about 3:1 to about 1.5:1. The reaction is carried out under an inert atmosphere, such as argon, initially
10 preferably at a reduced temperature of within the range of from about -78° to about 80°C, and more preferably from about 0 to about 50°C, although the reaction may be completed at room temperature.

Referring to Schemes III Part B and III Part
15 C, compounds of the invention IC' may be prepared through the palladium catalyzed base promoted coupling of allylic acetates (Types 1 or 2) with the phosphonosulfonate II to provide the coupled product of the invention IC'. Either allylic
20 isomer serves as a substrate in the reaction.

In carrying out the above reactions, the phosphonosulfonate II is employed in a molar ratio to allylic acetate of within the range of from about 5:1 to about 0.8:1, and preferably from about
25 3:1 to about 1.5:1. The reaction is carried out under an inert atmosphere, such as argon, initially preferably at a reduced temperature of within the range of from about -78° to about 110°C, and more preferably from about 0 to about 80°C, although the
30 reaction may be completed at room temperature.

The above reactions are carried out in the presence of a suitable inert organic solvent as described hereinbefore with respect to Scheme I, preferably employing tetrahydrofuran (THF) or

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dimethylformamide (DMF). Suitable bases are sodium hydride and sodium bis(trimethylsilyl)amide, and preferably bis(trimethylsilyl)acetamide (BSA) in the presence of palladium (0) catalyst such as

5 Pd[P(C₆H₅)₃]₄.

The base or BSA is employed in a molar ratio to allylic acetate within the range of from about 4:1 to about 1:1, while the Pd(0) is employed in a molar ratio to allylic acetate of within the

10 range of from about 0.005:1 to about 0.5:1.

Referring to Scheme IV, Part A, the coupling reaction is carried out with (dialkoxyphosphinyl)methane sulfonate ethyl ester II to yield the sulfonate salt ID directly from the

15 reaction. The product emerges by means of a concomitant iodide promoted dealkylation of the sulfonate ester.

The Scheme IV Part A, reaction is carried out in a manner similar to Scheme I.

The sulfonate salt ID may also be formed as shown in Scheme IV, Part B(1) and (2). Part B(1) depicts the dealkylation of the sulfonate ester ICa to yield ID, using various reagents as shown in the reaction sequence set out hereinbefore, while B(2)

20 shows the cleavage of an aryl methanesulfonate ester ICb by aqueous alkali containing from about 5 to about 20% by weight base) and heating at a temperature within the range of from about 40° to about 100°C, to give ID.

Referring to Scheme V, the diacid salt IE is prepared by the further hydrolysis of monoacid ID employing aqueous alkali (containing from about 5° to about 20% by weight base) optionally in the presence of a cosolvent, such as dimethoxyethane,

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dioxane or THF, and heating at a temperature within the range of from about 40 to about 100°C.

Referring to Scheme VI, the (dihydroxy-phosphinyl)methanesulfonic acid monoester IF is
5 prepared by the cleavage of the phosphorous ester IC (wherein R_1^2 and R_1^3 are each lower alkyl, arylalkyl, cycloalkyl and R_1^4 is lower alkyl, arylalkyl, cycloalkyl or aryl) with bromotrimethylsilane (TMSBr), optionally in the presence of a
10 proton scavenger such as 2,4,6-collidine, hexamethyl disilazane, alkyl, trimethylsilane, bis(trimethylsilyl)trifluoroacetamide, pyridine or triethylamine, followed by aqueous alkali (as described above except that elevated temperatures
15 are not necessary) or water wherein the TMSBr is employed in a molar ratio to IC of within the range of from about 2:1 to about 15:1, preferably from about 2: to about 5:1.

Scheme VII Parts A, B and C sets out the
20 chemical processes employed for the deprotection of phosphonosulfonate triester IC to phosphonosulfonic acid IG.

In Scheme VII, Part A shows the direct deprotection of the ester IC through the agency of
25 trimethylsilyl iodide (TMSI) (employs a molar ratio of TMSI:IC of within the range of from about 3:1 to about 20:1, preferably from about 3.5:1 to about 5:1) optionally in the presence of a proton scavenger as defined above, and followed by aqueous
30 alkali (as described above) or water at a temperature of within the range of from about 0° to about 50°C.

In Scheme VII Part B, phosphonosulfonic triacid IG is formed via a two step process where



in the first step, the sulfonate ester is removed as described in Part B, Scheme IV and in the second step treatment with bromotrimethylsilane optionally in the presence of a proton scavenger as defined
5 above, yields the silyl esters which are then hydrolyzed via aqueous alkali (as described hereinbefore) or water.

In Scheme VII Part C, the phosphonate esters are removed (from IC) first with bromo-
10 trimethylsilane (TMSBr) (employing a molar ratio of TMSBr:IC of within the range of from about 2:1 to about 20:1, preferably from about 2.5:1 to about 5:1) optionally in the presence of a proton
15 scavenger as defined above, to provide the intermediate bis(silyl)esters. Subsequent cleavage of the sulfonate ester with potassium iodide (18-crown-6, THF) and hydrolysis (MOH and H₂O) yields the phosphonosulfonic triacid IG.

Schemes VIII, IX, IXA and X relate to the
20 preparation of α -(alkyl- or aryl-hydroxyphosphinyl)sulfonates.

Schemes VIII and IX depict the general chemical process for the formation of diesters IK, and their deprotection to form IL and IO,
25 respectively.

Scheme IXA depicts the P-H route to diester IK. Starting sulfonate VI is treated with a strong base followed by dialkyl chlorophosphite (employing a molar ratio of dialkyl chlorophosphite:VI of
30 within the range of from 1:1 to about 10:1), followed by hydrolysis with water under acidic conditions, to form alkoxyphosphinyl sulfonate IO which serves as an intermediate for the synthesis of substituted (alkyl- or aryl-alkoxyphosphinyl)-

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methylsulfonate diesters via alkylation of IO. The alkylation methods are shown in Parts A, B, C and D.

In Scheme IXA Part A, diester IK where R^{5a}≠ aryl is formed by selective alkylation of IO by treating IO with base such as NaH, KH, LDA, butyllithium, Li-, Na- or K-bis(trimethylsilyl)-amide and a halide VIB of the structure



wherein Hal is I or Br, as described with respect to Scheme I.

In Scheme IXA Part B, diester IN where R⁵≠ aryl is formed by treatment of IO with chlorotrimethylsilane (TMSCl) and organic base such as triethylamine (Et₃N) in the presence of alkylating agent VIB. In carrying out this alkylation, the silane compound is employed in a molar ratio to IO of within the range of from about 1:1 to about 5:1, preferably from about 1:1 to about 3:1 while VIB is employed in a molar ratio to IO of within the range of from about 0.8:1 to about 10:1.

In Scheme IXA Part C, IK where R^{5a} is R⁷CHOH (and R⁷ is H, aryl or alkyl) is prepared by treating IO with base followed by aldehyde R⁷CHO, carried out by employing a molar ratio of R⁷CHO to IO of from about 1:1 to about 10:1. Alternatively, IO can be treated with (CH₃)₃SiCl and an organic base (such as triethylamine) followed by an aldehyde, followed subsequently with a standard desilylation reaction (such as tetrabutylammonium fluoride in THF) to provide IK with R⁵=R⁷CHOH.

In Scheme IXA, Part D IO is reacted with an aryl halide in the presence of a base such as triethylamine and Pd[P(C₆H₅)₃]₄, Ni[P(C₆H₅)₃]₄ or



other nickel and palladium catalysts, to yield IK when R^{5a} is aryl.

Scheme X depicts the preparation of (hydroxyphosphinyl)methanesulfonic acid diester IN by alkylation of diester V by treatment of V with base, such as NaH, and alkylating agent III as described hereinbefore in Scheme I. The intermediate V may be prepared via a coupling reaction of the alkylsulfonate VII with phosphonic acid chloride VIII employing a molar ratio of VII:VIII of within the range of from about 0.5:1 to about 10:1, preferably from about 1.5:1 to about 3:1, similar to that described in Scheme IA, for the conversion of IIA to IIC.

Schemes XI and XIA depict various routes (A, B and C) for the deprotection of diesters IK to yield IM.

Scheme XII Part A depicts the preparation of salts IQ by dealkylating IO using techniques as described hereinbefore, preferably with KI and acetone, to form monoester IP and then subjecting IP to hydrolysis to form salt IQ.

In Scheme XII Part B, the ester IP is treated with aldehyde (R^7CHO) in the presence of organic base such as triethylamine, diisopropylethylamine or 1,8-diazabicyclo[5.4.0]undec-7-ene, to form IK where R^{5a} is R^7CHOH . In this reaction, the aldehyde is employed in a molar ratio to IP of within the range of from about 1:1 to about 10:1, preferably from about 1:1 to about 5:1.

Scheme XIII depicts an alternate route to IC where IIA is treated with base (as per Scheme IA) and chlorophosphite (as described hereinbefore) and an oxidant such as m-chloroperbenzoic acid

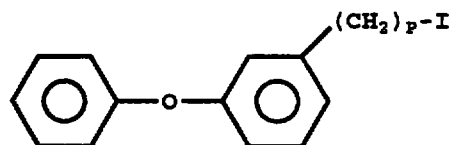
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(MCPBA), $t\text{-C}_4\text{H}_9\text{COOH}$, hydrogen peroxide or $\text{I}_2/\text{H}_2\text{O}$ to form IC.

Scheme XIV (Parts A and B) depict the preparation of prodrug esters.

5 Referring to Scheme XV, the individual isomers or enantiomers of the formula I compounds of the invention may be prepared, in accordance with the present invention, by treating the (R,R)-diamine XXR (or (S,S)-diamine XXS) where R^a is
10 alkyl or aralkyl, with an alkyl phosphonic dihalide XXA, such as methylphosphonic dichloride, in the presence of a tertiary amine base and an aprotic solvent such as benzene, toluene, dichloromethane or diethyl ether, to form the alkylphosphondiamide
15 XXI which is metalated with a base such as *n*-butyllithium, *sec*-butyllithium, *t*-butyllithium or lithium diisopropylamide, to form the lithium anion of XXI which is then alkylated by treatment the halide R^1X (IIIa) such as the iodide
20 XXIB



in the presence of an inert organic solvent such as tetrahydrofuran (THF), diethyl ether or dimethoxyethane or mixtures thereof, at a temperature within
25 the range of from about -90 to about 25°C , preferably from about -80 to about 0°C , to form XXII. Compound XXII is reacted with a base as above to form the lithium anion of XXII which is sulfurated with tetramethylthiuram disulfide or the
30 corresponding tetraethyl derivative at a temperature within the range of from about -100 to about 0°C , preferably from about -90 to about -60°C , to form a



mixture of isomers XXIIIIR and XXIIIS (which are novel compounds in accordance with the present invention).

Where the sulfuration is carried out at
5 below about 0°C, preferably at about -60°C to about -100°C, and the starting diamine is the (R,R)-diamine XXR and Z is H, a mixture of major XXIIIS (α -(S)) and minor XXIIIIR (α -(R)) thiocarbamate isomers (about 3:1 mixture at -90°C) is obtained.

10 It should be noted that in the above and following discussions and schemes α -(R) and α -(S) refer to the enantiomeric configuration at the chiral carbon center adjacent to the phosphorus and sulfur moieties.

15 It will be appreciated that where the (S,S)-diamine XXS is employed in place of (R,R)-diamine XXR and Z is H, the major isomer obtained will be the α -(R)-isomer XXIIIIR.

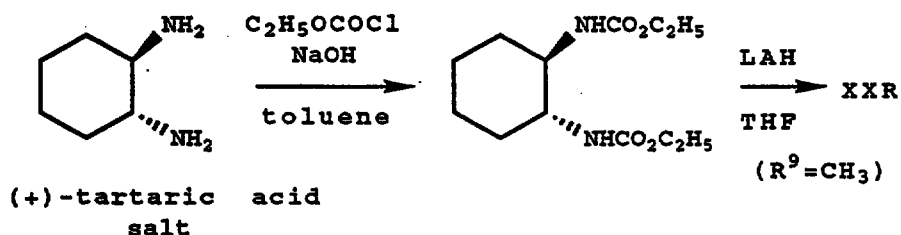
The thiocarbamate isomers XXIIIS and XXIIIIR
20 can be separated by chromatography on silica gel, crystallization or HPLC. The individual and separate diastereomers (XXIIIS and XXIIIIR) are then separately subjected to acid hydrolysis (such as treatment with aqueous acid such as HCl), to form
25 compound XXIVR or XXIVS (which are novel compounds in accordance with the present invention) which are separately subjected to oxidation (such as reaction with H₂O₂ in the presence of formic acid, acetic acid or mixtures of formic and acetic acids) and
30 salt formation by base treatment or ion exchange chromatography, to form the individual enantiomers IS and IR of the invention.

In carrying out the reactions of Scheme XV, the starting (R,R)-diamine with R⁹=methyl is

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prepared by a two-step reductive methylation of the L-(+)-tartaric acid salt (available from racemic 1,2-trans-cyclohexanediamine, Gasbol, F. et al (1972) Acta. Chem. Scand. 26, 3605 and Onuma, K. et al, (1980) Bull. Chem. Soc. Jap. 53, 2012) as follows:



Other examples of XXR and XXS where R^9 is alkyl or aralkyl are prepared as reported in the prior art as follows: Alexakis, A. et al, *J. Org. Chem.*, 1992, 57, 1224-1237; Denmark, S. et al, *J. Org. Chem.*, 1991, 56, 5063-5079; Hanessian, S. et al, *Tetrahedron*, 1992, 33, 7659-7662; and Koeller, K.J. et al, *Tetrahedron Lett.*, 1991, 32, 6297-6300.

The (R,R)-diamine XXR (or XXS) is employed in a molar ratio to the alkylphosphonic dichloride XXA of within the range of from about 0.5:1 to about 3:1, preferably from about 0.9:1 to about 1.5:1. The amine base, such as triethylamine, pyridine, diisopropylethylamine will be employed in a molar ratio to the alkylphosphonic dichloride XXIA of within the range of from about 1:1 to about 5:1, preferably from 1.5:1 to about 3:1.

The metalation (anion formation) of XXI is carried out at a temperature within the range of from about -90 to about 0°C, preferably from about -80 to about -60°C, employing a molar ratio of base compound to alkylphosphondiamide XXI of within the



range of from about 0.8:1 to about 2:1, preferably from about 0.9:1 to about 1.3:1. The alkylating agent R^1X (III) where X is preferably iodide, but may be Cl or Br as well, will be employed in a
5 molar ratio to alkylphosphondiamide XXI of within the range of from about 1:1 to about 4:1, preferably from about 1:1 to about 2:1.

As seen in Scheme XVI Part A(1), compound XXII may be prepared by a variety of routes which
10 will be apparent to those skilled in the art.

The metalation of XXII is carried out at a temperature within the range of from about -100°C to about 0°C , preferably from about -60°C to about -80°C employing a molar ratio of base to XXII of
15 within the range of from about 2:1 to about 0.8:1, preferably from about 1.4:1 to about 0.9:1.

The lithium anion of XXII is then sulfurated employing a molar ratio of tetramethylthiuram disulfide: lithium anion of XXII of within
20 the range of from about 3:1 to about 1:1, preferably from about 2:1 to about 1:1.

The acid hydrolysis of the individual isomer XXIIIS and XXIIIR to the corresponding thiocarbamate XXIVS and XXIVR, respectively, is
25 carried out by employing aqueous strong acid, such as aqueous HCl, formic acid or sulfuric acid, optionally in the presence of acetonitrile, dioxane or other inert organic solvent. The thiocarbamates XXIVS and XXIVR may be oxidized by conventional
30 techniques, for example, by reaction with hydrogen peroxide in the presence of acetic acid or formic acid, or mixtures thereof or peracids such as peracetic in acetic acid or metachloroperbenzoic acids in dichloromethane or diethyl ether, or using

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Oxone in alcoholic solvents, to the sulfonic acid which is treated with alkali metal hydroxide, such as KOH, NaOH, or LiOH or an ion exchange resin to form the triacid salt, IS or IR.

- 5 Referring to Scheme XV Part B, in accordance with the present invention, in an alternate synthesis of the Part A method, alkylphosphondiamide XXI (or (S,S)-isomer) is metalated by reaction with a base as described .
- 10 above, such as n-butyllithium, sec-butyllithium, t-butyllithium or lithium diisopropylamide in the presence of an inert organic solvent such as hexane, tetrahydrofuran or diethylether to form the lithium anion of XXI which is sulfurated by
- 15 treatment with sulfur and subjected to thiocarbamoylation with a dialkyl thiocarbamoyl halide to form XXV (a novel compound in accordance with the present invention). Compound XXV is then metalated by treatment with a base as described
- 20 above, alkylated by treatment with R¹Hal and the resulting mixture of isomers XXIIIS and XXIIIR are separated as described hereinbefore. Isomers XXIIIS and XXIIIR may then be subjected to acid hydrolysis and oxidation and salt formation as
- 25 described with respect to XXIIIS and XXIIIR in Part A, to form IR and IS.

- In carrying out the Scheme XV Part B method, the base, preferably n-butyllithium, is reacted with alkylphosphondiamine XXI under an
- 30 inert atmosphere such as argon or nitrogen at a temperature within the range of from about -100 to about 0°C, preferably from about -60 to about -80°C, employing a molar ratio of alkyllithium:XXI

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of within the range of from about 0.8:1 to about 2:1, preferably from about 1.2:1 to about 1:1.

The sulfuration reaction of lithiated XXI (with sulfur) is carried out at a temperature
5 within the range of from about -90 to about 0°C, preferably from about -80 to about -40°C, employing a molar ratio of sulfur:lithiated XXI of within the range of from about 4:1 to about 1:1, preferably from about 2:1 to about 1:1.

10 Thiocarbamoylation of the sulfurated XXI with the dialkylthiocarbamoyl halide, preferably, dimethyl- or diethyl-thiocarbamoyl chloride is carried out at a temperature within the range of from about -60 to about 25°C, preferably from about
15 -30 to about 0°C, employing a molar ratio of dialkylthiocarbomoyl halide:sulfurated XXI of within the range of from about 4:1 to about 1:1, preferably from about 2:1 to about 1:1. The thiocarbamoylation reaction is optionally carried
20 out in the presence of a weak organic base, such as triethylamine or pyridine.

The thiocarbamoylated compound XXV is metalated with a base, as described above, preferably n-butyllithium, at a temperature within
25 the range of from about -90 to about -60°C, preferably from about -80 to about -70°C, under an inert atmosphere such as argon or nitrogen, employing a molar ratio of alkylolithium:
thiocarbamoylated compound XXV of within the range
30 of from about 2:1 to about 0.8:1, preferably from about 1.4:1 to about 0.9:1.

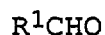
Alkylation of the lithiated XXV is carried out at a temperature within the range of from about -90 to about 0°C, preferably from about -80 to

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about -40°C , employing a molar ratio of R^1Hal :lithiated XXV of within the range of from about 4:1 to about 0.8:1, preferably from about 1.5:1 to about 0.9:1. The alkylation is preferably
5 carried out in the presence of a weak base such as hexamethylphosphoramide (HMPA), or tetramethylethylene diamine.

Still another alternative method for preparing the desired enantiomers of formula I
10 compounds, in accordance with the present invention, is shown in Scheme XV Part C wherein starting (R,R)-diamine XXR (or the corresponding (S,S)-diamine XXS) is made to undergo a phosphorous diamide formation by treating a
15 solution of XXR and weak organic base such as triethylamine or pyridine, in an inert organic solvent such as THF, dichloromethane or toluene, with phosphorus trichloride under an inert atmosphere such as argon or nitrogen, and then
20 treating the resulting filtrate (chilled), under an inert atmosphere, such as argon, with water, and a tertiary amine base, to form the phosphorous diamide XXVII. The diamide XXVII may then be subjected to a condensation reaction with the
25 aldehyde XXVIII



and a silylating agent such as, for example, bis(trimethylsilyl) acetamide, bis(trimethylsilyl) trifluoroacetamide or hexamethyl disilazane in the
30 presence of an inert organic solvent, such as methylene chloride, toluene or THF, under an inert atmosphere, such as argon or nitrogen, to form a mixture of protected isomers XXIXR (α -(R)isomer) and XXIXS (α -(S)isomer).

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The isomers XXIXR and XXIXS are separated by chromatography or other conventional means such as crystallization and each of the α -(R) isomer XXIXR and α -(S) isomer XXIXS in solution in an
5 inert organic solvent such as THF, diethyl ether, acetonitrile or dichloromethane, is separately treated with a fluoride source such as tetrabutylammonium fluoride, aqueous hydrofluoric acid or lithium tetrafluoroborate, to form the
10 compounds XXXR and XXXS.

Each of the isomers XXXR and XXXS can then be separately made to undergo a Mitsunobu displacement (Rollin, P., Tetrahedron Lett. 1986, 27, 4169-4170) wherein each of XXXR and XXXS is
15 separately treated with dimethyl (or diethyl) dithiocarbamic acid, zinc salt, and triphenylphosphine, tributylphosphine, triethylphosphite and diethyl diazodicarboxylate (DEAD) or diisopropyl azodicarboxylate (DIAD), in the presence of an
20 inert organic solvent such as THF, toluene, or dichloromethane, under an inert atmosphere such as argon or nitrogen, to form the separate isomers XXIIIS' and XXIIIR' which may be converted to the IS and IR isomers, respectively, as described in
25 Scheme XV Part A. Alternatively, the isomer separation can be carried out at the stage of XXXR and XXXS.

If desired, the phosphorous diamide XXVII may be converted directly into the alcohols XXXR and XXXS by subjecting XXVII to a condensation
30 reaction with aldehyde XXVIII in the presence of a base such as 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU), triethylamine, basic alumina or a fluoride source such as described above or potassium or



cesium fluoride, to form a mixture of XXXR and XXXS.

In carrying out the Scheme XV Part C method, the diamine XXR (or XXS) is reacted with
5 phosphorus trichloride at a temperature of within the range of from about 50°C to about -80°C, preferably from about 0°C to about -80°C, employing a molar ratio of trichloride:XXR of within the range of from about 3:1 to about 0.8:1, preferably
10 from about 1.5:1 to about 1:1.

The condensation reaction of the phosphorus diamide XXVII with the aldehyde XXVIII is carried out employing a molar ratio of diamide XXVII:aldehyde XXVIII of within the range of from
15 about 2:1 to about 0.8:1, preferably from about 1.5:1 to about 1:1, and a molar ratio of silyl protecting compound:XXVII of within the range of from about 3:1 to about 1:1, preferably from about 1.5:1 to about 1:1.

20 Reaction of the individual isomers XXIXS and XXIXR with the fluoride source is carried out employing a molar ratio of fluoride source to XXIXS or XXIXR of within the range of from about 4:1 to about 1:1, preferably from about 2:1 to about
25 1.1:1.

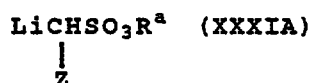
Where the phosphorus diamide XXVII is converted directly to the isomers XXXR and XXXS (see Scheme XV Part C(1)), the condensation reaction of XXVII with the aldehyde XXVIII and base
30 or fluoride source as described above will be carried out essentially under similar conditions previously described for formation of XXIXS and XXIXR, and XXXS and XXXR.

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The Mitsunobu displacement of XXXR and XXXS is carried out employing a molar ratio of dimethyl-dithiocarbamic acid or diethyl derivative, zinc salt or equivalent: XXXS or XXXR of within the
5 range of from about 2:1 to about 0.5:1, preferably from about 1.5:1 to about 0.6:1, and a molar ratio of triphenylphosphine or equivalent:XXXR or XXXS of within the range of from about 4:1 to about 1:1, preferably from about 2:1 to about 1:1.

- 10 A preferred method for forming the desired enantiomers of formula I is shown in Scheme XVI wherein a solution of the (R,R)-diamine XXR (or the corresponding (S,S)-diamine XXS where the α -(R) product is desired) in an aprotic solvent such as
15 toluene, benzene, dichloromethane or THF, and weak organic base such as triethylamine, pyridine or diisopropylethylamine is treated with phosphorus oxychloride to form the acid chloride XXXI which in solution with an inert organic solvent such as THF,
20 diethylether or dimethoxyethane is subjected to a coupling reaction with



- (prepared by reaction of an alkylmethanesulfonate
25 XXXIB with alkyllithium) to form the sulfonate XXXII (which is a novel intermediate in accordance with the present invention). Sulfonate XXXII is dealkylated by treatment with a dealkylating agent such as tetrabutylammonium iodide, in the presence
30 of an inert organic solvent such as THF, diethylether or acetone, to form sulfonate XXXIII (which is a novel intermediate in accordance with the present invention) which is made to undergo dianion formation by reaction with a metalating agent such



as n-butyllithium, sec-butyllithium, t-butyllithium or lithium diisopropylamide, under an inert atmosphere such as argon or nitrogen, in the presence of an inert organic solvent such as
5 hexane, THF or diethyl ether, and is then treated with alkylating agent $R^1\text{Hal}$ in an inert organic solvent such as THF, diethyl ether or hexane to form XXXIV (which is a novel intermediate in accordance with the present invention) optionally
10 in the presence of hexamethyl phosphoramide (HMPA) or tetramethyl ethylenediamine (TMEDA). XXXIV may be subjected to acid hydrolysis and ion exchange to form the individual enantiomer IS, when Z is H.

As indicated, where the starting diamine XX
15 is the (S,S)-enantiomer XXS, the final product will be the IR (R)-enantiomer, when Z is H.

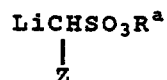
In carrying out the Scheme XVI method, the phosphorus oxychloride will be employed in a molar ratio to the diamine XXR of within the range of
20 from about 1.5:1 to about 0.8:1, preferably from about 1.1:1 to about 0.9:1. The reaction will be carried out at a temperature within the range of from about -20 to about 40°C, preferably from about 0 to about 25°C.

25 In forming $\text{LiCHSO}_3\text{R}^a$ (XXXIA) (where alkyl is preferably ethyl or cyclohexyl) the alkylmethane-sulfonate XXXIB is reacted with the alkylolithium or other strong base at a temperature within the range of from about -90 to about 0°C, employing a molar
30 ratio of alkylolithium:sulfonate XXXIB of within the range of from about 1.2:1 to about 0.8:1, preferably from about 1.1:1 to about 0.9:1.

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The



5 compound XXXIA will be reacted with the acid chloride XXXI at a temperature within the range of from about -90 to about 0°C, preferably from about -80 to about -30°C, employing a molar ratio of Li compound XXXIA to XXXI of within the range of from about 4:1 to about 1:1, preferably from about 2.5:1 to about 1.5:1.

10 The dealkylation of sulfonate XXXII is carried out employing a molar ratio of iodide:XXXII of within the range of from about 1.5:1 to about 0.9:1, preferably about 1:1.

15 In the dianion formation, sulfonate XXXIII is treated with the base at a temperature within the range of from about -100 to about 0°C, preferably from about -90 to about -60°C, employing a molar ratio of base:XXXIII of within the range of from about 2:1 to about 0.8:1, preferably from about 1.5:1 to about 1:1.

20 The lithiated XXXIII compound is alkylated with R¹Hal at a temperature within the range of from about -100 to about 0°C, preferably from about -90 to about -60°C, employing a molar ratio of R¹Hal:lithiated halide of within the range of from about 2:1 to about 1:1, preferably from about 1.5:1 to about 1.1:1.

30 The alkylated sulfonate XXXIV is made to undergo acid hydrolysis by treating XXXIV with strong aqueous acid, such as HCl, sulfuric or formic acids, and then with base such as KOH, NaOH or LiOH to form the major isomer IS where (S) is at the α-center when Z is H. As indicated, where the starting (S,S)-diamine XXS is employed, the major



isomer obtained is IR where (R) is at the α -center when Z is H.

An alternative preferred method for forming the desired enantiomers of the invention is shown in Scheme XVII. The starting aldehyde XXVIII (can be prepared by reaction of the alcohol R^1CH_2OH with methylsulfoxide, and oxalyl chloride in the presence of weak organic base such as triethylamine, that is the Swern oxidation or other standard alcohol oxidations), is treated with (2S,4S)-(+)-pentanediol (or the corresponding (2R,4R)-isomer) and p-toluenesulfonic acid in the presence of an inert solvent such as benzene, toluene or dichloroethane, to form the chiral acetal XL. Chiral acetal XL is subjected to an acetal opening reaction wherein acetal XL is reacted with a trialkylphosphite, such as triethylphosphite, in the presence of titanium (IV) chloride, and an inert organic solvent such as methylene chloride, toluene or benzene, under an inert atmosphere such as argon or nitrogen, to form the alcohol XLI which is oxidized via the Swern oxidation, pyridinium chlorochromate (PCC) or Jones reagent under standard conditions, to form XLII. The 3-butene-2-one portion of XLII is eliminated by treating XLII with p-toluenesulfonic acid or methanesulfonic acid in the presence of dioxane, or acetonitrile and water to form the diester XLIII which is subjected to a Mitsunobu displacement under the same conditions as described for the conversion of XXXS/R to XXIIIS'/R'. See P. Rollin, *supra*, to form XLIV. Compound XLIV is dealkylated by reaction with a dealkylating agent such as bromotrimethylsilane or iodotrimethylsilane in the



presence of an inert organic solvent such as methylene chloride, benzene or toluene, under an inert atmosphere such as argon or nitrogen, to form the diacid XLV which is oxidized by treatment with
5 hydrogen peroxide in formic acid, acetic acid or mixtures thereof or other oxidants as described for Scheme XV, and then treated with alkali metal hydroxide such as KOH, NaOH or LiOH, or ion exchange resin as described hereinbefore to form
10 the (R)-enantiomer IR.

It will be appreciated that in carrying out the above method, where the aldehyde XXVIII is reacted with the (R,R)-diol, the final product obtained will be the α -(S)-enantiomer IS.

15 In carrying out the method of Scheme XVII, the (2S,4S)-(+)-pentanediol will be reacted with the starting aldehyde XXVIII at a temperature within the range of from about 25 to about 100°C, preferably from about 60 to about 90°C, employing a
20 molar ratio of diol:XXVII of within the range of from about 4:1 to about 0.8:1, preferably from about 2:1 to about 1:1. The resulting chiral acetal XL is reacted with the trialkylphosphite and titanium(IV)chloride or equivalent at a temperature
25 within the range of from about -90 to about -20°C, preferably from about -80 to about -40°C, employing a molar ratio of phosphite:XL of within the range of from about 5:1 to about 1:1, preferably from about 3:1 to about 2:1, and a molar ratio of
30 phosphite:titanium tetrachloride of within the range of from about 3:1 to about 1:1, preferably from about 1.2:1 to about 1.6:1, to form alcohol XLI.

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The oxidation of alcohol XLI is carried out at a temperature within the range of from about -80 to about 0°C, and the elimination reaction involving XLII is carried out at a temperature within the range of from about 30 to about 150°C, preferably from about 80 to about 120°C, employing a molar ratio of p-toluenesulfonic acid or equivalent:XLII of within the range of from about 0.5:1 to about 0.005:1, preferably from about 0.1:1 to about 0.05:1.

The Mitsunobu displacement reaction is as described previously for Scheme XV Part C.

Dealkylation of XLIV is carried out employing a molar ratio of dealkylating agent:XLIV of within the range of from about 10:1 to about 2:1, preferably from about 6:1 to about 4:1.

Scheme XVIII sets out a purification procedure wherein the desired individual enantiomers (salt thereof) is subjected to ion exchange (H^+ form) such as by treatment with AG 50-X8 ion exchange resin, to form the free triacid IQ which is treated with an amine such as adamantanamine or (S)-(-)- α -methylbenzylamine (under an inert atmosphere such as argon where the latter amine is employed), in a molar ratio of amine:IQ within the range of from about 2.2:1 to about 1.9:1, preferably about 2:1, to form the corresponding bis-amine salt IQ' which is separated out by recrystallization. The so-formed diamine salt IQ' may be treated with ion exchange resin (M^+ form) such as Ag50-X8 (K^+ form) or basified with MOH (where M is K, Li or Na) to form the purified enantiomer. Amine salts IQ' of chiral amines and racemic triacid I may be used to resolve the

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racemate into α -(R) and α -(S) isomers by recrystallization.

If desired, the diamine salt IQ' may be treated with ion exchange resin (H^+ form) to form
5 the triacid IQ which may be treated with ion exchange resin (M^+ form) or basified with MOH to form the purified enantiomers, IS or IR.

Scheme XIX set out a reaction sequence for preparing prodrugs of the desired enantiomer. As
10 seen, the starting enantiomer IS (or IR) is treated with a silver salt such as silver nitrate to form the silver salt IAg which is alkylated by treatment of IAg (optionally in the presence of 4A molecular
15 sieves, anisole, thioanisole, 2,6-di-*t*-butylpyridine and mixtures thereof) with alkylating agent XI to form triester LI.

The triester LI is subjected to solvolysis in water, or optionally a water-miscible solvent such as ethanol, methanol, 2,2,2-trifluoroethanol,
20 acetonitrile or mixtures of water and the organic solvent, at $0^\circ C$ to $60^\circ C$, to form the diester LII which is made to undergo salt formation by treatment of LII with an alkali metal phosphate buffer, such as potassium phosphate buffer, or ion
25 exchange, to form the salt IS'.

The various acid and salt forms of the invention ID, IE, IF, IG, IL, IM, IN, IO, IP, IQ, IR, IS, IR', IS', LIIR, LIIS, IT and IU can be
30 interconverted by standard means, including ion exchange chromatography. It should be understood that all acids can be isolated either as salts (M =pharmaceutically acceptable cations such as Li^+ , Na^+ , K^+ , NH_4^+), or free acids ($M=H$).

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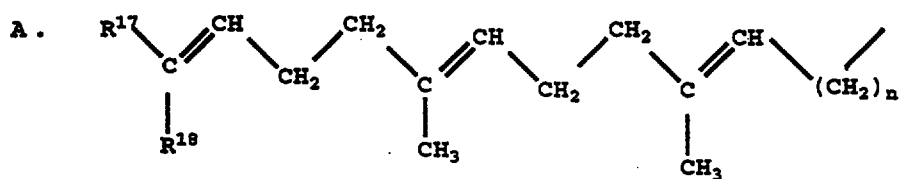
Examples of starting alkylating agents that is R^1X or R^1Hal suitable for use herein include the following which are either known in the literature or are simple derivatives of known compounds
5 prepared by employing conventional procedures.

It will be appreciated that the R^1X compounds listed in the following table represent all possible stereoisomers.

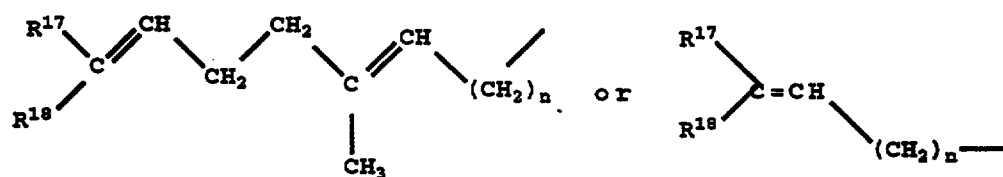
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$R^1\text{Hal}$ where Hal is Cl, Br or I, or Otosyl or OSO_2CF_3 is as follows in A. through F.



5



n is 1 to 8

10	<u>R^{17}</u>	<u>R^{18}</u>
1.	C_2H_5	CH_3
2.	CH_3	C_2H_5
3.	$n\text{-C}_3\text{H}_7$	CH_3
4.	CH_3	$n\text{-C}_4\text{H}_9$
15	5. $t\text{-C}_4\text{H}_9$	CH_3

$\text{---} (\text{CH}_2)_{s'} \text{---}$

$s' = 4 \text{ to } 6$

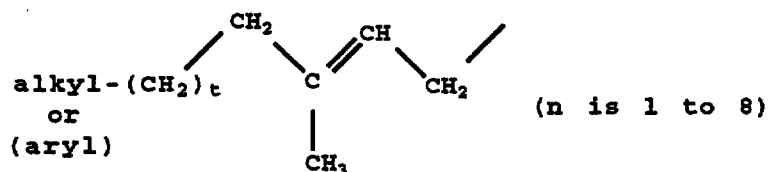
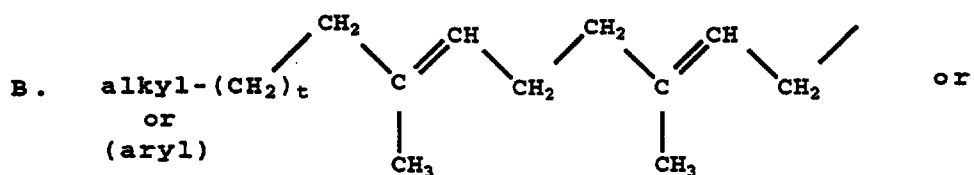
7.	H	H
8.	F	F
20	9. Cl	Cl
10.	CH_2F	CH_3
11.	---CH=CH_2	H
12.	$\text{CF}_3(\text{CH}_2)_t$	H

$t = 0 \text{ to } 8$

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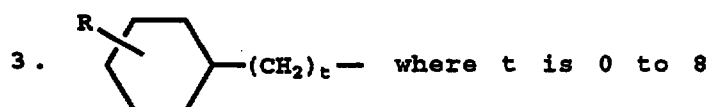
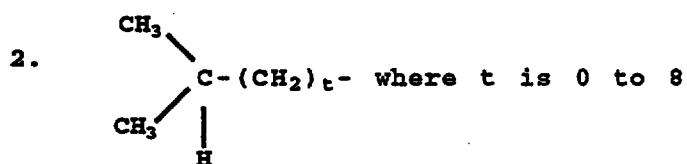




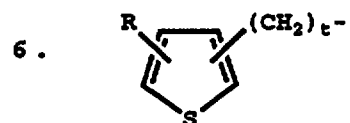
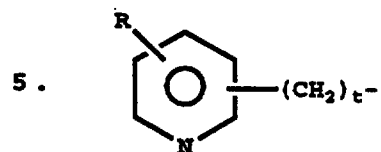
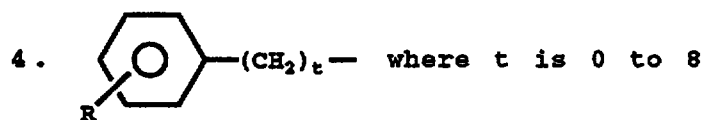
$\text{alkyl}(\text{CH}_2)_t-$

1. $\text{CH}_3(\text{CH}_2)_t$ where t is 0 to 8

5



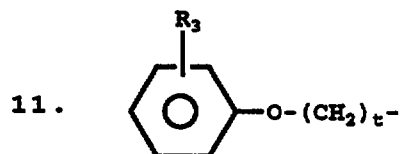
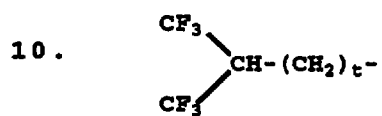
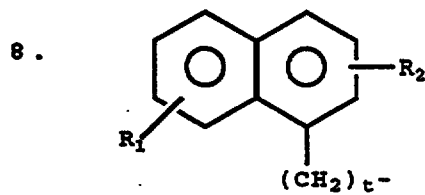
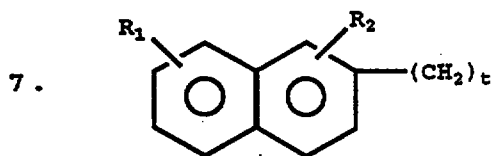
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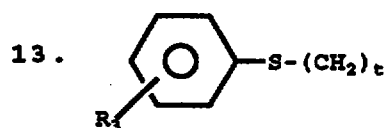
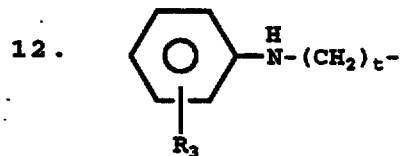
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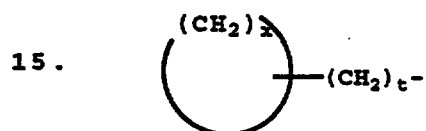
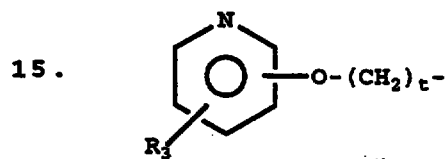




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Examples 5 to 10, $t = 0$ to 8

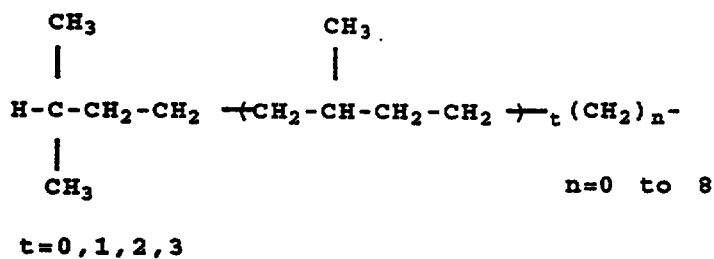
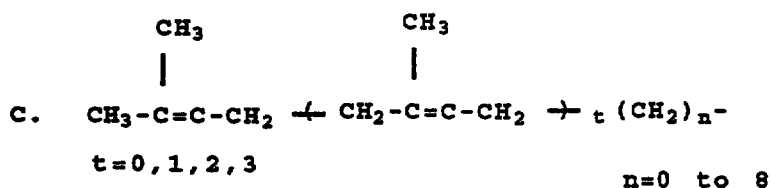
5 R_1 , R_2 and R_3 may be the same or different and can be any of the radicals included in R^6 .

Examples 11 to 15

$t = 1$ to 8

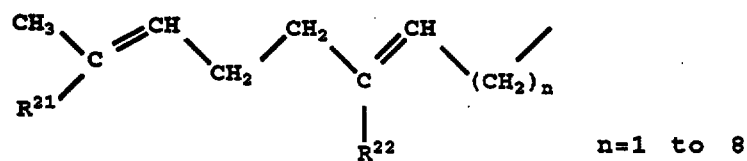
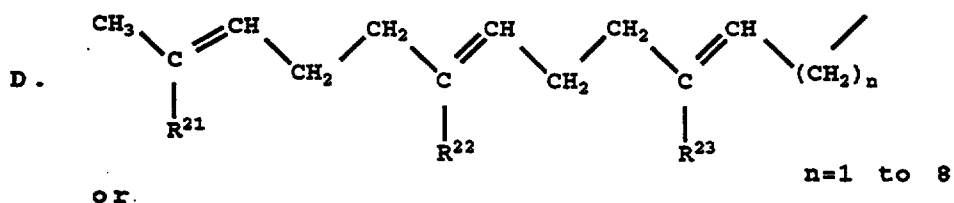
$x = 3$ to 8

10



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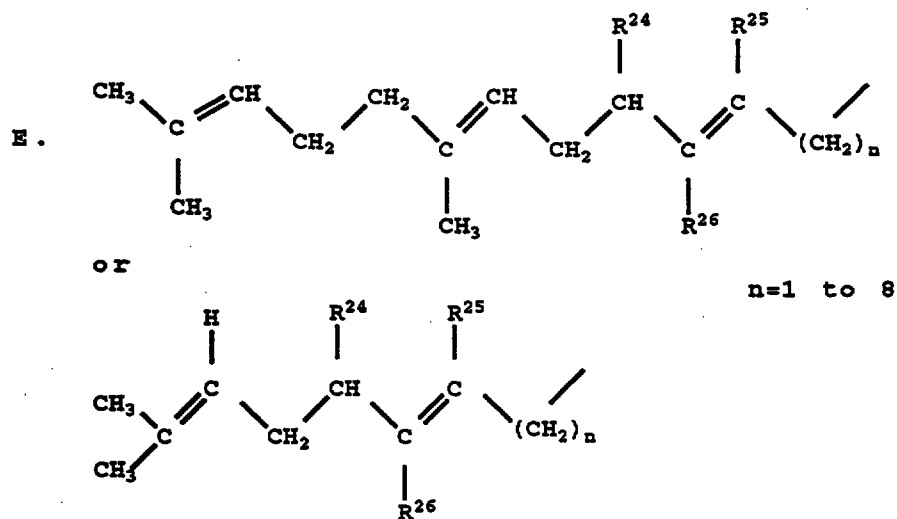




	<u>R²¹</u>	<u>R²²</u>	<u>R²²</u>
1.	C ₂ H ₅	C ₂ H ₅	CH ₃
5 2.	CH ₃	CH ₃	C ₂ H ₅
3.	CH ₃	C ₂ H ₅	C ₂ H ₅
4.	C ₂ H ₅	C ₂ H ₅	C ₂ H ₅
5.	CH ₃	C ₂ H ₅	CH ₃
6.	CH ₃	H	CH ₃
10 7.	CH ₃	CH ₃	H
8.	H	H	H
9.	CF ₃	CH ₃	CH ₃
10.	CH ₃	CF ₃	CH ₃
11.	CH ₃	CH ₃	CF ₃
15 12.	CF ₃	CF ₃	CH ₃
13.	CF ₃	CF ₃	CF ₃

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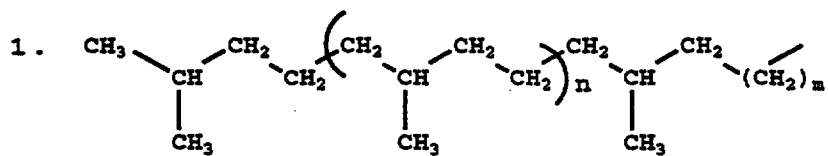


	<u>R²⁴</u>	<u>R²⁵</u>	<u>R²⁶</u>
1.	H	I	H
5 2.	H	H	I
3.	H	CH ₃	CH ₃
4.	CH ₃ S	CH ₃	H
5.	F	CH ₃	H
6.	CH ₃	CH ₃	H
10 7.	H	CH ₃	CH ₃
8.	H	CH ₃	Cl
9.	H	CF ₃	H
10.	H	Cl	H
11.	H	CH ₃	(CH ₃) ₃ Si
15 12.	H	CH ₃	F
13.	H	CF ₃	CH ₃
14.	H	CH ₃	CF ₃

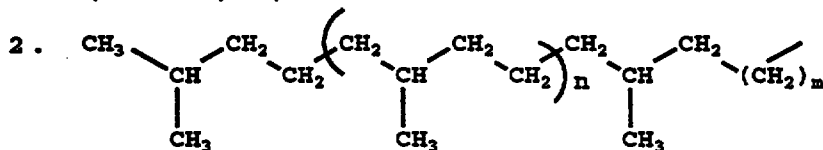
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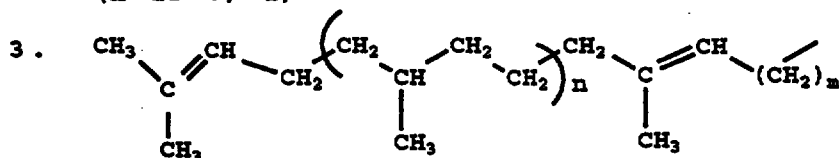
F. Other examples of R¹ include the following



(n is 0, 1)

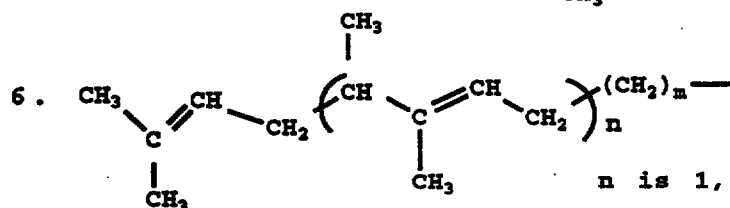
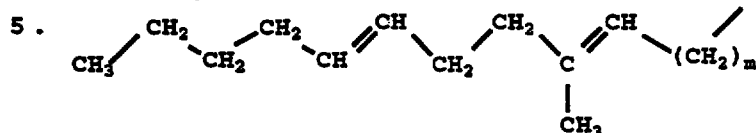
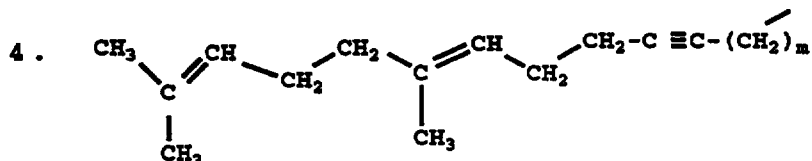


(n is 0, 1)

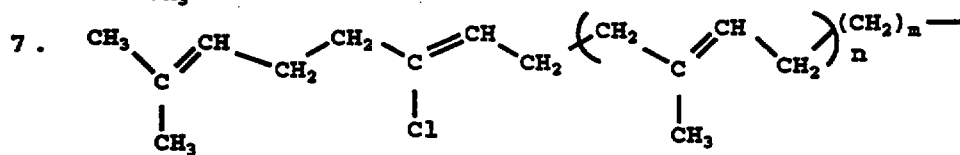


(n is 0, 1)

5



n is 1, 2)



(n is 0, 1)

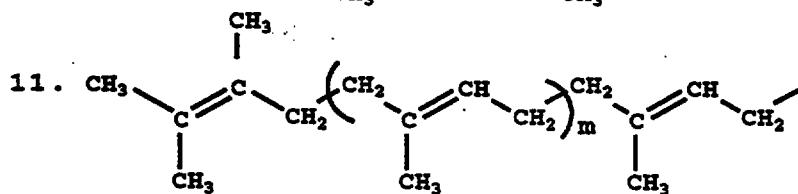
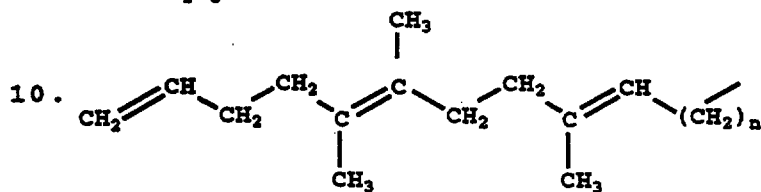
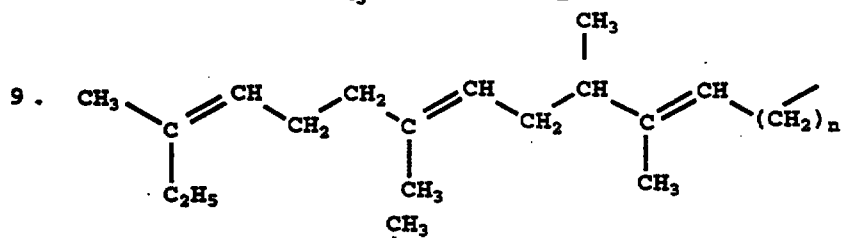
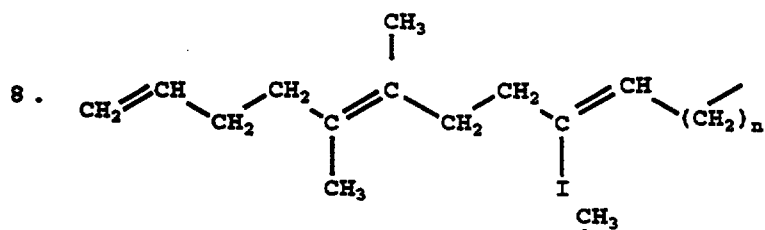
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In Examples 1 to 5, m is 1 to 8.

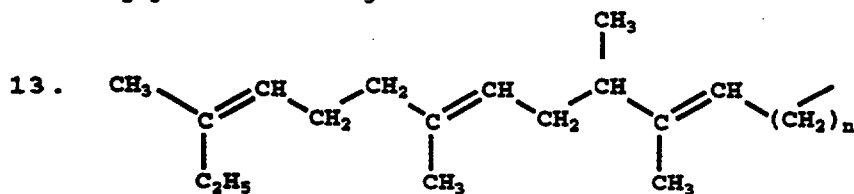
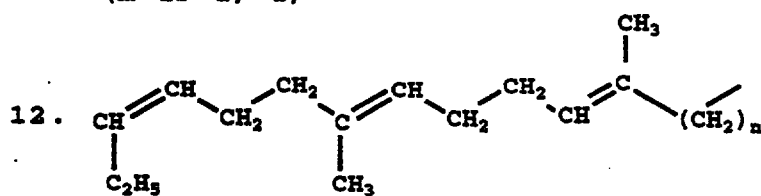
In Examples 6 and 7, m is 0 to 8.

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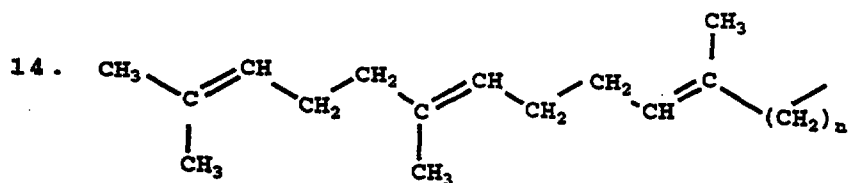
(m is 1, 2)



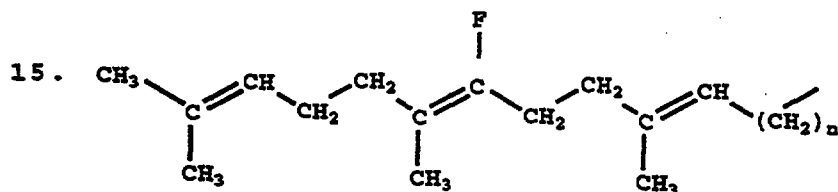
In Examples 8 to 13, n is 1 to 8.

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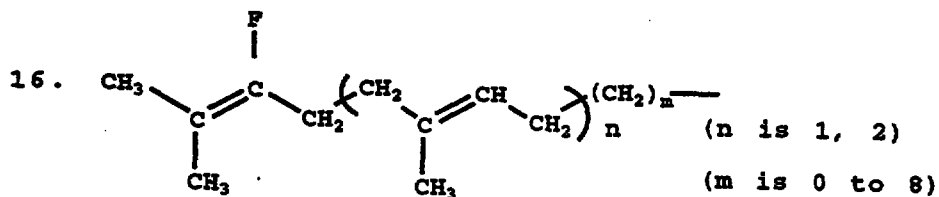




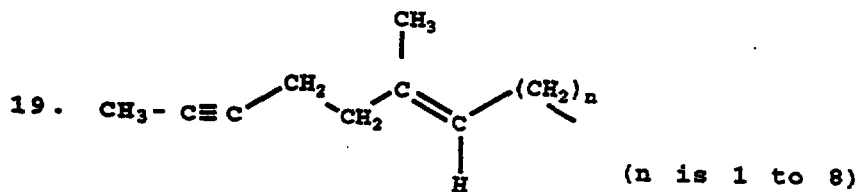
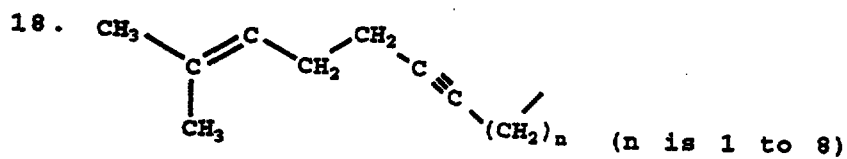
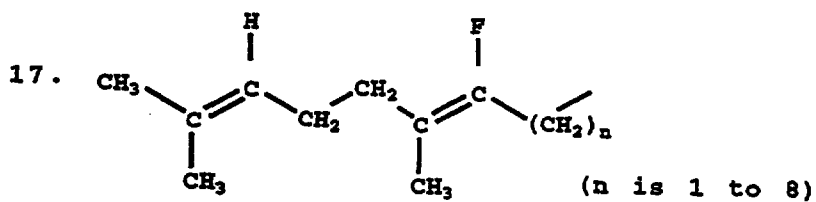
(n is 1 to 8)



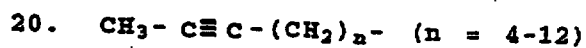
(n is 1 to 8)



5

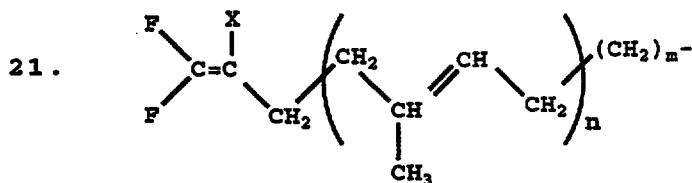


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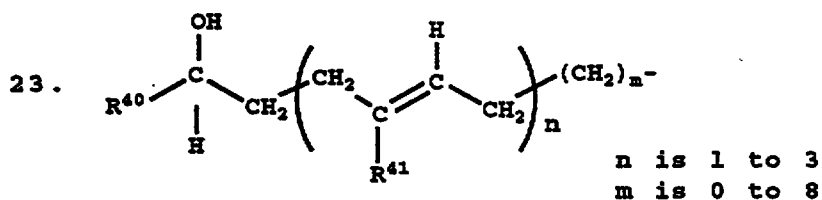
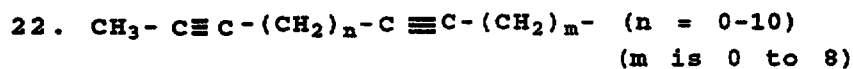


X = H, F, CH₃

n is 1 or 2

m is 0 to 8

5

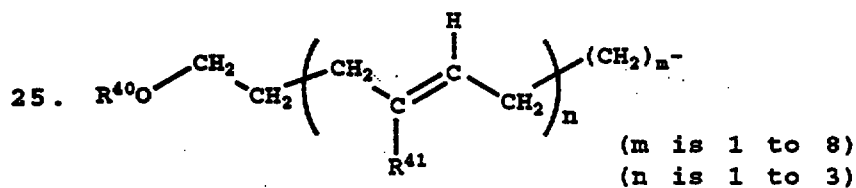
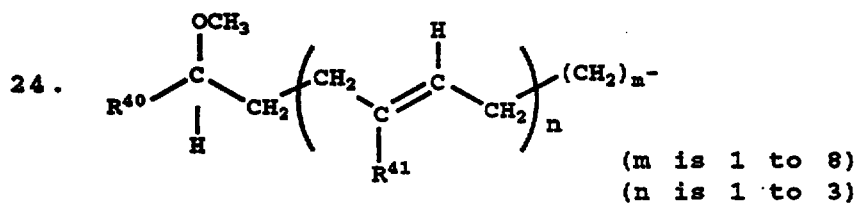


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R⁴⁰ = H, alkyl, cycloalkyl, or aryl such as methyl, ethyl, isopropyl, pentyl, phenyl and cyclopentyl

R⁴¹ = alkyl such as methyl, ethyl or halo such as Cl or F

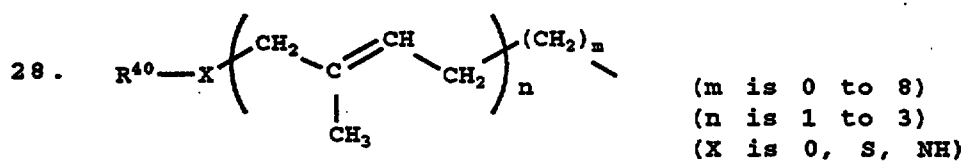
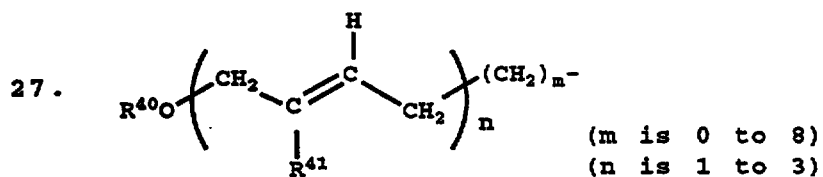
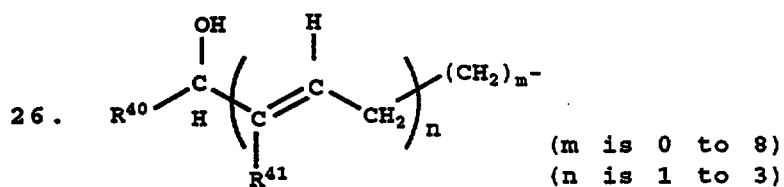
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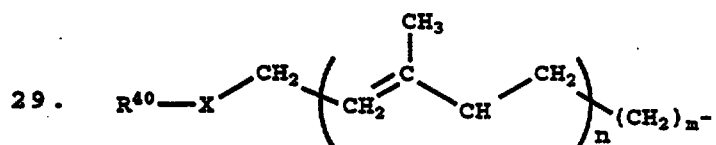
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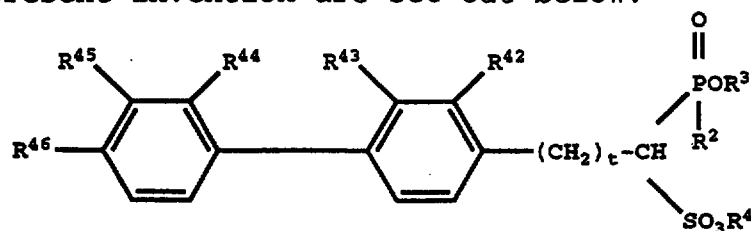


X is O, S, NH, CH₂)
(m is 0 to 8)
(n is 1 to 3)

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Additional compounds within the scope of the present invention are set out below.



5		R ⁴²	R ⁴³	R ⁴⁴	R ⁴⁵	R ⁴⁶	t
	30)	H	H	H	H	n-C ₃ H ₇	3
	31)	H	H	H	H	n-C ₄ H ₉	3
	32)	H	H	H	H	(CH ₃) ₂ -C=CH-	4
10	33)	H	H	H	H	(CH ₃) ₂ -C=CH-CH ₂ -	2
	34)	CH ₃	H	CH ₃	H	 -CH ₂ -	3
	35)	H	H	CH ₃	H	(CH ₃) ₂ -CH-CH ₂ -O-	3
	36)	H	CH ₃	CH ₃	H	n-C ₃ H ₇	3
	37)	CH ₃ O	H	H	H	n-C ₄ H ₉	3
15	38)	H	H	H	H	(CH ₃) ₂ -C=CH-	3
	39)	H	H	H	H	(CH ₃) ₂ -C=CH-CH ₂ -	4
	40)	CH ₃	H	H	H	 -CH ₂ -	5
	41)	F	H	CH ₃	H	n-C ₃ H ₇	3
	42)	CH ₃	H	F	H	n-C ₄ H ₉	3
20	43)	H	CH ₃	H	CH ₃	(CH ₃) ₂ -C=CH-	3
	44)	H	H	H	CF ₃	(CH ₃) ₂ -C=CH-CH ₂ -	3
	45)	H	H	H	F	 -CH ₂ -	3
	46)	H	Cl	Cl	H	CH ₂ =CH-CH ₂ -	3
	47)	CH ₃	H	H	H	C ₄ H ₉	3
25	48)	H	H	OH	H	C ₃ H ₇	3
	49)	H	H	OCH ₃	H	C ₃ H ₇	4
	50)	H	H	CH ₃	H	C ₃ H ₇	3
	51)	H	OH	H	H	C ₃ H ₇	3
	52)	H	OCH ₃	H	H	C ₃ H ₇	4
30	53)	H	CH ₃	H	H	C ₃ H ₇	3

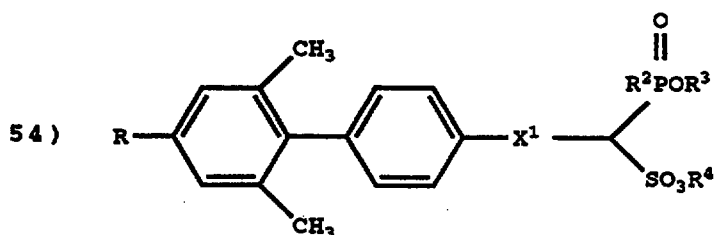
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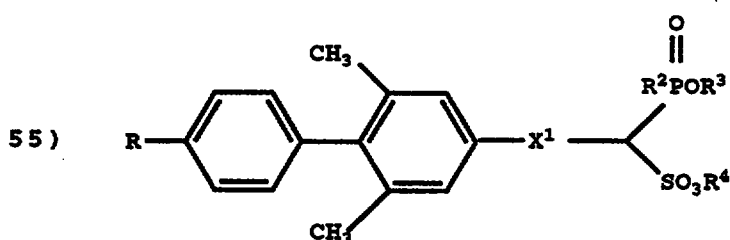
$R^2 = \text{H, Metal, alkyl, aryl}$

$R^3 = \text{H, metal ion or alkyl}$

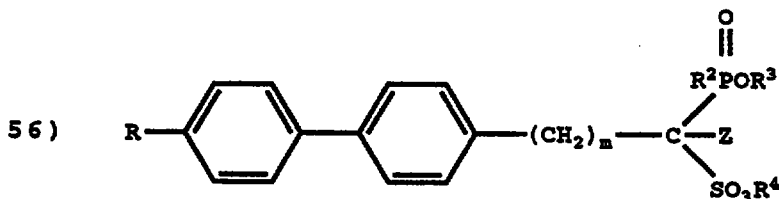
$R^4 = \text{H, metal ion or alkyl}$



5



$X^1 = -(\text{CH}_2)_n-, -\text{CH}=\text{CH}-\text{CH}_2-$
 $n = 1 \text{ to } 6$

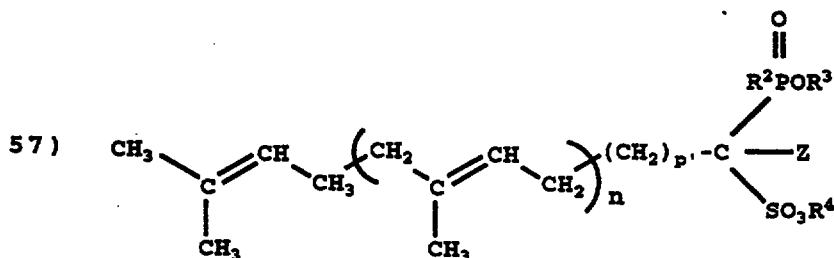


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Re 54) to 56)

R is $n\text{-C}_3\text{H}_7$, $n\text{-C}_4\text{H}_9$, $(\text{CH}_3)_2\text{-C}=\text{CH}-$, $\text{CH}_3\text{-CH}=\text{CH}-\text{CH}_2-$,
 $(\text{CH}_3)_2\text{-CH}=\text{CH}-\text{CH}_2-$, $\text{CH}_2=\text{CH}-\text{CH}_2\text{O}-$, $(\text{CH}_3)_2\text{-CH-O}-$,

15 $(\text{CH}_3)_2\text{CHCH}_2\text{O}-$, cyclopropyl-CH_2- , $\text{CH}_2=\text{CH}-\text{CH}_2-$, $\text{CH}_2=\text{CH}-\text{CH}_2\text{CH}_2-$,
 phenyl, pyridyl



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Z = Cl, F, alkyl such as methyl, ethyl, propyl or allyl

n = 0, 1, 2

p¹ = 0 - 8

5

m = 2 - 8

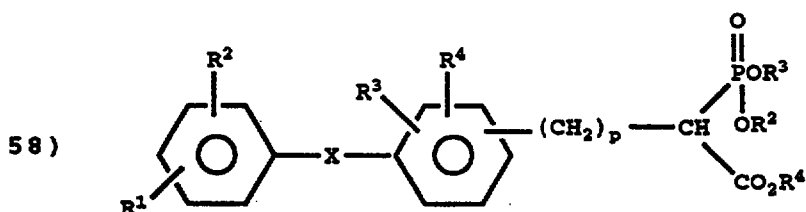
In compounds 49) to 52)

R³ = H, metal ion or alkyl

R⁴ = H, metal ion, alkyl or aryl

R² = H, metal, alkyl, aryl

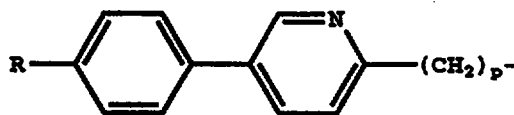
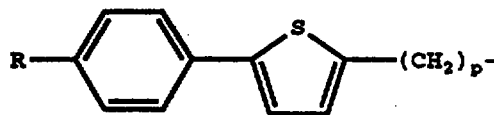
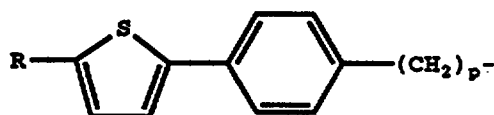
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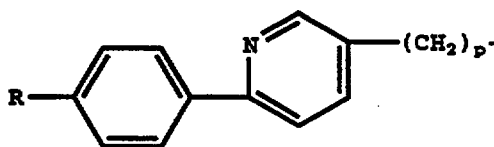
X is O, S NH, SO, SO₂, CR⁵R⁶, C=O

15 R¹, R², R³, R⁴, R⁵ and R⁶ are independently H, halogen, C₁-C₅alkyl, C₁-C₅alkenyl, C₁-C₅alkoxy, aryl, arylalkyl, aryloxy; for R⁵ and R⁶, halogen can be fluorine only.

20

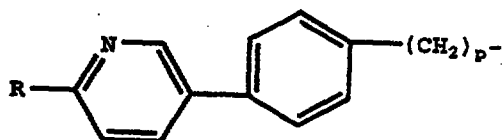
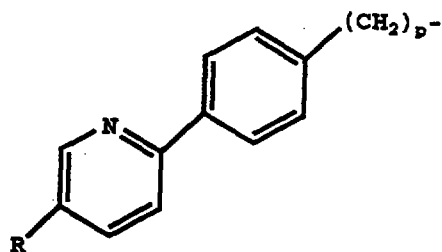


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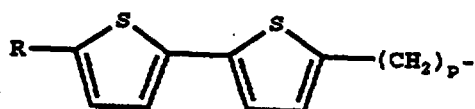
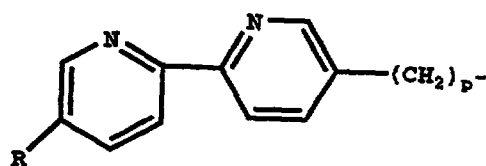


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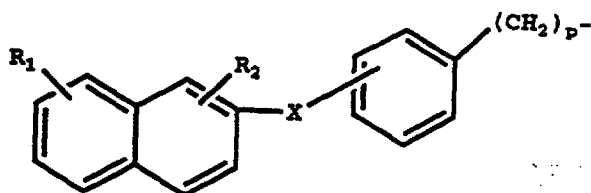
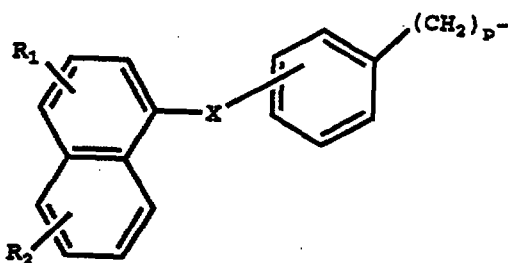




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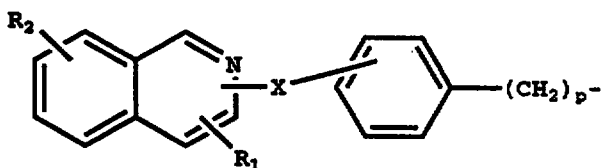
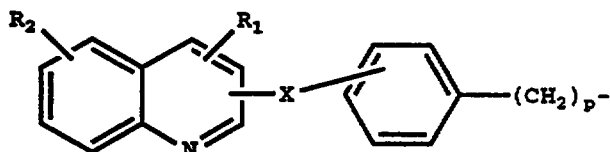
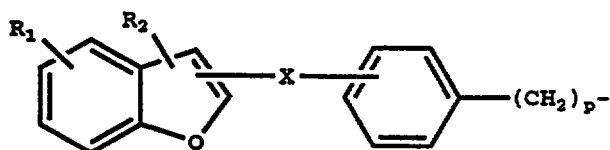
10 R is as defined for 54) to 56).



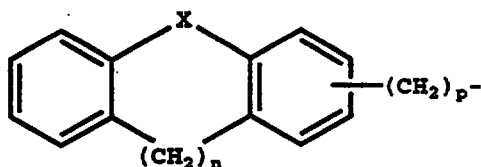
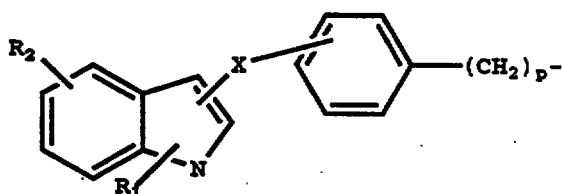
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10

X = bond, O, NH, S, CH₂, CR⁵R⁶

p = 1 to 8

n = 0 to 4; R¹, R², R⁵ and R⁶ are independently halogen, alkyl, alkenyl, alkoxy, aryl, H, aryloxy;

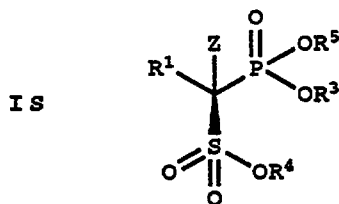
15 for R⁵ and R⁶ halogen can be fluorine only.

Preferred are enantiomers of compounds of formula I in the (S) configuration of the above preferred compounds, that is

20

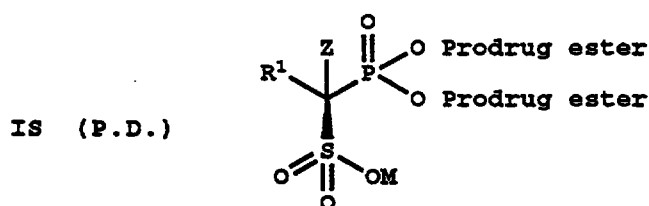
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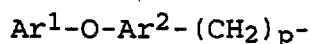


wherein Z is H, R¹ is preferably Ar¹-O-Ar²-(CH₂)_p-,
R³, R⁵ and R⁴ are an alkali metal such as K or Na.

More preferred are prodrug (P.D.) esters of
5 the (S)-enantiomer (IS), that is



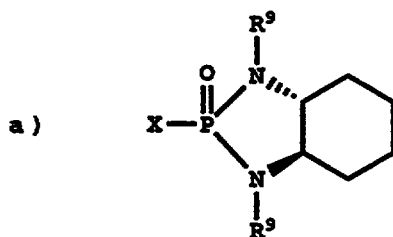
Most preferred are compounds of formula IS
10 where R¹ is



R⁴ is an alkali metal such as K or Na

Z is H and Prodrug ester is bis(pivaloyloxymethyl)
ester.

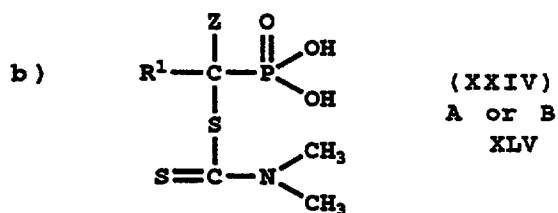
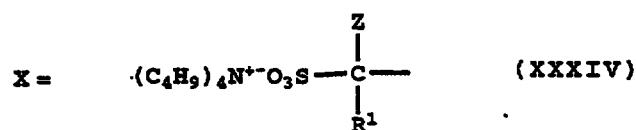
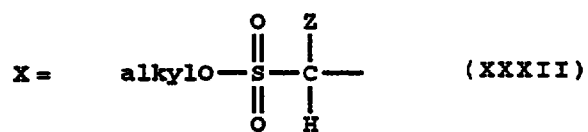
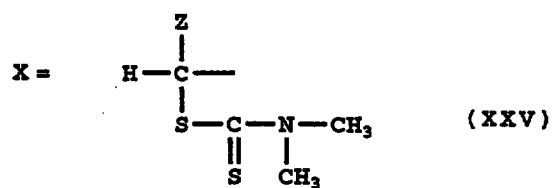
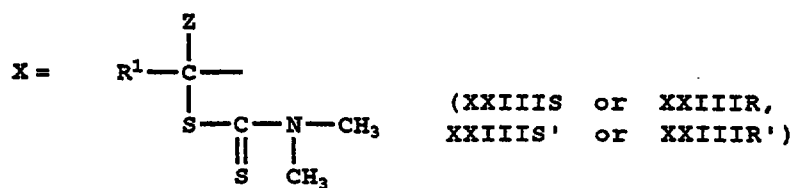
15 In addition, in accordance with the present
invention new intermediates are provided which are
prepared as described above, and have the following
formulae:



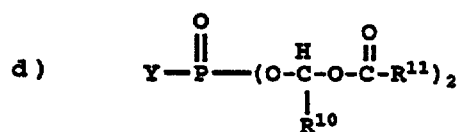
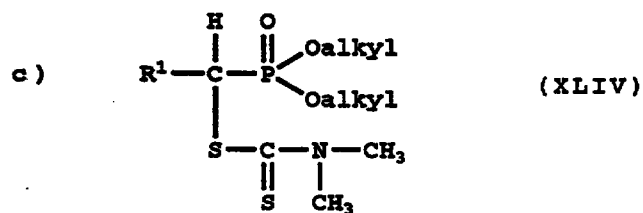
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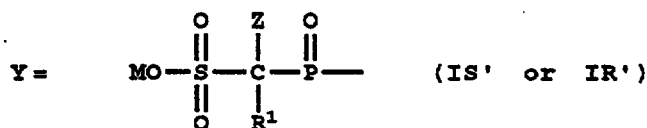
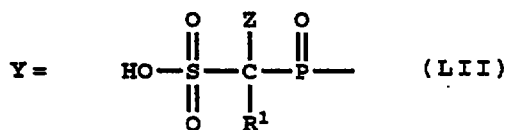
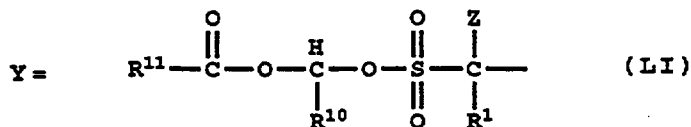


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The compounds of Formula I of the invention inhibit cholesterol biosynthesis by inhibition of de novo squalene production. These compounds inhibit the squalene synthetase enzyme and, in addition, some of the compounds of Formula I of the invention inhibit other enzymes in the pathway from isopentenyl diphosphate to squalene, that is, farnesyl diphosphate synthetase and isopentenyl diphosphate-dimethylallyl diphosphate isomerase.

The compounds of the invention are useful in treating hyperlipoproteinemia, hyperlipidemia, hypercholesterolemia, hypertriglyceridemia, combined hypercholesterolemia and hypertriglyceridemia, and/or in preventing development of and/or treating atherosclerosis. Thus, the compounds of the invention may be used to treat diseases such as chylomicronemia syndrome, Type I hyperlipoproteinemia, familial combined hyperlipoproteinemia, familial hypertriglyceridemia, mixed hyperlipoproteinemia, familial hypercholesterolemia and Type III hyperlipoproteinemia and/or atherosclerosis.

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In addition, the compounds of the invention may increase plasma high density lipoprotein cholesterol levels.

The compounds of the invention may also be
5 useful in inhibiting formation of gallstones,
treating hepatitis D (by virtue of protein
prenyltransferase inhibition, Glenn et al, Science,
Vol. 256, pp. 1331-1333, May 29, 1992), treating
tumors, lowering blood pressure, lowering blood
10 sugar, treating diabetes mellitus, treating
inflammation, as a diuretic, as an inotropic agent,
as an anti-arthritic (antirheumatic) agent, in
treating other diseases of calcium and phosphate
metabolism including treatment of bone resorption,
15 Paget's disease, osteoporosis, calcification of
joints, implants and metastasis, as antitartar and
anticalculus agents in toothpastes and mouthwashes,
treating various stones and calculi, treating
sickle cell anemia, treating hypoxia and ischemic
20 tissue, and as an anti-ameobal agent, as well as
for use in complexes with technetium-99m and
radioiodinated derivatives for use as diagnostics.

U.S. appication Serial No. 774,957, filed
October 11, 1991, discloses that post-translational
25 modification of CAAX box containing proteins may be
inhibited by administering a protein-prenyl
transferase inhibitor which inhibits the transfer
of the prenyl group [such as farnesyl (in the case
of ras oncogene products), geranyl or
30 geranylgeranyl] to the cysteine of the CAAX box by
the protein-prenyl transferase enzyme. The
protein-prenyl transferase inhibitor will block the
protein-prenyl transferase enzyme from catalyzing
the transfer of the prenyl group (for example,

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farnesyl, geranyl or geranyl-geranyl) from the prenyl pyrophosphate to the cys residue of the CAAX box, such as the ras p21 cys, or to the CAAX box cysteine of other CAAX box containing proteins. In the case of ras p21 oncogene products, inasmuch as the cys is not farnesylated, in the presence of the protein prenyl transferase inhibitor, it cannot effect interaction of the ras protein with the membrane so that neoplastic transformation of the cell will be prevented. In this manner protein-prenyl transferase inhibitors prevent neoplastic transformation of the cell, thereby acting as an anti-cancer agent for the treatment of and/or prevention of ras-related tumors.

Examples of CAAX box containing proteins which have been demonstrated or are believed to undergo prenylation include, but are not limited to, ras, nuclear lamins, α or γ subunits of heterotrimeric G-proteins, γ -subunits of retinal transducin, G25K and K-rev p21, and protein families including rho, rap, rac, ral, and rab.

The present invention includes a method for blocking or preventing the prenylation of CAAX box containing proteins such as ras oncogene products, and thereby inhibit disease promoting effects of the CAAX box containing protein or more specifically prevent and/or treat ras-related tumors, by administering to a patient in need of treatment a therapeutic amount of a compound of Formula I of the invention which serves as a protein-prenyl transferase inhibitor.

The Formula I protein-prenyl transferase inhibitors, unlike HMG CoA reductase inhibitors, will interfere with prenylation of the ras oncogene

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products and inhibit their transforming activity, yet may or may not interfere with the synthesis of FPP, a precursor in the synthesis of ubiquinones, dolichols and Haem A.

- 5 The compounds of the invention may also be employed in combination with an antihyperlipoproteinemic agent, hypocholesterolemic agent, and/or hypotriglyceridemic agent, and/or antiatherosclerotic agent such as one or more HMG CoA
- 10 reductase inhibitors, for example, pravastatin, lovastatin, simvastatin, velostatin, fluvastatin, rivastatin, compactin, SDZ-63,370 (Sandoz), CI-981 (W-L), HR-780, L-645,164, CL-274,471, dalvastatin, α -, β -, and γ -tocotrienol, (3R,5S,6E)-9,9-bis(4-
- 15 fluorophenyl)-3,5-dihydroxy-8-(1-methyl-1H-tetrazol-5-yl)-6,8-nonadienoic acid, L-arginine salt, (S)-4-[[2-[4-(4-fluorophenyl)-5-methyl-2-(1-methylethyl)-6-phenyl-3-pyridinyl]ethenyl]hydroxyphosphinyl]-3-hydroxybutanoic acid, disodium salt,
- 20 BB-476, (British Biotechnology), dihydrocompactin, [4R-[4 α ,6 β (E)]]-6-[2-[5-(4-fluorophenyl)-3-(1-methylethyl)-1-(2-pyridinyl)-1H-pyrazol-4-yl]ethenyl]tetrahydro-4-hydroxy-2H-pyran-2-one, and/or 1H-pyrrole-1-heptanoic acid, 2-(4-
- 25 fluorophenyl)- β , δ -dihydroxy-5-(1-methylethyl)-3-phenyl-4-[(phenylamino)carbonyl]calcium salt[R-(R*,R*)]; one or more fibric acid derivatives such as clofibrate, bezafibrate, Lopid(gemfibrozil) one or more other cholesterol biosynthesis inhibitors,
- 30 such as NB-598, N-(1-oxododecyl)-4 α ,10-dimethyl-8-aza-trans-decal-3 β -ol, 2,4-undecadienoic acid, 11-[3-(hydroxymethyl)-4-oxo-2-oxetanyl]-3,5,7-trimethyl-, [2R-[2 α (2E,4E,7R*),3 β]]; one or more bile acid sequestrants, for example,

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cholestyramine, colestipol, polidexide (DEAE-Sephadex); one or more antioxidants, for example probucol and Vitamin E; and/or one or more other lipid lowering and/or antiatherosclerotic agents, for example nicotinic acid or derivatives thereof, neomycin, p-aminosalicylic acid, probucol, hydroxypropylmethylcellulose, LS-2904, ethanol, 2-[[1-methyl-2-[3-(trifluoromethyl)phenyl]ethyl]amino]-benzoate (ester).

10 The above compounds to be employed in combination with the squalene synthetase inhibitor of the invention will be used in amounts as indicated in the Physicians' Desk Reference (PDR).

15 The compounds of the invention may also be employed with sodium lauryl sulfate or other pharmaceutically acceptable detergents to enhance oral bioavailability of such compounds.

Inhibition of squalene synthetase may be measured by the following procedure.

20 Rat liver microsomal squalene synthetase activity is measured using farnesyl diphosphate as substrate and quantitating squalene synthesis using gas chromatographic analysis. The assay was developed by modifying conditions originally described by Agnew (Methods in Enzymology 110:357, 1985).

30 A further aspect of the present invention is a pharmaceutical composition consisting of at least one of the compounds of the invention, such as Formula I, in association with a pharmaceutical vehicle or diluent. The pharmaceutical composition can be formulated employing conventional solid or liquid vehicles or diluents and pharmaceutical additives of a type appropriate to the mode of



desired administration. The compounds can be administered to mammalian species including humans, monkeys, dogs, etc., by an oral route, for example, in the form of tablets, capsules, granules or
5 powders, or they can be administered by a parenteral route in the form of injectable preparations. The dose for adults is preferably between 200 and 2,000 mg per day, which can be administered in a single dose or in the form of
10 individual doses from 1-4 times per day.

A typical capsule for oral administration contains active ingredient (250 mg), lactose (75 mg) and magnesium stearate (15 mg). The mixture is passed through a 60 mesh sieve and packed into a
15 No. 1 gelatin capsule.

A typical injectible preparation is produced by aseptically placing 250 mg of sterile active ingredient into a vial, aseptically freeze-drying and sealing. For use, the contents of the
20 vial are mixed with 2 mL of physiological saline, to produce an injectible preparation.

The following Examples represent preferred embodiments of the present invention.

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Introduction to Experimental

All temperatures are reported in degrees Centigrade.

¹H and ¹³C chemical shifts are reported as
5 δ -values with respect to Me₄Si (δ =0). ³¹P spectra
were obtained using 85% H₃PO₄ as an external
reference (δ =0). Coupling constants J are reported
in Hz. For mass spectra (mass spec or MS) the
value utilized for the parent M is that of the salt
10 form which was prepared and tested.

All reactions were carried out under an
atmosphere of dry argon or nitrogen. The following
reagents and solvents were distilled prior to use
from the indicated drying agents, where applicable:
15 CH₂Cl₂, 2,4,6-collidine, and diisopropylamine
(CaH₂); THF and diethyl ether (K, benzophenone);
N,N-diethyltrimethylsilylamine and oxalyl chloride.
Benzene was passed through neutral alumina
(activity I) and stored over 4A-molecular sieves.
20 Lithium bromide was dried at 100°C over P₂O₅ (E,E)-
Farnesol was purchased from Aldrich Chemical
Company.

TLC was performed on E. Merck Silica Gel 60
F-254 plates (0.25 mm) or E. Merck Cellulose F
25 plates (0.1 mm). Flash chromatography was carried
out using E. Merck Kieselgel 60 (230-400 mesh).

Reverse-phase chromatographic purification
of salts or mixed ester salts was carried on CHP20P
gel or SP207SS gel, highly porous, polystyrene-
30 divinyl benzene copolymers available from
Mitsubishi Chemical Industries. The indicated
general procedure was followed: An FMI Model RP-SY
pump was utilized for solvent delivery. A column
of CHP20P or SP207SS (2.5 cm diameter, 12-22 cm

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height) was slurry packed and washed with water (500-1000 mL), and a basic, aqueous solution of the crude salt was applied to the top of the column. Typically, the column was eluted with water, followed by a gradient composed of increasing concentrations of acetonitrile or methanol in water. The gradient was created by placing the tip of a tightly stoppered separatory funnel containing 300-500 mL of the organic solvent, or an aqueous-organic mixture, just beneath the surface of a reservoir containing 300-500 mL of pure water. To start the gradient, the stopcock of the separatory funnel was opened, so that as the solvent was withdrawn by the pump from the reservoir, it was replaced with the solvent from the separatory funnel. HPLC-grade solvents were employed. Fractions were collected (10-15 mL each) at a flow rate of 5-10 mL per minute. Those fractions that contained pure product as judged by TLC or HPLC were pooled, the organic solvents were evaporated and the aqueous residue was lyophilized to dryness.

Example 1

(E,E)-(6,10,14-Trimethyl-2-phosphono-5,9,13-pentadecatriene-1-sulfonic acid, trisodium salt

A. Bishomofarnesol

(1) (E,E)-3,7,11,-Trimethyl-2,6,10-dodecatrienyl bromide (farnesyl bromide)

A solution of 1.00 g (4.5 mmol) of (E,E)-farnesol (Aldrich, further purified by flash chromatography) in 10 mL of distilled ether at 0°C under argon in the dark was treated dropwise with a solution of 195 µL (2.05 mmol, 0.45 eq.) of PBr₃ in

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2 mL of diethyl ether (ether). The resultant mixture was stirred at 0°C for one hour, then quenched with water and separated. The organic phase was washed with 5 mL of H₂O, 5 mL of
5 saturated NaHCO₃, and 5 mL of brine, dried over Na₂SO₄ and evaporated to give 1.26 g (98%) of crude bromide as a clear oil.

TLC Silica (2:8 ethyl acetate:hexane) R_f=0.69.

10

(2) (E,E)-5,9,13-Trimethyl-4,8,12-tetra-
decatrienoic acid, 1,1-dimethylethyl ester

To a solution of 9.60 mL (68.5 mmol, 1.5 eq.) of diisopropylamine in 100 mL of tetrahydro-
15 furan (THF) at -78°C under argon was added 28.2 mL (45.0 mmol, 1.0 eq.) of 1.6 M n-butyllithium in hexanes over 20 minutes. After warming to 0°C for 15 minutes, the solution was recooled to -78°C and
20 6.05 mL (45 mmol, 1.0 eq.) of t-butyl acetate was added over 20 minutes. After an additional 15 minutes, 16.0 mL (92 mmol, 2.05 eq.) of hexamethylphosphoramide (HMPA) was added, followed by a solution of 12.53 g (45.0 mmol) of Part A(1) farnesyl bromide in 100 mL of THF over 20 minutes.
25 The reaction was stirred at -78°C for 2.5 hours, quenched with saturated NH₄Cl and allowed to warm to room temperature. After diluting with 400 mL of ethyl acetate, the mixture was washed with four 100 mL portions of water, and 200 mL of brine, dried
30 over MgSO₄ and evaporated to provide 12.96 g of crude product as a yellow oil. Purification by flash chromatography on 1 kg of silica gel, eluted with 1:9 ethyl acetate:petroleum ether afforded

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9.39 g (65%) of title compound as a pale yellow oil.

TLC Silica gel (2:98 ethyl acetate:hexane) R_f =0.16.

5

IR(neat) 2977, 2925, 2857, 1733, 1452, 1368, 1258, 1149 cm^{-1} .

Mass spec. (CI- $\text{CH}_4/\text{N}_2\text{O}$)

10 (+ ions) m/e 165 ($\text{M}+\text{H}-\text{C}_4\text{H}_8$), 247, 183, 137, 68, 67.
(- ions) m/e 319 ($\text{M}-\text{H}$), 279, 251, 100.

(3) Bishomofarnesol

15 To a stirred solution of 5.00 g (15.6 mmol) of Part (2) compound in 45 mL of dry diethyl ether at 0°C under argon was added 592 mg (15.6 mmol, 1 mol - eq.) of lithium aluminum hydride, and the resulting suspension was stirred at room temperature for 20 hours. After cooling to 0°C , the
20 reaction was quenched by treating with 5 mL of H_2O , 5 mL of 15% NaOH, and 15 mL of H_2O and stirring the suspension for 1/2 hour. After adding Na_2SO_4 , the slurry was filtered through Celite, washing well with diethyl ether and evaporated to obtain 3.62 g
25 of crude product. Purification by flash chromatography on 300 g of silica gel, eluted with 1:9 ethyl acetate:petroleum ether provided 3.516 g (90%) of bishomofarnesol as a colorless liquid.

30 TLC Silica gel (2:8 ethyl acetate (EtOAc):hexane) R_f =0.19.

IR(neat) 3330, 2964, 2926, 2873, 2958, 1448, 1384, 1107, 1059, 401 cm^{-1} .

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Mass Spec (CI-CH₄/N₂O, + ions) m/e 251 (M+H), 249 (M+H-H₂), 137, 123, 109, 69.

5 A¹. Bishomofarnesol (alternative
preparation)

(1) (E,E)-(3,7,11-Trimethyl-2,6,10-
undecadienyl)propanedicarboxylic acid,
diethyl ester

10 To a suspension of 1.62 g (40.5 mmol, 3
eq.) of a 60% suspension of sodium hydride in
mineral oil (washed three times with pentane) in
150 mL of tetrahydrofuran at room temperature under
argon was slowly added 6.15 mL (40.5 mmol, 3 eq.)
15 of diethyl malonate. The resulting solution was
stirred for 0.5 hours, then treated with a solution
of 3.83 g (13.5 mmol) of farnesyl bromide in 10 mL
of tetrahydrofuran. After stirring for 6 hours,
the reaction was quenched with saturated NH₄Cl and
20 diluted with 300 mL of diethyl ether. The organic
layer was washed with two 100 mL portions of water
and 100 mL of brine, dried over MgSO₄ and
evaporated and the bulk of the diethyl malonate
removed by spinning under high vacuum to afford
25 4.29 g (87%) of crude title product.

TLC Silica gel (ethyl acetate:hexane 1:9) R_f=0.37.

(TLC shows slight amount of diethyl malonate and a
30 second by-product.)

(2) (E,E)-5,9,13-Trimethyl-4,8,12-tetra-
decatrienoic acid, ethyl ester

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A mixture of 4.103 g (11.2 mmol) of Part A¹ (1) diester, 200 μ L (11.2 mmol, 1 eq.) of water and 950 mg (22.4 mmol, 2 eq.) of lithium chloride in 20 mL of dimethyl sulfoxide was heated at reflux
5 (~190°C) for four hours. After cooling, the reaction mixture was diluted with 180 mL of a 1:1 mixture of diethyl ether: petroleum ether and washed with five 50 mL portions of water and 50 mL of brine, dried over MgSO₄ and evaporated to yield
10 3.623 g of crude product as a yellow-orange oil. Kugelrohr distillation at 180°C (meter setting) and 0.025 mm allowed the collection of 2.100 g of a pale yellow oil, which was, however, still contaminated (by TLC). The distillation,
15 therefore, is unnecessary and should not be performed. Flash chromatography on 180 g of silica gel, eluted with 3:97 ethyl acetate:petroleum ether provided 1.844 g (56%) of desired title product as a pale yellow oil.
20
TLC Silica gel (ethyl acetate:hexane 5:95) R_f=0.27.

(3) Bishomofarnesol

A solution of 7.05 g (24 mmol) of Part A¹
25 (2) monoester in 65 mL of dry diethyl ether at 0°C under argon was treated in portions with 915 mg (24 mmol) of lithium aluminum hydride and stirred at room temperature for three hours. After cooling to 0°C, the reaction was quenched with 7 mL of water,
30 7 mL of 15% NaOH, then stirred for 15 minutes. Additional 21 mL of water was added, and the reaction was stirred 0.5 hours, then dried with Na₂SO₄. The mixture was filtered through Celite, washing well with diethyl ether, and evaporated to

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give 5.665 g of a colorless oil. Purification by flash chromatography on silic gel eluted with 15:85 ethyl acetate:petroleum ether provided 5.23 g (87%) of title compound as a colorless oil.

5

TLC Silica gel (2:8 ethyl acetate:hexanes) $R_f=0.21$.

IR(neat) 3330, 2964, 2926, 2873, 2858, 1448, 1384, 1107, 1059, 401 cm^{-1} .

10

Mass Spec (CI- $\text{CH}_4/\text{N}_2\text{O}$, + ions) m/e 251 (M+H), 249 (M+H- H_2), 137, 123, 109, 69.

15

B. (E,E)-5,9,13-Trimethyl-4,8,12-tetra-
decatrien-1-ol, methanesulfonate ester

To a stirred solution of 2.02 g (8.07 mmol) of bishomofarnesol (prepared as described in Example 1, Part A) in 20 mL of dichloromethane at 0°C was added 2.2 mL (16.1 mmol) of triethylamine followed by 0.69 mL (8.90 mmol) of methanesulfonyl chloride, dropwise over 15 minutes. After stirring for 1.5 hours at 0°C, the reaction was diluted with dichloromethane, washed with 20 mL each of 10% HCl, saturated NaHCO_3 and brine, dried (MgSO_4) and
20 evaporated to give 2.71 g (100%) of the crude title mesylate as a colorless oil.
25

TLC Silica gel (CH_2Cl_2) $R_f=0.46$.

30

C. (E,E)-14-Iodo-2,6,10-trimethyl-2,6,10-
tetradecatriene

The crude Example 1, Part B mesylate prepared from 441.1 mg (1.76 mmol) of the corresponding alcohol according to the procedure of Example

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1, Part B, was dissolved in 5 mL of acetone and treated with 530 mg (3.52 mmol) of sodium iodide. The reaction was allowed to stir for 16 hours at room temperature followed by 5 hours at reflux.

- 5 The suspension was diluted with hexane and stirred with dilute aqueous sodium bisulfite to discharge to yellow color. The organic layer was washed with water and brine, dried (MgSO_4), and evaporated to provide 577 mg of crude product. Flash chromatography on 35 g of silica gel eluted with hexane gave 550.9 mg (87%) of title iodide as a colorless liquid.

TLC Silica gel (hexane) $R_f=0.31$.

- 15 Mass Spec (CI- $\text{CH}_4/\text{N}_2\text{O}$, + ions) m/e 361, 359 (M+H), 137.

20 D. (Diethoxyphosphinyl)methanesulfonic
acid, ethyl ester

- A solution of ethyl methanesulfonate (4.27 mL, 40.3 mmol) in 100 mL of dry THF was treated at -78°C with 19.3 mL (44.4 mmol) of n-BuLi in hexane. After 15 min. diethyl chlorophosphate (3.30 mL, 22.2 mmol) was added. The solution was kept at -78°C for 0.5 h and allowed to stay at -50°C for 1 h. Saturated ammonium chloride (75 mL) was added to the solution and the mixture warmed to room temperature. The mixture was concentrated (THF removed), diluted with water and extracted with methylene chloride (3 X 70 mL). The combined organic fractions were dried (MgSO_4), concentrated and purified by distillation to yield 3.86 g (70%) of title compound.



b.p. 120-130°C, 1 mm Hg.

Ref. Carretero, J. C.; Demillequ, M.; Ghosez, L.

5 Tetrahedron Vol. 43, 1987, pp 5125.

E. (E,E)-1-(Diethoxyphosphinyl)-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, sodium salt

10 To a suspension of 192 mg (8.00 mmol) of NaH in 6 mL of dry DMF at 0°C under argon was added 2.16 g (8.33 mmol) of Part D sulfonate over 15 min. to give a yellow solution. The reaction was allowed to warm to room temperature and stir for
15 0.5 h when 1.00 g (2.77 mmol) of Part C iodide was added in one portion. The reaction mixture was stirred for 18 h when it was quenched with 10 mL of saturated NaCl solution and diluted with 50 mL of ethyl acetate. The layers were separated, the
20 organics dried (Na₂SO₄) and evaporated to provide a crude glass. The glass was dissolved with 2.0 mL of 1 M NaOH solution and purified by MPLC on a column of CHP20P gel (2.5 cm diam. X 15 cm height) eluting with water (150 mL), followed by a gradient
25 created by the gradual addition of 400 mL of acetonitrile to a reservoir of 250 mL of water. Approximately 8 mL fractions were collected. The aqueous solution was concentrated and lyophilized to provide 0.78 g (57%) of title compound as a
30 glass.

TLC Silica gel (8:1:1 propanol/conc. NH₃/water)
R_f=0.75.

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IR (film) 3476 2921, 1664, 1444, 1383, 1241, 1029, 968, 815 cm^{-1} .

Mass Spec (FAB, + ions) m/e 510 (M+Na).

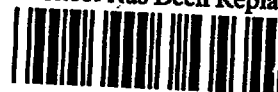
5

F. (E,E)-6,10,14-Trimethyl-1-phosphono-5,9,13-pentadecatriene-1-sulfonic acid, trisodium salt

- 10 To a stirred solution of 0.75 g (1.50 mmol) of Part E salt in 8 mL of dichloromethane at room temperature was added 0.54 g (4.50 mmol) of 2,4,6-collidine followed by 0.82 g (5.35 mmol) of bromo-trimethylsilane. The reaction was allowed to stir at room temperature for 14 h when the solvent was
- 15 evaporated and the semisolid residue pumped (≈ 1 mm pressure) for 0.5 h. The residue was dissolved by adding 6.6 mL (6.60 mmol), of 1 M NaOH solution then diluting with 15 mL of water. The solution was freeze dried to provide an off white solid.
- 20 The solid was purified by MPLC on a column of CHP20P gel (2.5 cm diam. X 15 cm height) eluting with water (150 mL) followed by a gradient created by the gradual addition of 400 mL of acetonitrile to a reservoir of 250 mL of water. Approximately
- 25 10 mL fractions were collected. The acetonitrile was removed under reduced pressure and the aqueous solution was lyophilized to provide 0.34 g (46.5%) of the title compound as a white lyophilate.
- 30 TLC Silica gel (5:4:1 n-propanol/conc. ammonia/water) $R_f=0.75$.

IR (KBr) 3438, 2966, 2926, 2859, 1636, 1449, 1206, 1137, 1110, 976 cm^{-1} .

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Mass Spec (FAB, + ions) m/e 475 (M+H), 453 (M-Na+2H).

- 5 Anal. Calc'd for $C_{18}H_{30}O_6Na_3PS + 1.70 H_2O$:
C, 42.80; H, 6.67; P, 6.13; S, 6.35
Found: C, 42.80; H, 7.01; P, 6.24; S, 6.56.

Example 1A

- 10 (E,E)-6,10,14-Trimethyl-1-phosphono-5,9,13-
pentadecatriene-1-sulfonic acid, trisodium salt

A. Methanesulfonic acid, cyclohexyl ester

- To a stirred solution of 25.0 g (0.25 mol)
15 of cyclohexanol (purchased from the Aldrich
Chemical Company and used without purification) and
27.3 g (0.27 mol) of triethylamine in 500 mL of
ether at -15°C was added 28.6 g (0.25 mol) of
methanesulfonyl chloride in 50 mL of ether dropwise
20 over 35 min. The reaction was warmed to 0°C and
stirred for 1 h when the mixture was diluted water
and washed with aqueous solutions of 1N HCl and
brine. The organics were dried ($MgSO_4$) and
concentrated under reduced pressure to provide 43.0
25 g, 96% yield of title mesylate as a colorless oil.
The mesylate was used without further purification.

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B. (Diethoxyphosphinyl)methanesulfonic
acid, cyclohexyl ester

To a rapidly stirred, nitrogen-purged
[Note 1] solution of 24.4 g (137 mmol) of Part A
5 mesylate in 600 mL of THF under nitrogen at -78°C
was added 55 mL (137.5 mmol, 2.5 M in hexanes) of
n-butyl-lithium over 35 min. The temperature was
not allowed to rise above -70°C [NOTE 2]. After an
additional 10 min, 11.8 g (68.5 mmol) of freshly
10 distilled diethyl chlorophosphate was added to the
resulting slightly turbid solution at a rate to
keep the temperature below -70°C . The reaction
mixture was stirred for 45 min and then a solution
of 8.30 g (138 mmol) of glacial acetic acid in 25
15 mL of THF was added over 5 minutes. The reaction
mass was warmed to room temperature and evaporated
at 30°C at reduced pressure. The residue was
partitioned between 250 mL of dichloromethane and
75 mL of water and extracted twice with
20 dichloromethane. The extracts were combined, dried
over MgSO_4 and evaporated. The crude product was
purified by flash chromatography [NOTE 3] (8 x 50
cm column, 2 L of dichloromethane, then 4 L of
11:89 ether/dichloromethane, then 2 L of 1:4
25 ether/dichloromethane) to give title compound as a
colorless oil, 11.4 g, 53%.

TLC Silica gel, (11:89 ether/dichloromethane)
 $R_f = 0.20$.

30

NOTE 1. The reaction is run under a rapid nitrogen
stream in an attempt to rigorously exclude oxygen
from the system.

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NOTE 2. Efficient and rapid mechanical stirring is essential to prevent formation of the impurities sometimes seen in this reaction.

5

NOTE 3. In an independent experiment, a 15.5 g sample of crude material was chromatographed on 850 g of silica gel eluted with 20:80 isopropanol/hexane, collecting 50 mL fractions.

10 Fractions 61-85 were combined to provide 13.8 g (73 %) yield of pure triester.

15

C. (E,E)-1-(Diethoxyphosphinyl)-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, cyclohexyl ester

20

To a suspension of 0.57 g (23.7 mmol, 1.9 eq.) of NaH in 50 mL of dry DMF at -20°C under argon was added 9.00 g (28.7 mmol, 2.3 eq.) of Part B sulfonate over 15 min. to give a yellow solution. The reaction was allowed to warm to room temperature and stir for 0.5 h when 4.48 g (12.46 mmol, 1 eq.) of Example 1 Part C iodide was added in one portion. The reaction mixture was stirred for 12 h when it was quenched with 100 mL of saturated NaCl solution and diluted with 250 mL of ether. The layers were separated, the organics dried (Na₂SO₄) and evaporated to provide a crude oil. Flash chromatography was performed on 500 g of silica gel eluting with 3:7 ethyl acetate/hexane to provide 5.20 g (76%) of title compound in the form of a pale yellow oil.

25

30

TLC Silica gel (1:1 ethyl acetate/hexanes) R_f=0.60.

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IR (film) 2934, 2861, 1449, 1352, 1260, 1173, 1053, 1024, 930 cm^{-1} .

Mass Spec. (CI, + ions) m/e 564 ($\text{M}+\text{NH}_4$), 547 ($\text{M}+\text{H}$),
5 482 ($\text{M}+\text{NH}_4-\text{C}_6\text{H}_{10}$), 465 ($\text{M}+\text{H}-\text{C}_6\text{H}_{10}$).

D. (E,E)-6,10,14-Trimethyl-1-phosphono-
5,9,13-pentadecatriene-1-sulfonic acid,
trisodium salt

10 To a solution of 1.00 g (1.82 mmol) of Part
C compound and 20 mL of methanol in a sealable tube
at 0°C was added NH_3 (g) until the solution was
saturated. The tube was sealed and placed in an
oil bath at 75°C for 16 h, at which point the tube
15 was opened and the volatiles removed under reduced
pressure. The remainder was dissolved in dry
toluene and evaporated two times (2 X 7.0 mL)
leaving an amber oil. The oil was dissolved in 10
mL of dry methylene chloride and treated with 2.40
20 mL (9.0 mmol) of bis(trimethylsilyl)trifluoro-
acetamide (BSTFA) for 0.5 h, followed by 0.79 mL
(6.0 mmol) of bromotrimethylsilane. The reaction
mixture was stirred for 18 h when the solvent was
evaporated and the residue pumped (≈ 0.5 mm
25 pressure) for 0.5 h. The remainder was dissolved
by adding 50 mL (10 mmol) of 0.2 M NaOH solution
and stirring vigorously for ten min. The soapy
solution was freeze dried to provide a white solid.
The solid was purified by MPLC on a column of
30 CHP20P gel (0.30 L) eluting with water (0.5 L)
followed by isocratic elution with 15% acetonitrile
in water. Approximately 25 mL fractions were
collected. Pure fractions were pooled and the
aqueous solution lyophilized to provide 0.80 g

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(91%) of title salt as a white lyophilate. The lyophilate was diluted with 0.6 mL of water and the mixture mashed to a gummy white solid. The solid was repeatedly washed and mashed with acetone (3 X 4 mL) until a granular solid resulted. The granular solid was dried under vacuum for 10 h and collected to yield 0.75 g (85%) of title salt as a fine white powder.

10 TLC Silica gel (6:3:1 n-propanol/conc. ammonia/water) $R_f=0.35$.

IR (KBr) 3434, 2924, 2857, 1667, 1449, 1209, 1136, 1109, 976 cm^{-1} .

15

Mass Spec (FAB, + ions) m/e 497 (M+Na), 475 (M+H).

Anal. Calc'd for $\text{C}_{18}\text{H}_{30}\text{O}_6\text{Na}_3\text{PS} + 0.81 \text{ H}_2\text{O}$:

C, 44.20; H, 6.52; P, 6.33; S, 6.55

20 Found: C, 43.83; H, 6.93; P, 6.02; S, 6.69.

Example 1B

(E,E)-6,10,14-Trimethyl-1-phosphono-5,9,13-pentadecatriene-1-sulfonic acid, tripotassium salt

25

To a solution of 11.11 g (20.3 mmol) of Example 1A, Part C compound and 120 mL of methanol in a sealable tube at 0°C was added NH_3 (g) until the solution was saturated. The tube was sealed and placed in an oil bath at 65°C for 24 h, at which point the tube was opened and the volatiles removed under reduced pressure. The remainder was dissolved in a 1:1 mixture of dry toluene/hexamethyl disilazane (HMDS) and evaporated

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two times (2 x 60 mL), leaving an amber oil. The oil was dissolved in 70 mL of dry methylene chloride and treated with 21.4 mL (101.6 mmol) of HMDS for 0.5 h at RT. The mixture was then treated
5 with 16.0 mL (121.9 mmol) of bromotrimethylsilane. The reaction was allowed to stir at RT for 45 h when the solvent was evaporated and the residue pumped ($\approx$ 0.5 mm pressure, 35°C) for 0.5 h. The remainder was dissolved by adding 120 mL (120 mmol)
10 of 1 M KOH solution and stirring vigorously for ten min. The soapy solution was freeze dried to provide a white solid. The solid was purified by MPLC on a column of CHP20P gel (1 L) eluting with water (2 L) followed by a stepwise gradient created
15 by the addition of: 1:9 acetonitrile/water (1.5 L), 1.5:8.5 acetonitrile/water (1.5 L), 2:8 acetonitrile/water (1 L) and finally 2.5:7.5 acetonitrile/water (1 L). Approximately 50 mL fractions were collected. Fractions 52 to 83 were
20 pooled, the acetonitrile was removed under reduced pressure and the aqueous solution lyophilized to provide 8.11 g (78%) of title compound as a white lyophilate which was 98.5% pure by HPLC. The lyophilate was dissolved with 16 mL of water, and
25 40 mg (0.5 mol %) of Trolox was added. The product was precipitated with 16 mL acetone, and the precipitate was repeatedly washed (2 X 8 mL) and mashed with acetone until a solid resulted. The solid was dried under vacuum for 24 h and collected
30 to yield 7.58 g (72%) of title compound as a fine white powder.

TLC Silica gel (6:3:1 n-propanol/conc. ammonia/water) R_f =0.35.

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IR (KBr) 3435, 2924, 2857, 1632, 1449, 1204, 1140, 1109, 974 cm^{-1} .

5 Mass Spec (FAB, + ions) m/e 561 (M+K), 523 (M+H), 485 (M-K+2H).

Anal. Calc'd for $\text{C}_{18}\text{H}_{30}\text{O}_6\text{K}_3\text{PS} + 0.59 \text{ H}_2\text{O}$:

C, 40.53; H, 5.89; P, 5.81; S, 6.13

10 Found: C, 40.50; H, 6.20; P, 5.67; S, 5.91.

Example 2

(E)-6,10-Dimethyl-1-phosphono-5,9-undecadiene-1-sulfonic acid, trisodium salt

15

The title compound was prepared as described herein and has the following properties.

20 TLC Silica gel (5:4:1 n-propanol/conc. ammonia/water) $R_f=0.45$.

IR (KBr) 3425, 2964, 2926, 2858, 1641, 1450, 1203, 1099, 1053, 974 cm^{-1} .

25 Mass Spec (FAB, + ions) m/e 429 (M+Na), 407 (M+H), 385 (M-Na+2H).

Anal. Calc'd for $\text{C}_{13}\text{H}_{22}\text{O}_6\text{Na}_3\text{PS} + 1.58 \text{ H}_2\text{O}$:

C, 35.92; H, 5.83; P, 7.13; S, 7.38

30 Found: C, 35.92; H, 5.99; P, 7.24; S, 7.28.

Example 3

α -Phosphono-[1,1'-biphenyl]-4-butanesulfonic acid, trisodium salt

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The title compound was prepared as described herein and has the following properties.

- 5 TLC Silica gel (5:4:1 n-propanol/conc. ammonia/water) $R_f=0.45$.

IR (KBr) 3433, 3029, 2931, 1636, 1487, 1450, 1202, 1094, 1053, 973 cm^{-1} .

10

Mass Spec (FAB, + ions) m/e 459 (M+Na), 437 (M+H), 415 (M-Na+2H).

Anal. Calc'd for $\text{C}_{16}\text{H}_{16}\text{O}_6\text{Na}_3\text{PS} + 2.00 \text{ H}_2\text{O}$:

15

C, 40.69; H, 4.27; P, 6.56; S, 6.79

Found: C, 40.90; H, 4.39; P, 6.43; S, 6.89.

Example 4

(E)-4-(4-Heptylphenyl)-1-phosphono-3-butene-1-sulfonic acid, tripotassium salt

20

The title compound was prepared as described herein and has the following properties.

- 25 IR (KBr pellet) 3414, 2924, 2853, 1653, 1198, 1154, 1092, 972 cm^{-1} .

Anal. Calc'd for $\text{C}_{17}\text{H}_{24}\text{K}_3\text{O}_6\text{PS} \cdot 2.25 \text{ H}_2\text{O}$:

C, 37.45; H, 5.27; P, 5.68; S, 5.88

30

Found: C, 37.09; H, 5.43; P, 6.08; S, 6.12.

MS (FAB, + ions) m/e 543 (M+K), 505 (M+H), 423 (M-2K-3H).

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Example 5

4-Heptyl- α -phosphonobenzenebutanesulfonic acid,
tripotassium salt

- 5 The title compound was prepared as described
herein and has the following properties.

IR (KBr pellet) 3434, 2926, 2855, 1649, 1460,
1200, 1084, 1049, 966 cm^{-1} .

10

Anal. Calc'd for $\text{C}_{17}\text{H}_{26}\text{K}_3\text{O}_6\text{PS} \cdot 0.75 \text{ H}_2\text{O}$:

C, 39.25; H, 5.33; P, 5.95; S, 6.16

Found: C, 39.45; H, 5.72; P, 5.71; S, 5.83.

- 15 MS (FAB, + ions) m/e 545 (M+K), 507 (M+H), 469
(M-K+2H).

Example 6

(E)-4-(4'-Propyl[1,1'-biphenyl]-4-yl)-1-phosphono-
20 3-butene-1-sulfonic acid, tripotassium salt

A. (E)-(4'-Propyl[1,1'-biphenyl]-4-yl)-
2-propen-1-ol, acetate ester

- 25 A(1). (E)-(4'-Propyl[1,1'-biphenyl]-4-yl)-
2-propenoic acid, n-butyl ester

A stirred solution of 4.13 g (15 mmol) of 4-
bromo-4'-n-propylbiphenyl, 106 mg (0.35 mmol) of
tri-p-tolylphosphine, 2.7 mL (19 mmol) of n-butyl
30 acrylate, 7.4 mL (30.8 mmol) of tributylamine and
10 mg (0.1 mmol) of hydroquinone was purged with a
stream of nitrogen gas for 20 min at room
temperature. To this mixture was added 4 mg (0.018
mmol) of palladium acetate. The reaction was

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heated to 150 °C for 18 h under argon and then cooled to room temperature. The resulting slurry was diluted with ether, extracted twice with 50 mL of 1 M hydrochloric acid, once with brine and once
5 with saturated sodium bicarbonate solution. The organic phase was dried (MgSO₄) and evaporated. The crude product (4.5 g) was purified by flash chromatography on silica gel (5 x 25 cm column) eluted with 1 L of hexanes and then 1:1
10 dichloromethane/hexanes to give 4.08 g (81%) of title ester as a colorless oil.

A(2). (E)-(4'-Propyl[1,1'-biphenyl]-4-yl)-
2-propen-1-ol, acetate ester

15 To a stirred solution of 3.22 g (10.0 mmol) of Part A(1) ester in 50 mL of dichloromethane at 0 °C under nitrogen was added a solution of 22 mL (22 mmol, 1 M in hexanes) of diisobutylaluminum hydride over 5 min. The resulting pale yellow solution was
20 stirred for 2 h and then quenched with 2 mL of methanol. The solution was then treated with 150 mL of 1 M potassium sodium tartrate. A gel formed which dissolved within 5 min. The reaction mixture was extracted twice with ether. The extracts were
25 combined, dried (Na₂SO₄) and evaporated. The resulting oil (2.6 g) was dissolved in 25 mL of THF, cooled to 0°C under nitrogen and 4.6 mL (25 mmol) of diisopropylethylamine and 2.4 mL (25 mmol) of acetic anhydride was added. After 1 h, the
30 reaction mixture was diluted with ether, washed twice with 1 M hydrochloric acid once with brine and once with saturated sodium bicarbonate. The organic phase was dried (MgSO₄) and evaporated onto 10 g of silica gel. Purification by flash



chromatography on silica gel (5 x 20 cm column) eluted with 9:11 dichloromethane:hexane to give title compound as a colorless oil, 2.21 g, 88% from Part A(1) ester.

5

B. (E)-1-(Diethoxyphosphinyl)-4-(4'-propyl[1,1'-biphenyl]-4-yl)-3-butene-1-sulfonic acid, cyclohexyl ester

To a stirred solution of 1.91 g (6.50 mmol) of Part A compound, 2.5 mL (10 mmol, 1.5 equiv.) of bis(tri-methylsilyl)acetamide, 3.00 g (9.5 mmol, 1.46 equiv.) of Example 1A, Part B sulfonate and 180 mg (0.7 mmol) of triphenylphosphine in 10 mL of THF under argon was added 400 mg (0.35 mmol) of tetrakis(tri-phenylphosphine)palladium. The resulting mixture was heated to reflux for 1 hour. The reaction was cooled, evaporated, diluted with ether and washed once with 10% citric acid and thrice with water. The organic phase was dried (MgSO₄) and evaporated. Purification by flash chromatography on silica gel (5 x 20 cm column) eluted with 3:97 ether/dichloromethane gave title compound as a colorless oil, 2.32 g, 65% yield.

25

C. (E)-4-(4'-Propyl[1,1'-biphenyl]-4-yl)-1-phosphono-3-butene-1-sulfonic acid, tripotassium salt

To a stirred solution of 578 mg (1.05 mmol) of Part B compound in 5 mL of dichloromethane under argon at room temperature was added 560 mL (2.1 mmol) of bis(trimethylsilyl)trifluoroacetamide and then 560 mL (4.2 mmol) of bromotrimethylsilane. After 72 h, the resulting clear solution was evaporated at 25°C and the residue dissolved in 5

30



mL of THF. To this stirred solution was added 180 mg (1.1 mmol) of dried, finely ground potassium iodide and 3 mg (0.01 mmol) of 18-crown-6. The resulting slurry was heated to reflux for 20 h, evaporated and then stirred for 1 h with 8 mL (4 mmol) of 0.5 M potassium hydroxide solution. The solution was lyophilized and then purified by MPLC (2.5x20 cm column of Mitsubishi Kasei Sepadbeads SP-207SS resin): 11.5 mL fractions, 7 mL/min flow rate, eluted with 200 mL of water and then a gradient prepared from 400 mL of water and 450 mL of 2:1 acetonitrile/water). Fractions 20-34 were collected and lyophilized to give title salt as a white solid, 505 mg, 85% yield.

IR (KBr pellet) 3422, 2959, 2930, 2870, 1653, 1497, 1202, 1080, 968 cm^{-1} .

Anal. Calc'd for $\text{C}_{19}\text{H}_{20}\text{K}_3\text{O}_6\text{PS} \cdot 2.2 \text{ H}_2\text{O}$:

C, 40.45; H, 4.36; P, 5.49; S, 5.68
Found: C, 40.11; H, 4.70; P, 5.18; S, 5.95.

MS (FAB, + ions) m/e 563 (M+K), 525 (M+H), 487 (M-K+2H).

Example 7

α -Phosphono-4'-Propyl[1,1'-biphenyl]-4-butane-sulfonic acid, tripotassium salt

A. α -(Diethoxyphosphinyl)-4'-propyl[1,1'-biphenyl]-4-butanefulfonic acid, cyclohexyl ester

To a nitrogen-purged solution of 1.30 mg (2.37 mmol) of Example 6 Part B compound in 50 mL

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of ethyl acetate in a 500 mL one-neck round bottom flask was attached a hydrogen-filled rubber bladder of approximately 1 L capacity. The reaction mixture was vigorously stirred for 16 h, purged with nitrogen, filtered through Celite and the filtrate evaporated. The oily residue was redissolved in dichloromethane, filtered through a 0.75 μ (micron) filter and re-evaporated to give title compound as a colorless oil, 1.28 g, 98% yield. The product was used without further purification.

B. α -Phosphono-4'-propyl[1,1'-biphenyl]-
4-butanesulfonic acid, tripotassium salt

To a stirred solution of 1.14 g (2.06 mmol) of Part A compound in 10 mL of dichloromethane under argon at room temperature was added 1.10 mL (8.3 mmol) of bromotrimethylsilane. After 24 h, the resulting clear solution was evaporated at 25 $^{\circ}$ C and the residue dissolved in 10 mL of THF. To this stirred solution was added 340 mg (2.1 mmol) of dried, finely ground potassium iodide and 5 mg (0.02 mmol) of 18-crown-6. The resulting slurry was heated to reflux for 24 h, evaporated and then stirred for 1 h with 8 mL (8 mmol) of 1.0 M potassium hydroxide solution. The solution was lyophilized and then purified by MPLC (2.5x20 cm column of Mitsubishi Kasei Sepadbeads SP207SS resin): 11.5 mL fractions, 7 mL/min flow rate, eluted with 200 mL of water and then a gradient prepared from 400 mL of water and 450 mL of 1:1 acetonitrile/water). Fractions 27-31 were collected and lyophilized to give title compound as a white solid, 450 mg, 39% yield.

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IR (KBr pellet) 3432, 2957, 2930, 2870, 1636,
1499, 1198, 1080, 1049, 966 cm^{-1} .

5 Anal. Calc'd for $\text{C}_{19}\text{H}_{22}\text{K}_3\text{O}_6\text{PS} \cdot 1.9 \text{ H}_2\text{O}$:

C, 40.68; H, 4.64; P, 5.52; S, 5.72

Found: C, 40.69; H, 5.00; P, 5.46; S, 6.00.

MS (ion spray, + ions) m/e 495 (M-3K+4H+2CH₃CN),
10 492 (M-2K+3H+CH₃CN), 489 (M-K+2H),
454 (M-3K+4H+CH₃CN), 451 (M-2K+3H), 413 (M-3K+4H).

Example 8

4-(2-Phenylethoxy)- α -phosphonobenzenebutanesulfonic
15 acid, dipotassium salt

The title compound was prepared as described
herein and has the following properties.

20 IR (KBr pellet) 3434, 3088, 2936, 2868, 1636,
1512, 1198, 1076, 966 cm^{-1} .

Anal. Calc'd for $\text{C}_{18}\text{H}_{21}\text{K}_2\text{O}_7\text{PS} \cdot 3.75 \text{ H}_2\text{O}$:

C, 38.73; H, 5.15; P, 5.55; S, 5.74

25 Found: C, 38.73; H, 5.10; P, 5.24; S, 5.51.

MS (FAB, + ions) m/e 567 (M+2K-H), 529 (M+K).

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Example 9

6-(Hexyloxy)- α -phosphono-2-naphthalenebutane-sulfonic acid, dipotassium salt

5 A. 2-Bromo-6-(hexyloxy)naphthalene

To a stirred solution of 4.46 g (20.0 mmol) of 6-bromo-2-naphthalenol (obtained from Aldrich Chemical Company (#B7,340-6) and used without purification), in 20 mL of DMF at room temperature
10 under argon was added 480 mg (20 mmol) of 95% sodium hydride over the course of 15 min. The resulting light yellow solution was stirred 30 min and 3.5 mL (22 mmol) of 1-bromohexane was added. The reaction was heated to 50°C and stirred for 60
15 min. The reaction was quenched with ice water, the resultings solids filtered, washed with water and dried in vacuo at 60°C. Purification of the residue by chromatography on silica gel (5 x 20 cm column, hexanes as elutant) gave 5.00 g, 81% yield,
20 of title compound as a colorless oil.

B. α -Ethenyl-6-(hexyloxy)-2-naphthalene-methanol

To a stirred solution of 2.23 g (7.25 mmol)
25 of Part A compound in 25 mL of THF under argon at -78°C was added a solution of 8.5 mL (14.5 mmol) of 1.7 M t-butyllithium in pentane over 10 min. After 15 min, a yellow slurry had formed. This was warmed to 0°C and the resulting organic solution
30 was stirred for 30 min. To this reaction mixture was added 550 mL (9.5 mmol, 1.3 equivalents) of freshly distilled acrolein at a rate to keep the temperature below 5°C. After an additional 30 min, the reaction was quenched with saturated ammonium



chloride solution, extracted twice with ether, dried (MgSO₄) and evaporated. Recrystallization from hexanes gave title compound as a white solid, mp 47-48°C, 1.83 g, 89%.

5

C. α -Ethenyl-6-(hexyloxy)-2-naphthalene-
methanol, acetate ester

To a solution of 1.43 g (5.0 mmol) of Part B compound and 1.1 mL (8 mmol) of triethylamine in
10 15 mL of CH₂Cl₂ at room temperature under argon was added 0.7 mL (6.6 mmol) of acetic anhydride and 20 mg (0.16 mmol) of 4-dimethylaminopyridine. After 10 min, the reaction mixture was evaporated, diluted with ether, washed once with 10% citric
15 acid, once with water, once with saturated sodium bicarbonate solution, dried (MgSO₄) and evaporated to give title compound as a colorless oil, 1.54 g, 94%. The compound was used without further purification for the subsequent reaction.

20

D. (E)-1-(Diethoxyphosphinyl)-4-[6-(hexyloxy)-2-naphthalenyl]-3-butenesulfonic
acid, cyclohexyl ester

To a stirred solution of 1.47 g (4.5 mmol)
25 of Part C compound, 1.55 mL (6.6 mmol, 1.5 equiv.) of bis(trimethylsilyl)acetamide, 1.85 g (5.85 mmol, 1.3 equiv.) of Example 1A, Part B sulfonate and 125 mg (0.5 mmol) of triphenylphosphine in 10 mL of THF under argon was added 270 mg (0.24 mmol) of
30 tetrakis(triphenylphosphine)palladium. The resulting mixture was heated to reflux for 1 hour. The reaction was cooled, evaporated, diluted with ether and washed once with 10% citric acid and thrice with water. The organic phase was dried



(MgSO₄) and evaporated. Purification by flash chromatography on silica gel (5 x 20 cm column) eluted with 1:24 ether/dichloromethane gave title compound as a colorless oil, 1.06 g, 41% yield.

5

E. α -(Diethoxyphosphinyl)-6-(hexyloxy)-2-naphthalenebutanesulfonic acid, cyclohexyl ester

To an argon-purged solution of 965 mg (1.66 mmol) of Part D compound and 100 mg of 10% palladium-on-carbon in 15 mL of ethyl acetate in a 500 mL one-neck round bottom flask was attached a hydrogen-filled rubber bladder of approximately 1 L capacity. The reaction mixture was vigorously stirred for 16 h, purged with nitrogen, filtered through Celite and the filtrate evaporated. The oily residue was redissolved in dichloromethane, filtered through a 0.75 μ (micron) filter and re-evaporated to give title compound as a colorless oil, 950 mg, 98% yield. The product was used without further purification.

25

F. 6-(Hexyloxy)- α -phosphono-2-naphthalenebutanesulfonic acid, dipotassium salt

To a stirred solution of 885 mg (1.52 mmol) of Part E compound in 10 mL of dichloromethane under argon at room temperature was added 800 μ L (8.9 mmol) of bromotrimethylsilane. After 18 h, the resulting clear solution was evaporated at 25°C and the residue dissolved in 15 mL of THF. To this stirred solution was added 320 mg (1.9 mmol) of dried, finely ground potassium iodide and 3 mg (0.01 mmol) of 18-crown-6. The resulting slurry

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was heated to reflux for 24h, evaporated and then stirred for 1 h with 9 mL (4.5 mmol) of 0.5 M potassium hydroxide solution. The solution was lyophilized and then purified by MPLC (2.5x20 cm column of Mitsubishi Kasei Sepadbeads CHP-20P resin): 11.5 mL fractions, 7 mL/min flow rate, eluted with 200 mL of water and then a gradient prepared from 400 mL of water and 450 mL of 1:1 acetonitrile/water). Fractions 44-52 were collected and lyophilized to give title compound as a white solid, 475 mg, 53% yield.

IR (KBr pellet) 3434, 3057, 2932, 2861, 1653, 1605, 1181, 1076, 966 cm^{-1} .

Anal. Calc'd for $\text{C}_{20}\text{H}_{27}\text{K}_2\text{O}_7\text{PS} \cdot 3.81 \text{ H}_2\text{O}$:

C, 40.76; H, 5.92; P, 5.26; S, 5.44

Found: C, 40.76; H, 5.81; P, 5.35; S, 5.35.

MS (FAB, + ions) m/e 559 (M+K), 521 (M+H).

Example 10

4-[(5-Methyl-4-hexenyl)oxy]- α -phosphonobenzene-butanesulfonic acid, tripotassium salt

The title compound was prepared as described herein and has the following properties.

IR (KBr pellet) 3432, 2963, 2928, 2866, 1636, 1512, 1242, 1202, 1080, 966 cm^{-1} .

Anal. Calc'd for $\text{C}_{17}\text{H}_{24}\text{K}_3\text{O}_7\text{PS} \cdot 1.33 \text{ H}_2\text{O}$:

C, 37.49; H, 4.93; P, 5.69; S, 5.89

Found: C, 37.48; H, 5.28; P, 5.62; S, 5.64.



MS (FAB, + ions) m/e 559 (M+K), 521 (M+H), 483 (M-K+2H).

5

Example 11

1-Phosphono-1-pentadecanesulfonic acid, tripotassium salt

10

A. (Diethoxyphosphinyl)methanesulfonic acid, 1-methylethyl ester

15

20

25

30

To a rapidly stirred solution of 8.28 g (60 mmol) of isopropyl methanesulfonate in 150 mL of THF at -73°C (internal temp.) was added 25 mL (60 mmol) of 2.4 M n-butyllithium dropwise over 20 min. The internal temperature was not allowed to rise above -69°C throughout the course of the addition. After an additional 15 min., 5.17 g (30 mmol) of freshly distilled diethyl chlorophosphate was added at a rate to keep the solution temperature below -69°C. The reaction mixture was stirred for 0.3 h at -73°C and for 0.5 h at -40°C when it was quenched with 125 mL of saturated NH₄Cl solution. The reaction mass was warmed to room temperature and the THF removed under reduced pressure. The remainder was partitioned between methylene chloride and water (3 X 75 mL). The extracts were dried (Na₂SO₄), concentrated, and purified by flash chromatography (350 g silica gel) eluting with 1:1 methylene chloride/ether to provide 5.20 g (67%) of title compound as a colorless oil.

TLC Silica gel (1:1 methylene chloride/ether)
R_f=0.37.

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B. 1-(Diethoxyphosphinyl)pentadecane-sulfonic acid, 1-methylethyl ester

To a suspension of 0.10 g (4.38 mmol) of NaH in 7 mL of dry DMF at 0°C under argon was added
5 1.20 g (4.38 mmol) of Part A compound over 5 min. to give a yellow solution. The reaction was allowed to warm to room temperature and stir for 0.5 h when 0.55 g (2.00 mmol) of tetradecanyl bromide was added in one portion. The reaction
10 mixture was stirred for 24 h when it was quenched with 20 mL of saturated NaCl solution and diluted with 50 mL of ether. The layers were separated, the organics dried (Na₂SO₄) and evaporated to provide a crude oil. Flash chromatography was
15 performed on 100 g of silica gel eluting with 3:7 ethyl acetate/hexane to provide 0.30 g (31 %) of title compound in the form of a pale yellow oil.

TLC Silica gel (1:1 ethyl acetate/hexanes) R_f=0.50.

20

IR (film) 2924, 2853, 1466, 1358, 1260, 1177, 1053, 1024, 930 cm⁻¹.

Mass Spec (CI, + ions) m/e 488 (M+NH₄), 471 (M+H),
25 347 (M+H-SO₃C₃H₈).

C. 1-Phosphono-1-pentadecanesulfonic acid, tripotassium salt

To a stirred solution of 0.25 g (0.53 mmol) of Part
30 B compound in 5 mL of dichloromethane at 0°C and in the dark was added 4.24 g (2.12 mmol) of iodotrimethylsilane. The reaction was allowed to stir for 16 h when the solvent was evaporated and the semisolid residue pumped (≈ 1 mm pressure) for

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0.5 h. The residue was dissolved by adding 3 mL of 1 M (3.0 mmol) KOH solution and freeze dried to provide an off white solid. The solid was purified by MPLC on a column of CHP20P gel (2.5 cm diam. X 15 cm height) eluting with water (100 mL) followed by a gradient created by the gradual addition of 400 mL of acetonitrile to a reservoir of 250 mL of water. Approximately 7 mL fractions were collected. The acetonitrile was removed under reduced pressure and the aqueous solution was lyophilized to provide 0.15 g (62%) of title salt as a white lyophilate.

TLC Silica gel (6:3:1 n-propanol/conc. ammonia/water) $R_f=0.40$.

IR (KBr) 3443, 2920, 2851, 1653, 1468, 1215, 1163, 1045, 966 cm^{-1} .

Mass Spec (FAB, + ions) m/e 525 (M+K), 487 (M+H).

Anal. Calc'd for $\text{C}_{15}\text{H}_{30}\text{O}_6\text{K}_3\text{PS} + 2.19 \text{ H}_2\text{O}$:

C, 34.24; H, 6.59; P, 5.89; S, 6.09

Found: C, 34.03; H, 6.88; P, 5.57; S, 6.02.

Example 12

(E)-10,14-Dimethyl-1-phosphono-9,13-pentadecadiene-1-sulfonic acid, dipotassium salt

A. Dichloro[μ -[1-hexanolato(2-)- C_6O_1]]-dimagnesium

To a stirred solution of 11.00 g (80.0 mmol) of 6-chloro-1-propanol (Aldrich) in 20 mL of THF at -20°C was added 27.0 mL (81.0 mmol) of 3.0 M

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methylmagnesium chloride in THF dropwise over 25 minutes. After 0.5 hours at -20°C , the reaction was allowed to warm to room temperature and 2.88 g (118.0 mmol) of magnesium turnings were added and
5 the reaction was heated to reflux. The reaction was initiated by adding a few crystals of iodine at the start of reflux and after 1 hour of heating. After 2 hours at reflux the reaction was cooled to room temperature providing the Grignard solution.
10 The molarity of the reaction mixture was determined by titration: 5.20 mL (2.60 mmol) of a 0.5 M solution of 2-propanol in benzene was slowly added to a blood red solution of 2-2'-biquinoline (indicator) in benzene and 2.0 mL of the freshly
15 prepared Grignard solution. The endpoint color was light green and the molarity was determined to be 1.3 M.

20 B. (E)-9,13-Dimethyl-8,12-tetradecadiene-
1-ol

A solution of 21.5 mL (28.0 mmol) of 1.3 M Part A Grignard reagent in THF and 5.0 mL of HMPA at 0°C was treated dropwise with 1.21 g (7.0 mmol) of geranyl chloride in 7 mL of THF over 7 minutes.
25 After the addition the reaction was allowed to warm to room temperature and stir for 2 hours, at which point the reaction was diluted with ether and quenched with 50 mL (50.0 mmol) of 1 M HCl solution. The organic layer was washed two times
30 with NH_4Cl solution, dried over MgSO_4 and evaporated to provide a crude oil. Flash chromatography was performed on 125 g of silica gel packed, loaded and eluted with 1:4 ethyl acetate/hexanes to

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provide 1.10 (66%) of title alcohol as an amber oil.

TLC Silica gel (1:9 ethyl acetate:hexane) $R_f=0.20$.

5

IR (CCl_4 solution) 3636, 2928, 2854, 1450, 1377, 1055 cm^{-1} .

MS (CI, NH_3 , + ions) 256 ($\text{M}+\text{NH}_4$).

10

C. (E)-9,13-Dimethyl-8,12-tetradecadien-1-yl iodide

To a stirred solution of 1.10 g (4.62 mmol) of Part B alcohol and 1.40 mL (10.00 mmol) of triethylamine in 10 mL of methylene chloride at 0°C was added 0.37 mL (4.80 mmol) of methanesulfonyl chloride dropwise over 15 minutes. After 1 hour at 0°C the reaction was diluted with ether and washed with aqueous solutions of NH_4Cl , NaHCO_3 , and brine. The organic layer was dried (MgSO_4) and concentrated under reduced pressure to provide 1.42 g (~ 4.5 mmol) of the crude mesylate. The residual oil was dissolved in 25 mL of acetone and treated with 3.00 g (20.0 mmol) of NaI . The resulting suspension was heated to reflux for 4 hours and diluted with ether, washed with brine, dried over MgSO_4 , and concentrated to provide a yellow oil. Flash chromatography was performed on 100 g of silica gel packed, loaded and eluted with hexanes to provide 1.10 g (68% overall yield) of title iodide in the form of a colorless oil.

TLC Silica gel (hexanes) $R_f=0.45$.

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IR (CCl₄ solution) 2962, 2928, 2854, 1450, 1375, cm⁻¹.

MS (CI, NH₃, + ions) 366 (M+NH₄), 348 (M).

5

D. (E)- α -(Diethoxyphosphinyl)-10,14-dimethyl-9,13-pentadecadiene-1-sulfonic acid, cyclohexyl ester

To a stirred suspension of 191 mg (4.77 mmol, 2 eq.) of sodium hydride (as a 60% mineral oil dispersion) in 2 mL of dry dimethylformamide (DMF) at 0 °C was added a solution of 1.50 g (4.77 mmol, 2 eq.) of Example 1A Part B sulfonate in 3 mL of DMF dropwise over 7 min. The solution was warmed to RT and stirred for 50 min. To the resulting clear yellow solution was added a solution of 831 mg (2.39 mmol, 1 eq.) of Part C iodide in 3 mL of dry DMF dropwise over 5 min. The reaction was stirred at RT for 16 h diluted with ether (100 mL) and washed with water (50 mL). The aqueous layer was extracted with ether (2 x 20 mL) and the combined organic layers were washed with brine, dried (MgSO₄), and concentrated to afford 1.77 g of a yellow oil. Flash chromatography was performed on 300 g of silica gel eluting with 30% ethyl acetate in hexanes. Fractions (40 mL each) containing clean product by TLC were pooled and concentrated to afford, after high vac (0.25 mmHg) removal of solvent remnants, 782 mg (61%) of title compound as a clear yellow oil.

TLC Silica gel (10% ether in CH₂Cl₂): R_f 0.50.

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E. (E)-10,14-Dimethyl-1-phosphono-9,13-pentadecadiene-1-sulfonic acid, dipotassium salt

To a solution of 515 mg (0.96 mol, 1 eq.) of Part D compound in 10 mL of methanol at 0°C was bubbled ammonia until the solution was saturated. The reaction tube was then sealed and heated at 75 °C for 16 h. The reaction mixture was allowed to cool to RT and then concentrated. The oily residue was dried by coevaporation with toluene (2x). High vac (0.25 mmHg) removal of solvent remnants afforded 480 mg of light yellow oil.

To a solution of the yellow oil in 4 mL of dry dichloromethane at RT was added 636 µL (4.81 mmol, 5 eq.) of 2,4,6-collidine all at once. To the resulting clear light yellow solution was added 890 µL (6.74 mmol, 7 eq.) of bromotrimethylsilane (TMSBr) dropwise over 3 min. As the TMSBr was added a white precipitate formed and upon completion of TMSBr addition, 1 mL of dichloromethane was added to the thick reaction mixture to facilitate stirring. After 17 h at RT the reaction was concentrated and the resulting semisolid was placed on high vac (0.25 mm Hg) for 1 h. The residue was dissolved by adding 4.8 mL (5 eq.) of 1 M potassium hydroxide followed by 10 mL of water and lyophilized to afford an off-white lyophilate. The lyophilate was purified by MPLC on a column of CHP20P (2.5 cm x 25 cm) eluting initially with 150 mL of water followed by a gradient formed by the gradual addition of 400 mL of 30% acetonitrile in water to a reservoir containing 400 mL of 10% acetonitrile in water. Fractions containing clean product by HPLC (Method 8) were pooled and

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concentrated. The semisolid residue was taken up in water, filtered, concentrated and finally triturated with acetone to afford, after high vac (0.025 mm Hg) removal of acetone remnants, 207 mg (43%) of title salt in the form of a white solid.

TLC silica gel (5:4:1 n-propanol:ammonium hydroxide:water): R_f 0.39

10 IR (KBr) 3450(br), 2920, 2851, 1462, 1215, 1080, 1040 cm^{-1} .

MS (FAB, + ions) m/z 473 (M + H), 511 (M + K), 549 (M - H + K).

15

Anal. Calc'd for $\text{C}_{17}\text{H}_{31}\text{O}_6\text{PSK}_2 \cdot 1.4 \text{ H}_2\text{O}$:

C, 41.01; H, 6.84; S, 6.44; P, 6.22

Found: C, 41.19; H, 6.52; S, 6.30; P, 5.95

20

Example 13

(E,E)-6,10,14-Trimethyl-1-phosphono-5,9,13-pentadecatriene-1-sulfonic acid, phenyl ester, dipotassium salt

25

The title compound was prepared as described herein and has the following properties.

TLC Silica gel (7:2:1 n-propanol:ammonium hydroxide:water): R_f 0.38.

30

IR (KBr): 3410 (br), 2965, 2924, 1636, 1487, 1339, 1194, 1148, 1098 cm^{-1} .

MS (FAB, + ions): m/z 523

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(M - K + 2H)⁺, 561 (M + H)⁺, 599 (M + K)⁺.

Anal. Calc'd for C₂₄H₃₅O₆PSK₂ • 0.84 H₂O:

C, 50.05; H, 6.42; P, 5.38; S, 5.72

5 Found: C, 50.05; H, 6.74; P, 5.11; S, 5.45

Example 14

(E,E)-9,13,17-Trimethyl-1-phosphono-8,12,16-octadecatriene-1-sulfonic acid, tripotassium salt

10

The title compound was prepared as described herein and has the following properties.

TLC Silica gel (6:3:1 n-propanol/NH₄OH/H₂O):

15 R_f = 0.21

IR (KBr) 2924, 2855, 1624, 1449, 1383, 1213, 1148, 1092, 1044, 966, 714 cm⁻¹.

20 MS (FAB, + ions) m/z 527 (M+2H-K), 565 (M+H), 603 (M+K).

Anal. Calc'd for C₂₁H₃₆K₃O₆PS • 1.0 equiv H₂O:

C, 43.27; H, 6.57; P, 5.31; S, 5.50.

25 Found: C, 42.93; H, 6.93; P, 5.03; S, 5.87.

Example 15

(E,E)-1-(Ethoxyhydroxyphosphinyl)-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, dipotassium salt

30

To a solution of 0.44 g (0.80 mmol) of Example 1A Part C compound and 10 mL of methanol in a sealable tube at 0°C was added NH₃ (g) until the



solution was saturated. The tube was sealed and placed in an oil bath at 70°C for 24 h, at which point the tube was opened and the volatiles removed under reduced pressure. The remainder was

5 dissolved in dry ethanol and evaporated two times (2 X 10 mL) leaving an amber oil. The oil was dissolved in 4.0 mL of a 1:1 ethanol/water solution and treated with 0.45 g (8.00 mmol) of potassium hydroxide. The mixture was heated to 80°C for 72 h

10 when the solvent was evaporated and the residue pumped ($\approx$ 0.5 mm pressure) for 0.5 h. The remainder was purified by MPLC on a column of CHP20P gel (2.5 cm diam. X 20 cm height) eluting with water (150 mL) followed by a gradient created

15 by the gradual addition of 400 mL of acetonitrile to a reservoir of 350 mL of water. Approximately 7 mL fractions were collected. Pure fractions were combined and the acetonitrile was removed under reduced pressure. The aqueous solution was

20 lyophilized to provide 0.30 g (74%) of title salt as a white lyophilate.

TLC Silica gel (6:3:1 n-propanol/conc. ammonia/water) R_f =0.55.

25

IR (KBr) 3459, 3052, 2969, 2926, 2859, 1636, 1445, 1383, 1221, 1105, 1190, 1055, 1038, 945 cm^{-1} .

Mass Spec (FAB, + ions) m/e 551 (M+K), 513 (M+H).

30

Anal. Calc'd for $\text{C}_{20}\text{H}_{35}\text{O}_6\text{K}_2\text{PS}$:

C, 46.85; H, 6.88; P, 6.04; S, 6.25

Found: C, 46.76; H, 6.89; P, 5.67; S, 6.60.

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Example 16

(E)-8,12-Dimethyl-1-phosphono-7,11-tridecadiene-1-sulfonic acid, dipotassium salt

5 The title compound was prepared as described herein and has the following properties.

TLC silica gel (5:4:1 n-propanol:ammonium hydroxide:water): R_f 0.39

10

IR (KBr): 3450(br), 2924, 2855, 1653, 1447, 1209, 1148, 1044 cm^{-1} .

MS (FAB, + ions): m/z 445 (M + H), 483 (M + K),
15 521 (M - H + 2K) .

Anal. Calc'd for $\text{C}_{15}\text{H}_{27}\text{O}_6\text{PSK}_2 \cdot 3.2 \text{ H}_2\text{O}$:

C, 35.87; H, 6.70; S, 6.38; P, 6.17

Found: C, 35.91; H, 6.30; S, 6.11; P, 6.10

20

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Example 17

α -Phosphono[1,1'-biphenyl]-4-heptanesulfonic acid,
tripotassium salt

5 A. 4-(6-Iodohexyl)[1,1'-biphenyl]

A(1). 6-([1,1'-Biphenyl]-4-yl)-6-
hexyn-1-ol

To suspension of 0.361 g (2.04 mmol, 0.02
10 eq) of palladium chloride and 1.07 g (4.08 mmol,
0.04 eq) of triphenylphosphine in 300 mL of
diethylamine at room temperature was added 26.1 g
(112 mmol, 1.1 eq) of 4-bromobiphenyl (from
Aldrich) followed by 0.766 g (4.08 mmol, 0.04 eq)
15 of copper (I) iodide (99.999% pure, from Aldrich).
After 5 min, 10.0 g (102 mmol, 1.0 eq) of 5-hexyn-
1-ol (from Aldrich) was added neat. After 43 h,
the reaction was concentrated and the residue was
partitioned between water (250 mL) and CH₂Cl₂ (250
20 mL). The aqueous solution was extracted with CH₂Cl₂
and the combined organic solutions were
concentrated. To remove the catalyst the residue
was filtered through silica gel (40 g) eluting
initially with CH₂Cl₂, then with CH₂Cl₂ containing 2%
25 EtOAc. Concentration afforded 31.9 g of a brownish
orange solid which was chromatographed on silica
gel (400 g) eluting with 2% EtOAc in CH₂Cl₂ (4 L),
then 4% EtOAc in CH₂Cl₂ (2 L). The isolated solid
was then recrystallized from chloroform/hexanes to
30 afford 16.2 g (64%) of the title compound as a
white solid; m.p. 64.0-64.5°C.

TLC Silica gel (25% EtOAc in hexanes): R_f 0.14.

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A(2). [1,1'-Biphenyl]-4-hexanol

To a solution of 9.0 g (36 mmol, 1 eq) of Part A(1) alcohol in 100 mL of THF was added 300 mg (0.36 mmol, 0.01 eq) of 10% palladium on activated
5 carbon. The resulting heterogeneous mixture was placed under an H₂ atmosphere at RT. After 67 h, the reaction was filtered through Celite and the filter cake was washed with Et₂O and CH₂Cl₂.
Concentration afforded 9.07 g (99%) of the title
10 compound as a fluffy white solid; m.p. 77.0-77.5°C

TLC Silica gel (25% EtOAc in hexanes): R_f 0.19.

A(3). 4-(6-Iodohexyl) [1,1'-biphenyl]

15 To a solution of 7.00 g (28 mmol, 1.0 eq) of Part A(2) biphenylhexanol in 30 mL of dry THF were added 8.66 g (33 mmol, 1.2 eq) of triphenylphosphine and 4.50 g (66 mmol, 2.4 eq) of imidazole. To the resulting homogeneous solution
20 was added dropwise a solution of 8.38 g (33 mmol, 2.4 eq) of iodine in 40 mL of dry THF over 25 min. After 45 min, the reaction was diluted with Et₂O and washed with 10% aqueous sodium bisulfite, brine and dried (MgSO₄). The solution was filtered and
25 the volume was reduced approximately by 50%. Silica gel (35 g) was added and the remainder of the solvent was removed. The product adsorbed onto silica gel was loaded onto a pre-equilibrated column (hexanes) of silica gel (20 g) and eluted
30 with hexanes. Fractions containing clean product were pooled and concentrated to afford 9.40 g (94%) of the title compound as a clear, colorless oil.

TLC Silica gel (25% EtOAc in hexanes): R_f 0.69.

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B. Methanesulfonic acid, phenyl ester

To a solution of 40.0 g (0.42 mol, 1 eq.) of phenol in 250 mL of dichloromethane at 0°C was
5 added 250 mL (1.8 mol, 4.2 eq.) of triethylamine.
After 5 min, 49.3 mL (0.64 mol, 1.5 eq.) of methanesulfonyl chloride was added dropwise over 20 min. The resulting cloudy yellow solution was warmed to RT and stirred for 14 h. The reaction
10 was partitioned between ether (250 mL) and water (100 mL) and the resulting organic layer was washed with cold 6 N hydrochloric acid (2 x 200 mL). The combined aqueous layers were extracted with ether (2 x 50 mL) and the combined organic layers were
15 washed with water (100 mL), saturated sodium bicarbonate (200 mL), brine (200 mL), dried (MgSO₄) and concentrated. Recrystallization of the orange solid from isopropanol afforded 44.94 g (61%) of the title compound as light yellow crystals; mp
20 58.0-58.5°C.

TLC Silica gel (25% ethyl acetate in hexanes):
R_f 0.29.

25 C. (Diethoxyphosphinyl)methanesulfonic acid, phenyl ester

To a turbid solution of 174 mL (0.174 mol, 1 eq.) of potassium bis(trimethylsilyl)amide (20% by weight in tetrahydrofuran (THF) from Callory Chem.)
30 at -88°C (internal temperature) was added a solution of 30.0 g (0.174 mol, 1 eq.) of Part B compound in 75 mL of dry THF at a rate to keep the internal temperature below -85°C (addition took 20 min). The reaction was stirred for 5 min at -85 °C

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then 15.2 mL (104 mmol, 0.6 eq.) of freshly distilled diethylchlorophosphate was added dropwise at a rate that kept the temperature below -72°C (addition took 13 min). After stirring at -65°C for 1h, the reaction was quenched at -65°C by the addition of a solution of 9.97 mL (0.174 mol, 1 eq.) of acetic acid in 25 mL of THF over 5 min. The resulting solution was warmed to RT and the majority of the solvent was removed in vacuo. The residue was partitioned between dichloromethane (300 mL) and water (100 mL). The aqueous layer was extracted with dichloromethane (2 x 20 mL) and the combined organic layers were dried (MgSO₄) and concentrated to afford 43.82 g of solid/liquid mixture. The product was isolated by flash chromatography on silica gel (1000 g) eluting with 7 : 3 ethyl acetate : hexanes. Fractions (40 mL each) containing clean product by TLC were pooled to afford 17.19 g (54%) of title compound as a white solid; m.p. 50.5-51.5°C.

TLC Silica gel (10% ether in dichloromethane):
R_f 0.38.

25 D. α -(Diethoxyphosphinyl)[1,1'-biphenyl-4-heptanesulfonic acid, phenyl ester

To a stirred suspension of 329 mg (8.23 mmol, 2 eq.) of sodium hydride (as a 60% mineral oil dispersion) in 3 mL of dry dimethylformamide (DMF) at 0°C was added a solution of 2.54 g (8.23 mmol, 2 eq.) of Part C compound in 6 mL of DMF dropwise over 10 min. The solution was warmed to RT and stirred for 30 min. To the resulting clear yellow solution was added a solution of 1.50 g

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(4.12 mmol, 1 eq.) of Part A iodide in 6 mL of dry DMF dropwise over 5 min. The reaction was stirred at RT for 43 h, diluted with ether (200 mL) and washed with water (100 mL). The aqueous layer was
5 extracted with ether (2 x 25 mL) and the combined organic layers were washed with brine, dried (MgSO₄), and concentrated to afford 3.36 g of a yellow oil. Flash chromatography was performed on 400 g of silica gel eluting with 40% ethyl acetate
10 in hexanes. Fractions (40 mL each) containing clean product by TLC were pooled and concentrated to afford, after high vac (0.25 mmHg) removal of solvent remnants, 1.06 g of a clear yellow oil, as well as 742 mg of the desired product contaminated
15 with dialkylated material. The contaminated material was rechromatographed on 200 g of silica gel and the clean product was combined with the previously isolated product to afford 1.375 g (61%) of title compound as a clear light yellow oil.
20
TLC Silica gel (10% ether in CH₂Cl₂): R_f 0.57.

E. α -Phosphono[1,1'-biphenyl]-4-heptane-sulfonic acid, tripotassium salt

25 To a solution of 600 mg (1.1 mmol, 1 eq.) of Part D compound in 5 mL of dioxane at RT was added 1.1 mL (1.1 mmol, 1 eq.) of 1 M potassium hydroxide. The initially turbid solution became homogeneous within 2 h. After 19 h, starting
30 material was still evident by TLC as well as a lower R_f spot (presumably due to over hydrolysis). An additional 1.1 mL (1.1 mmol, 1 eq.) of KOH was added and reaction was stirred for 16 h (35 h total) at RT. The reaction mixture was

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concentrated and the residual yellow oil was co-evaporated with toluene (4x) to remove water and placed on high vac (0.25 mmHg) for 2 h to afford a yellow solid.

- 5 To a heterogeneous solution of the yellow solid in 5 mL of dry dichloromethane at RT was added 1.45 mL (11.0 mmol, 10 eq.) of bromotrimethylsilane (TMSBr) dropwise over 3 min. As the TMSBr was added the solution began to clear and
- 10 upon completion of TMSBr addition the reaction was nearly homogeneous. After 17 h, an additional 750 μ L (5.7 mmol, 5.1 eq.) of TMSBr was added to complete consumption of the intermediate monoester. After 22 h (39 h total) at RT, the reaction was
- 15 concentrated and the resulting oil was placed on high vac (0.25 mm Hg) for 13 h. The residue was dissolved by adding 4.4 mL (4.4 mmol, 4 eq.) of 1 M potassium hydroxide followed by 20 mL of water and sonicating at 40°C for 10 min. The crude product
- 20 was purified by MPLC on a column of CHP20P (2.5 cm x 25 cm) eluting initially with 150 mL of water followed by a gradient formed by the gradual addition of 400 mL of acetonitrile in water to a reservoir containing 400 mL of water. Fractions
- 25 containing clean product were pooled and concentrated. The semisolid residue was taken up in water, filtered and lyophilized to afford 243 mg (39%) of a white lyophilate.
- 30 TLC silica gel (5:4:1 n-propanol: ammonium hydroxide:water): R_f 0.38.

IR (KBr): 3403(br), 2928, 2857, 1651, 1202, 1163, 1072 cm^{-1} .

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MS (FAB): m/z 489 (M - K + 2H)⁺, 527 (M + H)⁺.

Anal. Calcd for C₁₉H₂₂O₆PSK₃ • 2.31 H₂O:

5 C, 40.15; H, 4.72; S, 5.64; P, 5.45

Found: C, 40.15; H, 4.89; S, 5.60; P, 5.47

Example 18

10 (E)-4-(4'-Pentyl[1,1'-biphenyl]-4-yl)-1-phosphono-
3-butene-1-sulfonic acid, tripotassium salt

The title compound was prepared as described herein and has the following properties.

15 IR (KBr pellet) 3430, 2928, 2855, 1636, 1497,
1202, 1078, 968 cm⁻¹.

Anal. Calc'd for C₂₁H₂₄K₃O₆PS•2.2 H₂O:

C, 42.58; H, 4.83; P, 5.23; S, 5.41

20 Found: C, 42.18; H, 5.19; P, 5.63; S, 5.42.

MS (FAB, + ions) m/e 591 (M+K), 553 (M+H), 515
(M-K+2H).

25 Example 19

α-Phosphono-4'-Pentyl[1,1'-biphenyl]-4-butaneful-
sonic acid, tripotassium salt

30 The title compound was prepared as described herein and has the following properties.

IR (KBr pellet) 3424, 3088, 2928, 2859, 1663,
1499, 1202, 1082, 1049, 966 cm⁻¹.

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Anal. Calc'd for $C_{21}H_{26}K_3O_6PS \cdot 1.42 H_2O$:

C, 43.46; H, 5.01; P, 5.34; S, 5.52

Found: C, 43.46; H, 4.93; P, 5.37; S, 5.25.

5 MS (FAB, + ions) m/e 593 (M+K), 555 (M+H), 517 (M-K+2H).

Example 20

4-(2-Naphthalenyl)- α -phosphonobenzenebutanesul-
10 fonic acid, tripotassium salt

A. 2-(4-Bromophenyl)naphthalene

To a stirred solution of 4.14 g (20.0 mmol) of 2-bromonaphthalene in 50 mL of THF at -78°C
15 under nitrogen was added a solution of 23.5 mL (40.0 mmol, 1.7 M in pentane) of t-butyllithium over 10 minutes. The resulting slurry was stirred for 30 minutes and then warmed to 0°C for 15 minutes. To this deep indigo solution was added a
20 solution of 3.50 g (25.6 mmol) of thrice-fused zinc chloride in 25 mL of THF. The resulting light yellow solution was warmed to room temperature and stirred for 1 hour. After cooling to -78°C , a solution of 5.66 g (20.0 mmol) 1-bromo-4-
25 iodobenzene and 300 mg (0.26 mmol) of tetrakis-(triphenylphosphine)palladium in 20 mL of THF was added over the course of 15 minutes. After an additional 20 min, the cooling bath was removed, the reaction stirred at room temperature for 16
30 hours and then quenched with 50 mL of 2 M hydrochloric acid. The mixture was extracted thrice with ether, the extracts combined, washed once with saturated sodium bicarbonate solution and once with 10% sodium thiosulfate. The organic



extract was dried (MgSO₄) and evaporated. The crude product was purified by flash chromatography on silica gel (5 x 25 cm column, hexanes as eluent) to give 4.05 g (72%) of title compound as a white solid, mp 121-123°C.

B. α -Ethenyl-4-(2-naphthalenyl)benzene-methanol, acetate ester

To a stirred solution of 2.59 g (9.13 mmol) of Part A compound in 20 mL of THF at -78 °C under nitrogen was added a solution of 10.8 mL (18.4 mmol, 1.7 M in pentane) of *t*-butyllithium over 20 minutes. The resulting magenta slurry was warmed to 0°C and stirred for 1 h. To the resulting solution was added 0.8 mL (14 mmol) of freshly distilled acrolein over 5 min. The resulting light yellow solution was stirred for 1 hour and then quenched with saturated ammonium chloride. The mixture was extracted twice with ether, dried (MgSO₄) and evaporated to give a white solid.

The solid was dissolved in 50 mL of dichloromethane, stirred under nitrogen at room temperature and treated with 2.0 mL (14.4 mmol) of triethylamine, 1.23 mL (13 mmol) of acetic anhydride and 50 mg (0.4 mmol) of DMAP. After 16 h, the reaction mixture was evaporated, redissolved in ether and washed once with 10% citric acid solution, once with brine and once with saturated sodium bicarbonate solution. The organic phase was dried (MgSO₄) and evaporated. The crude product was purified by flash chromatography on silica gel (5 x 20 cm column, 1:1 dichloromethane/hexanes as eluent) to give 1.83 g (66% from Part A compound) of title compound as a white solid, mp 61-63°C.



C. (E)-1-(Diethoxyphosphinyl)-4-[4-(2-naphthalenyl)phenyl]-3-butene-1-sulfonic acid, 1-methylethyl ester

5 To a stirred solution of 1.55 g (5.13 mmol) of Part B compound, 2.75 mL (12.9 mmol, 2.5 equivalents) of bis(trimethylsilyl)acetamide, 2.81 g (10.2 mmol, 2.0 equivalents) of Example 11, Part A sulfonate and 125 mg (0.48 mmol) of triphenyl-
10 phosphine in 10 mL of THF under nitrogen was added 270 mg (0.24 mmol) of tetrakis(triphenylphosphine)-palladium. The resulting mixture was heated to 45°C for 2 h. The reaction was cooled and evaporated and pumped at room temperature @ 0.2
15 Torr for 24 hours. The residue was diluted with dichloromethane and evaporated onto 5 g of silica gel. Purification by flash chromatography on silica gel (5 x 20 cm column) eluted with 1:16 ether/dichloromethane gave title compound as a
20 yellow oil, 950 mg, 36% yield.

D. α -(Diethoxyphosphinyl)-4-(2-naphthalenyl)benzenebutanesulfonic acid, 1-methylethyl ester

25 To a nitrogen-purged solution of 950 mg (1.85 mmol) of Part C compound and 350 mg of 10% Pd/C in 25 mL of ethyl acetate in a 200 mL one-neck round bottom flask was attached a hydrogen-filled rubber bladder of approximately 1 L capacity. The
30 reaction mixture was vigorously stirred for 16 h, purged with nitrogen, filtered through Celite and the filtrate evaporated. The oily residue was redissolved in dichloromethane, filtered through a 0.75 m filter and re-evaporated to give title

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compound as a colorless oil, 960 mg, 100% yield.
The product was used without further purification.

5 E. 4-(2-Naphthalenyl)- α -phosphonobenzene-
 butanesulfonic acid, tripotassium salt

To a stirred solution of 950 mg (1.81 mmol)
of Part D compound in 10 mL of dichloromethane
under nitrogen at room temperature was added 1.4 mL
(10.5 mmol) of bromotrimethylsilane. After 24 h,
10 the resulting clear solution was evaporated at 25°C
and the residue dissolved in 10 mL of THF. To this
stirred solution was added 0.5 g (3 mmol) of dried,
finely ground potassium iodide and 6 mg (0.02 mmol)
of 18-crown-6. The resulting slurry was heated to
15 reflux for 20 h, evaporated and then stirred for 1
h with 12 mL (6 mmol) of 0.5 M potassium hydroxide
solution. The solution was lyophilized and then
purified by MPLC (2.5x20 cm column of CHP20P
resin): 11.5 mL fractions, 7 mL/min flow rate,
20 eluted with 200 mL of water and then a gradient
prepared from 400 mL of water and 450 mL of 2:1
acetonitrile/water). Fractions 66-72 were collected
and lyophilized to give title salt as a white
solid, 560 mg, 55% yield.

25

IR (KBr pellet) 3418, 3055, 2934, 2864, 1661,
1503, 1339, 1196, 1078, 966 cm⁻¹.

MS (FAB, + ions) m/e 573 (M+K), 535 (M+H), 497
30 (M-K+2H).

Anal. Calc'd for C₂₀H₁₈K₃PSO₆·1.3H₂O:

C, 43.04; H, 3.72; P, 5.55; S, 5.74

Found: C, 43.04; H, 3.86; P, 5.79; S, 6.09.

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Example 21

4-Phenoxy- α -phosphonobenzenebutanesulfonic acid,
tripotassium salt

5

The title compound was prepared as
described herein and has the following properties.

TLC (silica gel) (6:3:1 *n*-propanol/NH₄OH/H₂O):

10 $R_f = 0.15$

IR (KBr) 3042, 2936, 2864, 1663, 1589, 1507, 1489,
1240, 1198, 1076, 966 cm^{-1} .

15

MS (FAB, + ions) m/z 463 ($M+2H-K$), 501 ($M+H$), 539
($M+K$).

Anal. Calc'd for C₁₆H₁₆K₃O₇PS · 1.0 equiv H₂O:

C, 37.05; H, 3.50; P, 5.97; S, 6.18.

20

Found: C, 36.77; H, 3.86; P, 6.42; S, 6.48.

Example 22

1-Phosphono-7-(4-propylphenoxy)-1-heptanesulfonic
acid, tripotassium salt

25

The title compound was prepared as
described herein and has the following properties.

TLC (silica gel) (6:3:1 *n*-propanol/NH₄OH/H₂O):

30 $R_f = 0.21$

IR (KBr) 2932, 2868, 1636, 1512, 1200, 1074,
966 cm^{-1} .



MS (FAB, + ions) m/z 509 (M+H), 547 (M+K).

Anal. Calc'd for $C_{16}H_{24}K_3O_7PS \cdot 1.6 \text{ equiv } H_2O$:

C, 35.75; H, 5.10; P, 5.76; S, 5.97.

5 Found: C, 35.79; H, 5.49; P, 5.54; S, 5.95.

Example 23

α -Phosphono-4-(4-propylphenoxy)benzenebutanesul-
fonic acid, tripotassium salt

10

A. 4-(4-Propylphenoxy)benzaldehyde

Anhydrous potassium carbonate (14.9 g, 0.12 mol) was added to a mixture of 4-propylphenol (13.6 g, 0.10 mol) and 4-fluorobenzaldehyde (12.4 g, 0.10 mol) in *N,N*-dimethylacetamide (100 mL) under argon. The heterogeneous mixture was brought to reflux, maintained at that temperature for 5 h, then cooled to RT. Water (100 mL) and CH_2Cl_2 (100 mL) were added, resulting in a tri-phase system. The bottom layer was removed; the middle layer was dried over $MgSO_4$; and, the top layer was extracted with CH_2Cl_2 (100 mL) and dried over $MgSO_4$. The dried layers were combined and concentrated in vacuo at 50 °C to give an orange oil. The crude product was purified by distillation to give title compound (16.6 g, 69%) as a colorless oil. bp 133-150°C (0.2 mm Hg)

15

20

25

30

B. α -Ethenyl-4-(4-propylphenoxy)benzene-
methanol, acetate ester

A solution of Part A compound (2.00 g, 8.33 mmol) in THF (15 mL) was added dropwise over 10 min to a solution of vinylmagnesium bromide (9.2 mL, 1.0M in THF, 9.2 mmol) in THF (15 mL) at -40°C.



under argon. The reaction was warmed to -20°C over 30 min, whereupon the heterogeneous mixture went to clear yellow. Additional vinylmagnesium bromide (1.5 mL, 1.0M in THF, 1.5 mmol) was added dropwise.
5 The reaction was stirred at -20°C for 10 min, then quenched by addition of saturated NH_4Cl (10 mL). The solvent was removed in vacuo, and the mixture was diluted with diethyl ether (50 mL). The organic layer was washed with water (10 mL), 1N HCl
10 (10 mL), and brine (20 mL), then dried over MgSO_4 . Evaporation gave the alcohol (2.6 g) as a yellow oil.

Acetic anhydride (0.94 mL, 10.0 mmol), triethylamine (2.3 mL, 16.7 mmol), and 4-dimethyl-
15 aminopyridine (10 mg, 0.08 mmol) were added to a solution of the crude alcohol in CH_2Cl_2 (30 mL) under argon. The yellow reaction was stirred at RT for 2.5 h, diluted with CH_2Cl_2 (50 mL), and washed with water and brine (20 mL each), then dried over
20 MgSO_4 . Evaporation gave a heterogeneous yellow oil, which was purified by flash chromatography on silica gel (150 g) eluted with 3:97 EtOAc/hexane to give title compound (1.85 g, 72%) as a pale yellow oil.

25

C. (E)-1-(Diethoxyphosphinyl)-4-[4-(4-propylphenoxy)phenyl]-3-butene-1-sulfonic
acid, 1-methylethyl ester

Tetrakis(triphenylphosphine)palladium (196
30 mg, 0.17 mmol) was added to a mixture of Part B compound (1.74 g, 5.61 mmol), Example 11, Part A compound (3.07 g, 11.2 mmol), bis(trimethylsilyl)-acetamide (2.8 mL, 11 mmol), and triphenylphosphine (73 mg, 0.28 mmol) in THF (20 mL). The reaction

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was heated at 45°C for 3 h, cooled to RT, and concentrated in vacuo to give a yellow oil. The crude product was purified by flash chromatography on silica gel (200 g) eluted with a step gradient of 30:70 EtOAc/hexane to 40:60 EtOAc/hexane to afford title compound (706 mg, 24%) as a colorless oil.

10 D. 1-(Diethoxyphosphinyl)-4-(4-propylphenoxy)benzenebutanesulfonic acid, 1-methylethyl ester

A mixture of Part C compound (700 mg, 1.34 mmol) and 10% palladium on carbon (40 mg) in EtOAc (5 mL) was stirred at RT under an atmosphere of H₂ (balloon) overnight, then was filtered through a pad of Celite with the aid of CH₂Cl₂. Evaporation gave title compound (669 mg, 95%) as a colorless oil.

20 E. α -Phosphono-4-(4-propylphenoxy)benzenebutanesulfonic acid, tripotassium salt

Ammonia gas was bubbled through a solution of Part D compound (610 mg, 1.16 mmol) in methanol (10 mL) for 10 min at RT. During the saturation, the solution turned yellow and became slightly exothermic. The reaction mixture was heated at 75°C in a sealed tube overnight (20 h), then cooled to RT. The reaction was concentrated in vacuo, and the residue was azeotroped with toluene (2 x 10 mL) to give a pale yellow oil.

The crude product prepared above was dissolved in CH₂Cl₂ (6 mL) under argon and bromotrimethylsilane (1.1 mL, 8.1 mmol) was added dropwise. The cloudy yellow reaction was stirred

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at RT overnight (19 h), concentrated in vacuo, and pumped at high vacuum for 3 h.

The crude residue prepared above was dissolved in 1N KOH (5.8 mL, 5.8 mmol) and stirred at RT for 15 min, diluted with water (5 mL), then lyophilized to give a white solid. Purification was performed by chromatography on CHP20P gel (2.5 x 20 cm column) eluted with water followed by a gradient created by the gradual addition of acetonitrile to a reservoir of water. The product fractions were concentrated to approximately a 5 mL volume, then lyophilized to provide title salt (445 mg, 71%) as a white solid.

TLC (silica gel) (6:3:1 n-propanol/NH₄OH/H₂O):
R_f = 0.18

IR (KBr) 2959, 2870, 1503, 1240, 1200, 1078, 966 cm⁻¹.

MS (FAB, + ions) m/z 543 (M+H), 581 (M+K).

Anal. Calc'd for C₁₉H₂₂K₃O₇PS · 2.0 equiv H₂O:
C, 39.43; H, 4.53; P, 5.35; S, 5.54.

Found: C, 39.63; H, 4.70; P, 5.18; S, 5.50.

Example 24

(E,E)-1-(Diethoxyphosphinyl)-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, sodium salt

To a solution of 0.50 g (0.91 mmol) of Example 1A Part C compound and 10 mL of methanol in a sealable tube at 0°C was added NH₃ (g) until the solution was saturated. The tube was sealed and

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placed in an oil bath at 70°C for 24 h, at which point the tube was opened and the volatiles removed under reduced pressure. The remainder was dissolved with 1.20 mL (1.20 mmol) of 1 N sodium hydroxide solution. The compound was purified by MPLC by loading the basic solution on a column of CHP20P gel (2.5 cm diam. X 20 cm height) and eluting with water (150 mL) followed by a gradient created by the gradual addition of 400 mL of acetonitrile to a reservoir of 350 mL of water. Approximately 7 mL fractions were collected. Pure fractions (#30-34) were combined and the acetonitrile was removed under reduced pressure. The aqueous solution was lyophilized to provide 0.39 g (87%) of title salt as an amber oil.

TLC Silica gel (6:3:1 n-propanol/conc. ammonia/water) $R_f=0.80$.

IR (CHCl₃) 3459, 2969, 2926, 2859, 1647, 1445, 1236, 1165, 1098, 1069, 1034, 970 cm⁻¹.

Mass Spec (FAB, + ions) m/e 509 (M+Na).

Anal. Calc'd for C₂₂H₄₀O₆NaPS-0.73 H₂O:
C, 53.91; H, 8.31; P, 6.32; S, 6.54
Found: C, 53.91; H, 8.23; P, 6.17; S, 6.33.

Example 25

(E)-6-Methyl-10-phenyl-1-phosphono-5-decene-1-sulfonic acid, tripotassium salt

The title compound was prepared as described herein and has the following properties.



IR (KBr) 3424, 2932, 2857, 1653, 1200, 1080,
966 cm^{-1} .

5 MS (Ion Spray, + ions) 429 (M-2K+3H), 467
(M-K+2H), 505 (M+H).

Anal. Calc'd. for $\text{C}_{17}\text{H}_{24}\text{K}_3\text{PO}_6\text{S} \cdot 2.1 \text{ H}_2\text{O}$:

C, 37.64; H, 5.24; P, 5.71; S, 5.91

10 Found: C, 37.64; H, 5.19; P, 5.34; S, 6.09

Example 26

4-(3-Phenylpropyl)- α -phosphonobenzenebutanesulfonic
acid, tripotassium salt

15

The title compound was prepared as
described herein and has the following properties.

IR (KBr pellet) 3428, 3084, 2934, 2859, 1659,
20 1514, 1196, 1107, 1084, 966 cm^{-1} .

Anal. Calc'd for $\text{C}_{20}\text{H}_{18}\text{K}_3\text{O}_6\text{PS} \cdot 1.1 \text{ H}_2\text{O}$:

C, 41.77; H, 4.46; P, 5.67; S, 5.87

Found: C, 41.77; H, 4.68; P, 5.46; S, 6.08.

25

MS (FAB, + ions) m/e 565 (M+K), 527 (M+H), 489
(M-K+2H).

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Example 27

(E,E)-1-(Hydroxymethylphosphinyl)-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid,
dipotassium salt

5

The title compound was prepared as described herein and has the following properties.

10 TLC Silica gel (7:2:1 n-propanol:ammonium hydroxide:water): R_f 0.47.

IR (KBr) 2922, 2857, 1213, 1188, 1088, 1034 cm^{-1} .

15 MS (FAB, + ions) m/z 483 (M+H), 445 (M+2H-K), 407 (M+3H-2K).

Anal. Calcd. for $\text{C}_{19}\text{H}_{33}\text{O}_5\text{PSK}_2$:

C, 47.28; H, 6.89; P, 6.42; S, 6.64

Found: C, 47.30; H, 6.92; P, 6.04; S, 6.94

20

Example 28

(E,E)-1-(Hydroxyphosphinyl)-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, dipotassium
salt

25

A. (E,E)-6,10,14-Trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, ethyl ester

30 *n*-Butyllithium (11.1 mL, 2.5 M in hexanes, 27.8 mmol) was added dropwise over 15 min to a solution of ethyl methanesulfonate (5.17 g, 41.7 mmol) in THF (50 mL) at -78°C under argon. The clear colorless reaction mixture was stirred at -78°C for 20 min, whereupon a solution of Example 1 Part C iodide (5.00 g, 13.9 mmol) in THF (10 mL)



was added dropwise over 10 min. The reaction was warmed to -60°C (internal temperature) and stirred at that temperature for 1.5 h. The reaction was then warmed to -20°C over 2 h, then quenched by
5 addition of saturated NH_4Cl (20 mL). Diethyl ether (300 mL) was added, and the organic layer was washed with water (2 x 50 mL) and brine (10 mL), then dried over MgSO_4 . Evaporation gave a yellow
10 oil, which was purified by flash chromatography on silica gel (200 g) eluting with a step gradient of 5:95 to 8:92 EtOAc/hexane to provide title compound (3.61 g, 73%) as a colorless oil.

B. (E,E)-1-(Ethoxyphosphinyl)-6,10,14-
15 trimethyl-5,9,13-pentadecatriene-1-
sulfonic acid, ethyl ester

n-Butyllithium (2.7 mL, 2.5 M in hexanes, 6.7 mmol) was added dropwise to a solution of Part A compound (2.00 g, 5.62 mmol) in THF (15 mL) at
20 -78°C under argon. The yellow reaction was stirred at -78°C for 30 min, whereupon diethyl chlorophosphite (2.4 mL, 16.9 mmol) was added rapidly in one portion. The colorless reaction was stirred at -78°C for 1 h, then allowed to warm to RT over 2.5
25 h. The reaction was diluted with anhydrous diethyl ether (50 mL). Water (10 mL) was then added, and the resultant biphasic mixture was stirred vigorously at RT for 1 h. The aqueous layer was removed, and the organic layer was washed with
30 water (10 mL) and brine (15 mL), then dried over MgSO_4 . Evaporation gave a colorless oil, which was purified by flash chromatography on CC7 buffered silica gel (250 g) eluting with a step gradient of 25:75 to 35:65 to 45:55 EtOAc/hexane to give title

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compound (2.07 g, 82%) as a colorless oil as a 1:1 mixture of diastereomers.

5 C. (E,E)-1-(Hydroxyphosphinyl)-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, dipotassium salt

Potassium iodide (317 mg, 1.91 mmol) was added to a solution of Part B compound (816 mg, 1.82 mmol) in acetone (10 mL) under argon. As the
10 mostly insoluble potassium iodide reacted, the product precipitated out of the reaction mixture. The white heterogeneous reaction was stirred at RT overnight, concentrated in vacuo, then pumped at high vacuum to give a white solid.

15 The crude sulfonate salt was dissolved in 1N KOH (3.6 mL, 3.6 mmol), then chromatographed on CHP-20P gel (2.5 x 20 cm column) eluting with water followed by a gradient created by the gradual addition of acetonitrile to a reservoir of water.
20 The product fractions were concentrated in vacuo to give an opaque white gum. Acetone (2 mL) was added and the product was precipitated out as a solid. The solid was filtered, washed with acetone (2 x 5 mL), then pumped at high vacuum to give title salt
25 (507 mg, 60%) as a white solid.

TLC (silica gel) (7:2:1 n-propanol/NH₄OH/H₂O):

R_f = 0.43

30 IR (KBr) 2928, 2857, 2288, 1202, 1094 cm⁻¹.

MS (ES, + ions) m/z 393 (M+3H-2K), 410 [(M+2H-2K)+NH₄], 427 [(M+2H-2K)+NH₃+NH₄],
431 (M+2H-K), 448 [(M+2H-K)+NH₃], 469 (M+H).

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Anal. Calc'd for $C_{18}H_{31}K_2O_5PS$:

C, 46.13; H, 6.67; P, 6.61; S, 6.84.

Found: C, 46.18; H, 6.68; P, 6.28; S, 7.17.

5

Example 29

4-(Phenylmethyl)- α -phosphonobenzenebutanesulfonic acid, tripotassium salt

10

The title compound was prepared as described herein and has the following properties.

IR (KBr pellet) 3426, 3063, 2934, 2864, 1636, 1198, 1074, 966 cm^{-1} .

15

MS (FAB, + ions) m/e 536 (M+K), 499 (M+H), 461 (M-K+2H).

Anal. Calc'd for $C_{17}H_{18}K_3PSO_6 \cdot 1.1H_2O$:

20

C, 39.33; H, 3.94; P, 5.97; S, 6.18

Found: C, 39.33; H, 4.06; P, 5.71; S, 5.89.

Example 30

25 (E,E)-1-[Hydroxy(methoxymethyl)phosphinyl]-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, dipotassium salt

A. (Methoxymethyl)phosphonic acid,
diethyl ester

30

To a sample of 17.90 mL (0.104 mol) of triethylphosphite at $-78^{\circ}C$ under argon was added dropwise 8.50 mL (0.104 mol) of bromomethyl methyl ether. The mixture slowly warmed to RT and stirred for 24 h, when it was fractionally distilled (bp



100°C, 5 mm) to provide 16.22 g (98%) of title compound as a pale yellow oil.

TLC Silica gel (Ethyl acetate) R_f =0.50.

5

B. Chloro(methoxymethyl)phosphinic acid, ethyl ester

To a solution of 5.0 g (27.6 mmol, 1 eq) of Part A compound in 5 mL of dry benzene at 0°C was
10 added 5.75 g (27.6 mmol, 1 eq) of phosphorus pentachloride as a solid in one portion. The resulting heterogeneous solution was stirred at 0°C for 5 min, then warmed to room temperature and stirred for 5 min. The resulting homogeneous
15 solution was heated at reflux for 1 h, cooled to room temperature and concentrated. The residue was co-evaporated twice with benzene followed by exposure to high vacuum (0.25 mmHg) for 1 h to afford 4.52 g (95%) of title compound as a yellow
20 liquid which was used in the next step without purification.

C. [Ethoxy(methoxymethyl)phosphinyl]-methanesulfonic acid, cyclohexyl ester

25 To a solution of 9.84 g (55.2 mmol, 2.1 eq) of Example 1A Part A mesylate compound in 200 mL of dry tetrahydrofuran (THF) at -75°C (internal temperature) was added dropwise via syringe 22.1 mL (55.2 mmol, 2.1 eq) of a 2.5 M n-butyllithium
30 solution in hexanes at a rate that kept the temperature below -71°C (over 40 min). The resulting solution was stirred for 5 min at -75°C. A solution of 4.52 g (26.2 mmol, 1 eq) of freshly prepared Part B compound in 20 mL of THF was added



dropwise at a rate to keep the temperature below -71°C (over 30 min) and the resulting light brown solution was stirred at -75°C for 1 h. The reaction was quenched by addition of a solution of
5 3.16 mL (55.2 mmol, 2.1 eq) of glacial acetic acid in 15 mL of THF over 5 min, then allowed to warm to room temperature. The solution was concentrated and the viscous residue was taken up in dichloromethane (250 mL), washed with water (100 mL), brine
10 (100 mL), dried (MgSO₄) and concentrated to afford 12.4 g of a light brown oil. The desired product was isolated by flash chromatography on silica gel (250 g) eluting with ethyl acetate. The fractions containing product by TLC were combined and
15 concentrated to afford a solid which was contaminated by an unknown impurity as evidenced by extraneous peaks in the ¹H NMR spectrum. The solid was recrystallized from hexanes/chloroform to afford 5.04 g (61%) of the title compound as a
20 white solid, m.p. 78.5-79.5°C.

TLC Silica gel (ethyl acetate) R_f 0.40.

25 D. (E,E)-1-[Ethoxy(methoxymethyl)phosphinyl]-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, cyclohexyl ester

To a suspension of 222 mg (5.6 mmol, 2 eq) of sodium hydride (as a 60% dispersion in mineral oil) in 1 mL of dry dimethylformamide (DMF) at 0°C
30 was added a solution of 1.74 g (5.6 mmol, 2 eq) of Part C compound in 4 mL of DMF dropwise over 10 min. The bubbling heterogeneous mixture was allowed to warm to room temperature and stir for 30 min. To the resulting homogeneous solution was

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added a solution of 1.0 g (2.8 mmol, 1 eq) of Example 1 Part C iodide in 3 mL of DMF. After 20 h, the reaction was diluted with brine (25 mL). The resulting cloudy solution was extracted with
5 ether (1 x 100 mL, 3 x 15 mL), dried (MgSO₄) and concentrated to afford 1.64 g of a yellow oil. The desired product was isolated by flash chromatography on silica gel (250 g) eluting with 40% ethyl acetate in hexanes. Fractions containing clean
10 product by TLC were pooled and concentrated to afford 801 mg (52%) of title compound as a viscous yellow oil.

TLC Silica gel (1:1 ethyl acetate:hexanes):
15 R_f 0.23.

E. (E,E)-1-[Hydroxy(methoxymethyl)phosphinyl]-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, dipotassium
20 salt

To a solution of 600 mg of Part D compound in 12 mL of dry methanol at 0°C was introduced ammonia until the solution was saturated. The tube was sealed with a threaded teflon cap fitted with
25 an O-ring and heated at 75°C for 16 h. The volatiles were removed in vacuo and the oily residue was co-evaporated twice with toluene before placing on high vac (0.25 mmHg) for three hours. To the resulting clear yellow oil was added 7 mL of
30 dry CH₂Cl₂ followed by 806 µL (6.1 mmol, 4.5 eq) of dry 2,4,6-collidine. To the resulting light yellow clear solution was added 1.25 mL (9.5 mmol, 7 eq) of bromotrimethylsilane (TMSBr) and the resulting white heterogeneous mixture was stirred at room



temperature. After 21 h, the reaction mixture was concentrated and placed on high vac (0.25 mmHg) for 30 min. The resulting yellow white solid was dissolved by adding 7.0 mL (7.0 mmol, 5.2 eq) of 1 M potassium hydroxide, and the resulting solution was frozen and lyophilized. The light brown lyophilate was dissolved in water and chromatographed on a column of CHP20P (2.5 cm x 25 cm) eluting initially with water (150 mL) followed a gradient formed by the gradual addition of a 63% solution of acetonitrile in water (400 mL) to a reservoir containing water (400 mL). No fractions (10 mL each) containing clean product by HPLC were obtained. The fractions containing approximately 2% of an impurity (which eluted just before the desired product) were pooled, concentrated and rechromatographed using a step gradient. After eluting with water (150 mL) the column was eluted with 15% acetonitrile in water (300 mL) followed by 20% acetonitrile in water (500 mL). Fractions containing pure product by HPLC were concentrated and the residual waxy residue was triturated with acetone to afford 245 mg of title salt (35%) as a white solid.

25

TLC Silica gel (7:2:1 n-propanol:ammonium hydroxide:water): R_f 0.42.

30

IR (KBr): 3437, 2926, 1449, 1200, 1076, 1030 cm^{-1} .

MS (FAB, + ions) m/z 551 (M + K), 513 (M + H).

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Anal. Calc'd for $C_{20}H_{35}O_6PSK_2 \cdot 0.55 H_2O$:

C, 45.96; H, 6.96; P, 5.93; S, 6.13

Found: C, 45.96; H, 6.80; P, 5.54; S, 6.50

5

Example 31

(E,E)-1-[Hydroxy(hydroxymethyl)phosphinyl]-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, dipotassium salt

10

Potassium iodide (370 mg, 2.23 mmol) was added to a solution of Example 28 Part B compound (950 mg, 2.12 mmol) in acetone (10 mL) under argon. As the mostly insoluble potassium iodide reacted, the product precipitated out of the reaction

15

mixture. The white heterogeneous reaction was stirred at RT overnight, concentrated in vacuo, then pumped at high vacuum to give a white solid.

20

A heterogeneous mixture of the sulfonate salt paraformaldehyde (254 mg, 8.48 mmol), and diisopropylethylamine (184 mL, 1.06 mmol) in absolute ethanol (7 mL) was heated at 60°C under argon. After 15 min, the reaction went from milky white to clear and colorless. After 7 h at 60°C, the reaction was allowed to cool to RT. The reaction was concentrated in vacuo, then pumped at high vacuum to give a white semi-solid.

25

30

Aqueous KOH (6.4 mL, 1N, 6.4 mmol) was added to the mono-ester prepared above. The initially white foamy dispersion was stirred at RT under argon overnight, after which time the reaction was clear and colorless. The reaction mixture was chromatographed on CHP20P gel (2.5 x 20 cm column) eluting with water followed by a gradient created by the gradual addition of



acetonitrile to a reservoir of water. The product fractions were concentrated in vacuo to give an opaque white gum. Acetone (5 mL) was added and the product was precipitated out as a solid. The solid
5 was filtered, washed with acetone (3 x 5 mL), then pumped at high vacuum to give the title product (520 mg, 49%) as a white solid.

TLC (silica gel) (7:2:1 n-propanol/NH₄OH/H₂O):

10 R_f = 0.36

IR (KBr) 3430, 2926, 1636, 1449, 1204, 1078, 1024 cm⁻¹.

15 Mass Spec (FAB, + ions) m/z 499 (M+H), 537 (M+K).

Anal. Calc'd for C₁₉H₃₃K₂O₆PS:

C, 45.76; H, 6.67; P, 6.21; S, 6.43.

Found: C, 45.41; H, 6.92; P, 6.47; S, 6.77.

20

Example 32

(E,E)-7,11,15-Trimethyl-2-phosphono-6,10,14-hexadecatriene-2-sulfonic acid, tripotassium salt

25 A. (E,E)-7,11,15-Trimethyl-2-(diethoxyphosphinyl)-6,10,14-hexadecatriene-2-sulfonic acid, cyclohexyl ester

To a suspension of 47 mg (1.2 mmol, 1.1 eq) of sodium hydride (as a 60% mineral oil dispersion)
30 in 1 mL of dry DMF at 0°C was added a solution of 580 mg (1.1 mmol, 1 eq) of Example 1A Part C compound in 2 mL of DMF over 1 min. The bubbling solution was allowed to warm to RT and stirred for 30 min. To the resulting yellow homogeneous

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solution of anion at RT was added 264 μ L (4.2 mmol, 4 eq) of methyl iodide over 1 min. After 16 h, the turbid yellow reaction mixture was diluted with ether (100 mL) and washed with brine (50 mL). The aqueous layer was extracted with ether (2 x 15 mL) and the combined organic layers were dried (MgSO_4) and concentrated to afford 583 mg of a light yellow cloudy oil. ^1H NMR of the crude oil indicated no unalkylated starting material was present. The desired product was isolated via flash chromatography on silica gel (75 g) eluting with 35% ethyl acetate in hexanes. Fractions containing the desired product by TLC were pooled and concentrated to afford 418 mg (68%) of title compound as a clear viscous oil.

TLC Silica gel (10% ether in CH_2Cl_2): R_f 0.46.

B. (E,E)-7,11,15-Trimethyl-2-phosphono-6,10,14-hexadecatriene-2-sulfonic acid, tripotassium salt

To a solution of 408 mg of Part A compound in 8 mL of dry methanol at 0°C was introduced ammonia until the solution was saturated. The tube was sealed with a threaded teflon cap fitted with an O-ring and heated at 75°C for 17 h. The volatiles were removed in vacuo and the oily residue was co-evaporated twice with toluene before placing on high vac (0.25 mmHg) for three hours. To the resulting clear yellow oil was added 4 mL of dry CH_2Cl_2 followed by 769 μ L (5.8 mmol, 8 eq) of dry 2,4,6-collidine. To the resulting light yellow clear solution was added 768 μ L (5.8 mmol, 8 eq) of bromotrimethylsilane (TMSBr) and the resulting

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white heterogeneous mixture was stirred at room temperature. After 84 h, the reaction mixture was concentrated and placed on high vac (0.25 mmHg) overnight. The resulting yellow white solid was
5 dissolved by adding 5.0 mL (5.0 mmol, 6.8 eq) of 1 M potassium hydroxide (pH 12.45) and 5 mL of water and the resulting solution (pH 12.35) was frozen and lyophilized. The light brown lyophilate was dissolved in water and chromatographed on a column
10 of CHP20P (2.5 cm x 25 cm) eluting initially with water (150 mL) followed a gradient formed by the gradual addition of acetonitrile (400 mL) to a reservoir containing water (400 mL). Fractions (10 mL each) were collected and analyzed by HPLC
15 (Method 8). One fraction contained material $\geq 98\%$ pure. This fraction was concentrated, taken up in a minimum volume of water, filtered and precipitated using acetone. The resulting solid was dried on high vac to afford 134 mg of an off-white solid
20 which did not pass elemental analysis. The $>95\%$ material from the column above was rechromatographed on CHP20P under isocratic conditions with 20% acetonitrile in water. Fractions containing $\geq 98\%$ material were combined with the $>98\%$ material
25 obtained from the first column, dissolved in water and concentrated. The resulting glassy solid was triturated with acetone to afford, after high vacuum removal of the acetone remnants, 94 mg title salt in the form of an off-white solid (24%).

30

TLC Silica gel (5:4:1 n-propanol:ammonium hydroxide:water): R_f 0.24.

IR (KBr): 3434, 2928, 1452, 1202 cm^{-1} .

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MS (FAB, + ions) m/z 499 (M + 2H - K),
521 (M - K + Na + H), 537 (M + H).

- 5 Anal. Calc'd for $C_{19}H_{32}O_6PSK_3 \cdot 0.5 H_2O$:
C, 41.81; H, 6.09; P, 5.67
Found: C, 42.20; H, 6.41; P, 4.94.

Example 33

- 10 4'-(2-Methyl-1-propenyl)- α -phosphono[1,1'-biphenyl]-4-butanesulfonic acid, tripotassium salt

A. 1-Bromo-4-(2-methyl-1-propenyl)benzene

- To a stirred slurry of 17.29 g (40.0 mmol)
15 of isopropyltriphenylphosphonium iodide and 500 mg
(2 mmol) of 18-crown-6 in 100 mL of THF under
nitrogen at 5°C was added 4.50 g (40.0 mmol) of
potassium t-butoxide over 5 min. the resulting
deep red-orange slurry was stirred 10 min and then
20 a solution of 6.50 g (35.0 mmol) 4-bromobenzalde-
hyde in 40 mL of THF was added at a rate to keep
the temperature below +10°C. The resulting bright
yellow slurry was stirred for 20 min and then
poured into 300 mL of hexanes. The solids were
25 filtered off and the filtrate evaporated. This
residue was purified by flash chromatography (5x15
cm column) and eluted with hexanes to provide 5.66
g (77%) of title bromide as a colorless oil.
30 TLC Silica gel (hexanes) $R_f=0.32$.

Anal. Calc'd for $C_{10}H_{11}Br$:

C, 56.90; H, 5.25

Found: C, 56.83; H, 5.22.

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MS (CI-NH₃, - ions) m/e 209 (M-H).

5 B. 4'-(2-Methyl-1-propenyl)[1,1'-
biphenyl]-4-carboxylic acid, methyl
ester

To a stirred solution of 52 mL (88.4 mmol, 1.7 M in pentane) of t-butyllithium at -78°C under argon was added a solution of 7.92 g (37.5 mmol) of
10 Part A bromide in 15 mL of THF over 10 minutes. The resulting deep red slurry was stirred for 1 hour, warmed to -22°C and a solution of 6.16 g (45.2 mmol) of thrice-fused zinc chloride in 40 mL of THF was added over 20 minutes. The light
15 yellow, faintly turbid solution was stirred for 1 hour and then cannulated into a stirred solution of 7.04 g (26.9 mmol) of methyl 4-iodobenzoate and 600 mg (0.52 mmol) of tetrakis(triphenylphosphine)-palladium in 30 mL of THF at -22°C under argon.
20 After the addition was complete, the reaction was warmed to room temperature and stirred for 16 hours. The reaction mixture was diluted with ether, washed successively with 1 M hydrochloric acid, saturated sodium bicarbonate and saturated
25 sodium sulfite solution. The organic extract was dried (MgSO₄) and evaporated to give a dark brown solid. Recrystallization from methanol gave title ester as a light yellow solid, mp 66-68°C, 6.13 g, 86% yield.

30

C. 4'-(2-Methyl-1-propenyl)[1,1'-
biphenyl]-4-methanol

To a stirred solution of 3.00 g (11.3 mmol) of Part B ester in 10 mL of THF at room temperature



under nitrogen was added 6.0 mL of lithium aluminum hydride solution (1.0 M in THF, 6.0 mmol). After 1 hour, the reaction was quenched with 1 mL of brine and then sufficient 1 M hydrochloric acid to bring
5 the solution to pH 1. The resulting mixture was extracted twice with ether, the combined extracts washed with saturated sodium bicarbonate solution, dried (MgSO₄) and evaporated. Purification by flash chromatography on silica gel (5 x 10 cm
10 column, 3:97 ether/dichloromethane as eluent) gave title alcohol as a colorless oil, 2.42 g, 90% yield.

15 D. 4-(Bromomethyl)-4'-(2-methyl-1-propenyl)[1,1'-biphenyl]

To a stirred solution of 2.82 g of triphenylphosphine (8.4 mmol) and 2.33 g (9.79 mmol) of Part C alcohol in 30 mL of dichloromethane under argon at -40°C was added 1.92 g (11.7 mmol)
20 of N-bromosuccinimide over 20 minutes. After 1 hour, the reaction mixture was evaporated onto 10 g of silica gel. Purification by flash chromatography on silica gel (5 x 20 cm column, 12% CH₂Cl₂ in hexanes as the eluent) gave title bromide as a
25 colorless oil, 2.75 g, 93% yield.

E. 4'-(2-Methyl-1-propenyl)[1,1'-biphenyl]-4-propanoic acid, 1,1-dimethylethyl ester

30 To a stirred solution of 1.01 mL (7.2 mmol) of diisopropylamine in 15 mL of THF at -5°C under argon was added 2.8 mL (7.0 mmol, 2.5 M in hexane) of n-butyllithium at a rate to keep the temperature below 0°C. After stirring the resulting pale



yellow solution for 15 minutes, 3.0 mL (17 mmol) of hexamethylphosphoramide was added. After an additional 15 minutes, the deep yellow solution was cooled to -78°C and 0.98 mL (7.2 mmol) of t-butyl acetate was added over the course of 5 minutes. The solution was stirred for 30 minutes and then a solution of 1.75 g (5.8 mmol) of Part D bromide in 10 mL of THF was added over 5 minutes. The reaction mixture was stirred for 8 hours at -78°C , quenched with 10% citric acid solution and extracted twice with ether. The extracts were combined, washed twice with water, once with saturated sodium bicarbonate solution, dried (MgSO_4) and evaporated. Purification by flash chromatography on silica gel (5 x 20 cm column, 1:1 hexanes/dichloromethane as eluent) gave title ester as a white foamy solid, 1.85 g, 95% yield.

F. 4'-(2-Methyl-1-propenyl)[1,1'-biphenyl]-4-propanol

To a stirred solution of 1.08 g (3.20 mmol) of Part E ester in 5 mL of THF at room temperature under nitrogen was added 2.0 mL of lithium aluminum hydride solution (1.0 M in THF, 2.0 mmol). The reaction was heated to reflux for 1 hour, quenched with 1 mL of brine and then sufficient 1 M hydrochloric acid to bring the solution to pH 1. The resulting mixture was extracted twice with ether, the combined extracts washed with saturated sodium bicarbonate solution, dried (MgSO_4) and evaporated. The oily residue was passed through a 2 cm high pad of silica gel, eluting with dichloromethane to give title alcohol as a white solid, 0.824 g, 97% yield.

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G. 4-(3-Iodopropyl)-4'-(2-methyl-1-propenyl)[1,1'-biphenyl]

To a stirred solution of 813 mg (3.05 mmol) of Part F alcohol, 882 mg (3.36 mmol) of triphenylphosphine and 440 mg (6.4 mmol) of imidazole in 20 mL of THF was added a solution of 813 mg (3.2 mmol) of iodine in 10 mL of THF over 20 min. After 10 min, the light yellow reaction mixture was diluted with hexanes and washed once each with 10% sodium bisulfite solution, water and brine. The organic layer was dried (MgSO₄) and evaporated onto 5 g silica gel. Purification by flash chromatography on silica gel (5x5 cm column) eluted with dichloromethane gave title iodide, 1.11 g (97%) as a white solid, mp 58-61°C.

H. 4'-(2-Methyl-1-propenyl)- α -phosphono-[1,1'-biphenyl]-4-butanesulfonic acid, cyclohexyl ester

To a stirred slurry of 85 mg (2.1 mmol, 60% mineral oil dispersion) of sodium hydride in 3 mL of DMF under argon at -10°C was added a solution of 670 mg (2.4 mmol, 1.3 equiv.) of Example 1A Part B compound in 1 mL of DMF. After addition was complete, the reaction was warmed to room temperature and stirred for 30 min. To the resulting solution was added a solution of 700 mg (1.86 mmol) of Part G compound in 1 mL of DMF. The reaction was stirred for 16 h, diluted with ether and washed once with 10% citric acid and thrice with water. The organic phase was dried (MgSO₄) and evaporated. Purification by flash chromatography on silica gel (5 x 20 cm column)

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eluted with 1:24 ether/dichloromethane gave title salt as a colorless oil, 610 mg, 62% yield.

5 I. 4'-(2-Methyl-1-propenyl)- α -phosphono-
[1,1'-biphenyl]-4-butanesulfonic acid,
tripotassium salt

A solution of 500 mg (0.89 mmol) of Part H ester in 15 mL of methanol under argon at room temperature was saturated with ammonia gas. The
10 flask containing the reaction mixture was sealed and heated to 75°C. After 16 h, the reaction was cooled to room temperature and evaporated under dry conditions. The residue was dissolved in 10 mL of dichloromethane and 0.59 mL (4.5 mmol) of 2,4,6-
15 collidine and then 940 mL (7.1 mmol) of bromotrimethylsilane was added. After 24 h, the resulting clear solution was evaporated at 25°C and then stirred for 1 h with 8 mL (4 mmol) of 0.5 M potassium hydroxide solution. The solution was
20 lyophilized and then purified by MPLC (2.5x20 cm column of Mitsubishi Kasei Sepadbeads HP-20 resin): 11.5 mL fractions, 7 mL/min flow rate, eluted with water and then a gradient prepared from 400 mL of water and 450 mL of 2:1 acetonitrile/water).
25 Fractions 39-48 were collected and lyophilized to give title salt as a white solid, 310 mg, 62% yield.

IR (KBr pellet) 3403, 2967, 2932, 1653, 1497,
30 1184, 1051, 966 cm⁻¹.

Anal. Calc'd for C₂₀H₂₂K₃O₆PS·1.5 H₂O:

C, 42.46; H, 4.45; P, 5.47; S, 5.67

Found: C, 42.35; H, 4.80; P, 5.20; S, 6.06.

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Mass Spec (FAB, + ions) m/e 577 (M+K), 539 (M+H),
501 (M-K+2H).

5 Example 34

4'-Butyl- α -phosphono[1,1'-biphenyl]-4-butan-
sulfonic acid, tripotassium salt

The title compound was prepared as
10 described herein and has the following properties.

IR (KBr pellet) 3424, 3027, 2957, 2930, 2859,
1653, 1499, 1200, 1078, 966 cm^{-1} .

15 Anal. Calc'd for $\text{C}_{20}\text{H}_{24}\text{K}_3\text{O}_6\text{PS} \cdot 0.75 \text{H}_2\text{O}$:

C, 43.34; H, 4.64; P, 5.59; S, 5.78

Found: C, 43.01; H, 4.88; P, 5.16; S, 6.21.

Mass Spec (FAB, + ions) m/e 579 (M+K), 541 (M+H),
20 503 (M-K+2H), 465 (M-2K+3H).

Example 35

(E)-6-Methyl-1-phosphono-9-(4-propylphenyl)-5-
nonene-1-sulfonic acid, tripotassium salt

25

The title compound was prepared as
described herein and has the following properties.

TLC (5:4:1 n-propanol/ammonium hydroxide/water)
30 $R_f = 0.22$.

MS (FAB, +ions) 533 (M+H), 457 (M+H-K).

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IR (KBr) 3235, 2934, 2872, 1653, 1458, 1144, 1098, 1052, 964 cm^{-1} .

Anal. Calc'd for $\text{C}_{19}\text{H}_{28}\text{O}_6\text{PSK}_3\text{-H}_2\text{O}$:

5 C, 41.43; H, 5.49; S, 5.82; P, 5.62;

Found C, 41.43; H, 5.72; S, 6.23; P, 5.29.

Example 35A

2,2-Dimethylpropanoic acid, (E)-8-iodo-5-methyl-4-
10 octen-1-yl ester

The title compound was prepared as described herein and has the following properties.

15 TLC Silica gel (8:2 hexane/ethyl acetate) $R_f=0.81$.

Example 36

(E)-6-Methyl-8-phenyl-1-phosphono-5-octene-1-sul-
fonic acid, tripotassium salt

20

A. 4-[(t-Butyldimethylsilyl)oxyl]-1-butanol

To a solution of 300 mL of THF, 90 g (1 mol) of butanediol and 13.6 g (0.20 mol) of imidazole was added 30.1 g (0.20 mol) of t-butyldimethylsilyl
25 chloride in 50 mL of THF. After 2 h the reaction mixture was diluted with 700 mL of water and 500 mL of diethyl ether. The layers were equilibrated and separated. The organic fraction was washed with water, dried (MgSO_4) and concentrated to leave 38.7
30 g (95%) of title alcohol as a colorless oil.

TLC Silica gel (3:7 ethyl acetate/hexane) $R_f=0.35$.

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IR (neat) 3450, 2940, 2880, 1465, 1385, 1250, 1100, 1055, 835, 770 cm^{-1} .

Mass Spec (CI- NH_3 ; + ions) m/e 205 (M+H).

5

B. 4-[(t-Butyldimethylsilyl)oxy]butanol

To a solution of 100 mL of methylene chloride and 3.21 g (41.17 mmol) of methyl sulfoxide at -78°C was added 6.67 g (37.74 mmol) of
10 oxalyl chloride dropwise over 15 min. After gas evolution ceased (≈ 15 min.), 7.0 g (34.31 mmol) of Part A alcohol was added to the reaction mixture. The mixture was stirred at -78°C for 0.5 h, when 13.8 g (137.2 mmol) of triethylamine was added
15 rapidly over 4 min. The mixture was warmed to -20°C over 0.5 h and quenched with 200 mL of ether and 200 mL of water. The layers were equilibrated and separated. The organic fraction was dried (Na_2SO_4) and concentrated to leave 5.85 g (85%) of
20 title aldehyde as a colorless oil.

TLC Silica gel (1:9 ethyl acetate/hexane) $R_f=0.45$.

25 C. (E)-2-Methyl-6-[(t-butyldimethylsilyl)oxy]-2-hexenoic acid, ethyl ester

To a solution of 8.62 g (36.25 mmol) of triethyl 2-phosphonopropionate in 50 mL of THF at 0°C was added 0.84 g (35.0 mmol) of NaH in three
30 equal portions over 15 min. After gas evolution ceased, 5.85 g (29 mmol) of Part B aldehyde was added in one portion. The mixture was warmed to RT over 30 min. and diluted with 100 NH_4Cl solution and 100 mL of ether. The layers were equilibrated

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and separated. The organic fraction was dried (Na₂SO₄) and concentrated. The remainder was purified by flash chromatography (300 g of silica gel) with 5:95 ethyl acetate/hexanes to yield 5.50 g (66%) of title ester as an amber oil.

TLC Silica gel (1:9 ethyl acetate/hexanes) R_f=0.33.

10 D. (E)-2-Methyl-6-[(*t*-butyldimethylsilyl)oxy]-2-hexen-1-ol

To a solution of 25 mL of dichloromethane and 5.20 g (18.18 mmol) of Part C ester at -78°C was added 40 mL (40 mmol) of a 1M solution of diisobutylaluminum hydride in cyclohexane over 20 min. After 1 h, the mixture was diluted with 100 mL (100 mmol) of an aqueous 1M solution of sodium potassium tartrate and 100 mL of ether. The mixture was stirred at RT for 2.5 h when the layers were separated, the organics dried (Na₂SO₄) and concentrated. The remainder was purified by flash chromatography (250 g silica gel) with 15:85 ethyl acetate/hexanes to yield 3.0 g (67%) of title alcohol as a colorless oil.

25 TLC Silica gel (3:7 ethyl acetate/hexanes) R_f=0.45.

IR (film) 3347, 2953, 2859, 1472, 1406, 1256, 1098, 837 cm⁻¹.

30 Mass Spec (CI-NH₃, + ions) m/e 262 (M+NH₄), 245 (M+H), 227 (M+H-H₂O).

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E. (E)-1-Chloro-2-methyl-6-[(t-butyl-
dimethylsilyl)oxyl]-2-hexene

To a solution of 30 mL of dichloromethane,
3.00 g (13.30 mmol) of Part D alcohol and 2.83 g
5 (28.00 mmol) of triethylamine at 0°C was added 1.60
g (14.00 mmol) of methanesulfonyl chloride in 5 mL
of dichloromethane. After 2 h the reaction mixture
was diluted with 70 mL of water and 125 mL of
diethyl ether. The layers were equilibrated and
10 separated. The organic fraction was washed with
water, dried (Na₂SO₄) and concentrated to leave the
crude mesylate. The residue was diluted with 10 mL
of dimethylformamide and treated with 1.70 g (40.00
mmol) of LiCl. The reaction mixture was stirred at
15 RT for 6 h, at which point it was diluted with 100
mL of ether and 100 mL of water. The layers were
equilibrated and the organic fraction dried
(Na₂SO₄) and concentrated. The residue was
purified by flash chromatography (100 g of silica
20 gel) with 2:98 ethyl acetate/hexane to yield 1.20 g
(35%) of title chloride as an amber oil.

TLC Silica gel (1:9 ethyl acetate/hexane) R_f=0.80.

25 IR (film) 2930, 2859, 1472, 1389, 1256, 1103,
837 cm⁻¹.

Mass Spec (CI-NH₃, + ions) m/e 263, 265 (M+H), 227
(M+H-HCl).

30

F. (E)-3-Methyl-1-phenyl-7-[(t-butyl-
dimethylsilyl)oxyl]-3-heptene

A solution of 3 mL (6 mmol) of 2 M benzyl-
magnesium chloride in THF and 2 mL of HMPA at 0°C



was treated dropwise with 1.0 g (3.80 mmol) of Part E chloride in 5 mL of THF over 5 min. The solution was allowed to warm to RT and stir for 2 h, at which point the reaction was diluted with ether and
5 3 mL (3 mmol) of 1N HCl solution. The organic layer was washed two times with NH_4Cl solution, dried (MgSO_4) and concentrated to an oil. The oil was purified by flash chromatography performed on 125 g of silica gel packed, loaded and eluted with
10 3:95 ethyl acetate/hexane to provide 1.10 g (91%) of title compound as a colorless oil.

TLC Silica gel (5:95 ethyl acetate/hexane) $R_f=0.80$.

15 IR (film) 3086, 3063, 3028, 2930, 2859, 1603, 1497, 1472, 1256, 1101, 1032, 1007, 964, 837 cm^{-1} .

Mass Spec (CI- NH_3 , + ions) m/e 336 ($\text{M}+\text{NH}_4$), 319 ($\text{M}+\text{H}$).

20

G. (E)-5-Methyl-7-phenyl-4-hepten-1-ol

A solution of 2 mL of THF and 1.10 g (3.45 mmol) of Part F compound at 0°C was treated dropwise with 0.30 mL (5.00 mmol) of acetic acid
25 and 4.0 mL (4.00 mmol) of a 1M tetrabutylammonium fluoride solution in THF. The solution was allowed to warm to RT and stir for 48 h, at which point the reaction was diluted with 50 mL of ether and 25 mL of NaHCO_3 solution. The organic layer
30 was washed two times with NaHCO_3 solution, dried (MgSO_4) and concentrated to an oil. Flash chromatography was performed on 80 g of silica gel packed, loaded and eluted with 3:7 ethyl



acetate/hexane to provide 0.59 g (83%) of title alcohol as a colorless oil.

TLC Silica gel (3:7 ethyl acetate/hexane) R_f =0.60.

5

IR (film) 3339, 3027, 2932, 2859, 1603, 1452, 1385, 1231, 1181, 1057, 698 cm^{-1} .

Mass Spec (CI- NH_3 , + ions) m/e 222 ($\text{M}+\text{NH}_4$), 205

10 (M+H).

H. (E)-1-Iodo-5-methyl-7-phenyl-4-heptene

To a stirred solution of 0.59 g (2.89 mmol) of Part G alcohol and 0.66 mL (6.00 mmol) of triethylamine in 10 mL of methylene chloride at 0°C was added 0.37 g (3.20 mmol) of methanesulfonyl chloride dropwise over 10 min. After 1 h at 0°C the reaction was diluted with ether and washed with aqueous solutions of NH_4Cl , NaHCO_3 , and brine. The organics were dried (Na_2SO_4) and concentrated under reduced pressure to provide the crude mesylate. The residual oil was dissolved in 25 mL of acetone and treated with 1.00 g (6.66 mmol) of NaI . The resulting solution was stirred at RT for 36 h and diluted with ether. The organics were washed with water, dried over MgSO_4 , and concentrated to provide a yellow oil. Flash chromatography was performed on 100 g of silica gel packed, loaded and eluted with hexanes to provide 0.68 g (2.16 mmol, 100% overall yield) of title iodide as a colorless oil.

TLC Silica gel (hexane) R_f =0.27.

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IR (film) 3061, 3027, 2932, 2857, 1603, 1495, 1452, 1204, 1165, 1030, 743, 698 cm^{-1} .

Mass Spec (CI-NH₃, + ions) m/e 332 (M+NH₄), 314

5 (M).

I. (E)-1-(Diethoxyphosphinyl)-6-methyl-8-phenyl-5-octenesulfonic acid, cyclohexyl
ester

10 To a suspension of 83 mg (3.44 mmol) of NaH in 7 mL of dry DMF at 0°C under argon was added 1.25 g (4.00 mmol) of Example 1A Part B sulfonate over 15 min. to give a yellow solution. The reaction was allowed to warm to room temperature
15 and stir for 0.5 h when 0.60 g (1.91 mmol) of Part H iodide was added in one portion. The reaction mixture was stirred for 18 h when it was quenched with saturated aq NH₄Cl solution and diluted with ether. The organic fraction was washed with water,
20 brine, dried (Na₂SO₄) and evaporated to provide a crude yellow oil. Flash chromatography was performed on 75 g of silica gel eluted with 4:6 ethyl acetate/hexane to provide 0.76 g (79%) of title compound as a pale yellow oil.

25

TLC Silica gel (3:7 ethyl acetate/hexane) R_f=0.28.

IR (film) 3059, 3026, 2938, 2863, 1454, 1354, 1261, 1172, 1053, 1022, 927, 866 cm^{-1} .

30

Mass Spec (CI-NH₃, + ions) m/e 518 (M+NH₄), 436 (M+NH₄-C₆H₁₀).

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J. (E)-6-Methyl-8-phenyl-1-phosphono-5-
octene-1-sulfonic acid, tripotassium salt

To a solution of 0.76 g (1.52 mmol) of Part
I compound and 10 mL of methanol in a sealable tube
5 at 0°C was added NH₃ (g) until the solution was
saturated. The tube was sealed and placed in an
oil bath at 60°C for 24 h, at which point the tube
was opened and the volatiles removed under reduced
pressure. The remainder was dissolved in a 1:3
10 hexamethyldisilazane/toluene solution and
evaporated two times (2 X 10 mL) leaving a
colorless viscous oil. The oil was dissolved in 7
mL of dry methylene chloride and treated with 1.48
mL (7.00 mmol) of hexamethyldisilazane and 1.00 mL
15 (7.50 mmol) of bromotrimethylsilane. The reaction
was allowed to stir at RT for 18 h when the solvent
was evaporated and the residue pumped ($\approx$ 0.5 mm
pressure) for 0.5 h. The remainder was dissolved
by adding 5 mL (5 mmol) of 1 M KOH solution and
20 stirring vigorously for ten min. The soapy
solution was freeze dried to provide a white solid.
The solid was purified by MPLC on a column of
CHP20P gel (250 mL) eluting with water (150 mL)
followed by a gradient created by the gradual
25 addition of 500 mL of acetonitrile to a reservoir
of 300 mL of water. Approximately 7 mL fractions
were collected. Fractions 26 to 30 were pooled,
the acetonitrile was removed under reduced pressure
and the aqueous solution lyophilized to provide
30 0.45 g (63%) of title compound as a white
lyophilate which was 98.5% pure by HPLC.

TLC Silica gel (6:3:1 n-propanol/conc. NH₃/water)
R_f=0.17.

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IR (KBr) 3418, 3063, 3027, 2934, 2863, 1663, 1454, 1383, 1196, 1111, 1086, 1047, 964, 698 cm^{-1} .

5 Mass Spec (FAB, + ions) m/e 515 (M+K), 477 (M+H), 439 (M-K+2H).

Anal. Calc'd for $\text{C}_{15}\text{H}_{20}\text{O}_6\text{SPK}_3 + 1.36 \text{ H}_2\text{O}$:

C, 35.95; H, 4.57; P, 6.18; S, 6.40

10 Found: C, 36.26; H, 4.76; P, 5.84; S, 6.21.

Example 37

(E,E)-7,11,15-Trimethyl-1-phosphono-6,10,14-hexadecatriene-1-sulfonic acid, tripotassium salt

15

The title compound was prepared as described herein and has the following properties.

TLC (Silica gel, 7:2:1 n-propanol/ammonia/water)

20 $R_f = 0.10$.

MS (Ion Spray, -ions) 421 (M-3K+2H).

25 IR (KBr) 3457, 2965, 2926, 2857, 1655, 1624, 1451, 1400, 1383, 1213, 1173, 1140, 1090, 1044, 966, 885, 837, 785, 694, 644, 556 cm^{-1} .

Anal. Calc'd for $\text{C}_{19}\text{H}_{32}\text{O}_6\text{SPK}_3 - 1.21\text{H}_2\text{O}$:

C, 40.85; H, 6.21; P, 5.54; S, 5.74.

30 Found: C, 40.85; H, 6.32; P, 5.75; S, 5.60.

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Example 38

(all-E)-7,11,15-Trimethyl-1-phosphono-4-(3,7,11-trimethyl-2,6,10-dodecatrienyl)-6,10,14-hexadecatriene-1-sulfonic acid, tripotassium salt

5

The title compound was prepared as described herein and has the following properties.

TLC (Silica gel, 7:2:1 n-propanol/ammonia/water)

10 $R_f = 0.13$.

MS (FAB, + ions) m/e 779 (M+K), 742 (M+H), 703 (M+2H-K).

15

IR (KBr) 3443, 2969, 2924, 2857, 1678, 1451, 1400, 1383, 1208, 1090, 1045, 968, 891, 835, 721 cm^{-1} .

Anal. Calc'd for $\text{C}_{34}\text{H}_{56}\text{O}_6\text{PSK}_3 \cdot 2.28\text{H}_2\text{O} \cdot \text{KOH}$:

C, 48.71; H, 7.40; S, 3.82; P, 3.69;

20 Found C, 48.71; H, 7.47; S, 4.05; P, 3.91.

Example 39

(E,E)-4-Hydroxy-6,10,14-trimethyl-1-phosphono-5,9,13-pentadecatriene-1-sulfonic acid,

25 tripotassium salt

A. (E,E)-3,7,11-Trimethyl-2,6,10-dodecatrienal

30

To a CH_2Cl_2 solution (15 mL) of oxalyl chloride (7.81 mL, 87.7 mmol) was added dimethyl sulfoxide (12.5 mL, 175.4 mmol) dropwise over 30 min at -60°C . The resulting clear solution was stirred at this temperature for 20 min. A solution of trans, trans- farnesol (Aldrich Chemical Co.)

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(15 g, 67.5 mmol) in CH_2Cl_2 (325 mL) was added dropwise over 15 min. The reaction mixture became cloudy white during addition. The heterogeneous reaction mixture was stirred at -60°C for 30 min, whereupon triethylamine (56.4 mL, 405 mmol) was added dropwise over 10 min. The reaction mixture became thick. The reaction mixture was allowed to warm to RT over 1 h. Ethyl ether (800 mL) was added and the organic layer was washed with H_2O (500 mL), brine (500 mL) and dried over MgSO_4 . Evaporation gave 15 g (100%) of title compound as a crude oil.

15 B. (E,E)-3-Hydroxy-5,9,13-trimethyl-4,8,12-tetradecatrienoic acid, 1,1-dimethylethyl ester

n-Butyllithium solution (32.4 mL, 2.5 M in THF, 81.0 mmol) was added dropwise to a solution of diisopropylamine (11.35 mL, 81.0 mmol) in THF (20 mL) at 0°C . After stirring 15 min, the reaction solution was cooled to -78°C . *tert*-Butyl acetate (7.07 mL, 84.3 mmol) in THF (50 mL) was added dropwise and stirring was continued for 30 min. A solution of Part A compound (15 g, 67.5 mmol) was added dropwise over 30 min and stirring was continued at -78°C for 1 h. Water (100 mL) was added and reaction mixture was warmed to RT. The reaction mixture was diluted with ethyl acetate (500 mL) and the organic layer was washed with H_2O (500 mL), brine (500 mL) and dried over MgSO_4 . Evaporation gave a crude oil. Flash chromatography was performed on 1 kg silica gel, loaded and eluted with 10:90 ethyl acetate/hexane. The pure



fractions were combined and evaporated to give 16.0 g (71%) of title compound as a yellowish oil.

5 C. (E,E)-5,9,13-Trimethyl-3-[[[(1,1-dimethylethyl)dimethylsilyl]oxy]-4,8,12-tetradecatrienoic acid, 1,1-dimethylethyl ester

tert-Butyldimethylsilyl chloride (2.96 g, 19.7 mmol) was added to a mixture of Part B
10 compound (6.0 g, 17.9 mmol) and imidazole (1.58 g, 23.2 mmol) in DMF (50 mL) at RT. The reaction mixture was stirred at RT for 2 h, then partitioned between ethyl ether (800 mL) and H₂O (500 mL). The aqueous layer was extracted with ethyl ether (200
15 mL). The combined organic layers were washed with H₂O (2 x 500 mL), brine (2 x 500 mL) and dried over MgSO₄. Evaporation gave 8.01 g (100%) of title compound as a crude oil.

20 D. (E,E)-5,9,13-Trimethyl-3-[[[(1,1-dimethylethyl)dimethylsilyl]oxy]-4,8,12-tetradecatrien-1-ol

Diisobutylaluminum hydride solution (39.3 mL, 1M in toluene, 39.3 mmol) was added dropwise to
25 a solution of Part C compound (8.0 g, 17.9 mmol) in toluene (70 mL) at 0°C under argon. Stirring was continued for 1.5 h. Methanol (5 mL) was added until bubbling ceased. A 1 M potassium sodium tartrate solution (300 mL) was added and vigorous
30 stirring was begun. After a few minutes the reaction mixture gelatinized. Stirring was continued for 1 h. Ethyl acetate (500 mL) was added and the organic layer was washed with brine (500 mL), then dried over MgSO₄. Evaporation gave

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a pale yellow oil. Purification was performed by flash chromatography on 750 g silica gel, loaded and eluted with 10% ethyl acetate in hexane. Pure fractions were combined and evaporated to give 4.5 g (65%) of title compound as a colorless oil.

E. (E,E)-5,9,13-Trimethyl-3-[[[(1,1-dimethylethyl)dimethylsilyl]oxy]-4,8,12-tetradecatrien-1-yl iodide

10 To a mixture of Part D alcohol (4.50 g, 11.84 mmol), triphenylphosphine (3.40 g, 13.0 mmol) and imidazole (1.60 g, 23.7 mmol) in THF (30 mL), a solution of iodine (2.83 g, 13.0 mmol) in THF (5 mL) was added dropwise at RT. After stirring for
15 20 min, hexane (300 mL) was added to dilute the reaction mixture. The organic layer was washed with 10% sodium bisulfite (100 mL), saturated sodium bicarbonate (300 mL), brine (300 mL) and dried over MgSO₄. The filtrate was evaporated to a
20 volume of 100 mL, silica gel (10 g) was added and evaporation was continued to dryness. Flash chromatography was performed on 500 g silica gel, loaded and eluted with 1:99 ethyl acetate/hexane. Pure fractions were combined and evaporated to give
25 5.2 g (90%) of title compound as a colorless oil.

30 F. (E,E)-1-(Diethoxyphosphinyl)-6,10,14-trimethyl-4-[[[(1,1-dimethylethyl)dimethylsilyl]oxy]-5,9,13-pentadecatriene-1-sulfonic acid, cyclohexyl ester

To a suspension of sodium hydride (0.51 g, 21.22 mmol) in DMF (12 mL) under argon, a solution of Example 1A Part B sulfonate (8.3 g, 26.53 mmol) in DMF (12 mL) was added dropwise over 10 min at

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0°C (ice bath). The ice bath was removed and the reaction mixture was stirred at RT until the reaction solution was clear. The reaction was recooled to 0°C, and a solution of Part E compound
5 (5.2 g, 10.61 mmol) in DMF (12 mL) was added dropwise over 15 min. Stirring was continued for 2 h. The reaction mixture was warmed to RT and stirring was continued overnight. Diethyl ether (300 mL) was added to dilute reaction solution.
10 The organic layer was washed with H₂O (200 mL), brine (200 mL) and dried over MgSO₄. Evaporation gave a crude oil. Flash chromatography was performed on 450 g silica gel, loaded and eluted with 10:90 isopropanol/hexane. Pure fractions were
15 combined and evaporated to give 4.8 g (70%) of title compound as a colorless oil.

20 G. (E,E)-1-(Diethoxyphosphinyl)-4-hydroxy-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, cyclohexyl ester

A stock HF/pyridine(Py)/THF solution was prepared by combining commercial HF_x · py (2 mL) and dry pyridine (4 mL) in THF (14 mL).

25 Part F compound (4.8 g, 7.10 mmol) was dissolved in a stock solution of HF/Py/THF (200 mL) at RT. The reaction mixture was stirred at RT overnight. Ethyl acetate (500 mL) was added and
30 the organic layer was washed with H₂O (100 mL), 1N HCl (100 mL), saturated sodium bicarbonate (100 mL), brine (100 mL) and dried over MgSO₄. Evaporation gave a crude oil. Flash chromatography was performed on 300 g silica gel, loaded and

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eluted with 1:1 ethyl acetate/hexane. Pure fractions were combined and evaporated to give 1.85 g (68%) of title compound as a colorless oil.

5 H. (E,E)-4-Hydroxy-6,10,14-trimethyl-1-phosphono-5,9,13-pentadecatriene-1-sulfonic
acid, tripotassium salt

To a solution of Part G compound (1.00 g, 1.79 mmol) in methanol (20 mL) was bubbled
10 anhydrous ammonia gas until the solution was saturated. Then the sealed tube containing the reaction mixture was heated in an oil bath (70°C) overnight. The reaction mixture was evaporated to dryness. Purification was performed by
15 chromatography on CHP20P gel (2.5 x 20 cm), loaded and eluted with water followed by gradual addition of CH₃CN to a reservoir of water. The pure fractions were combined, evaporated and azeotroped with toluene. To a stirred solution of the
20 resulting residue (780 mg, 1.57 mmol) and collidine (1.03 mL, 7.85 mmol) in dichloromethane (10 mL) at RT under argon was added bromotrimethylsilane (1.66 mL, 12.56 mmol). The mixture was stirred at RT for 20 h. The solvent was evaporated and the residue
25 was pumped at high vacuum for 2 h. The residue was dissolved in 1 M potassium hydroxide (10 mL, 10 mmol) and the reaction mixture was stirred for 2 h. The solution was lyophilized to give a white solid. The crude product was purified by chromatography on
30 CHP20P gel (2.5 x 20 cm), loaded and eluted with water followed by gradual addition of CH₃CN to a reservoir of water. The combined pure fractions were evaporated to remove CH₃CN and the remaining aqueous solution was precipitated with acetone to



provide 220 mg (30%) of title compound as a white solid.

IR (KBr) 2924, 1661, 1198, 1082, 964 cm^{-1} .

5

MS (FAB, +ions) m/z 521 [(M+H)-H₂O], 539 (M+H), 577 (M+K).

Anal. Calcd for C₁₈H₃₀K₃O₇PS · 1.0 H₂O:

10

C, 38.83; H, 5.79; P, 5.56; S, 5.76

Found: C, 38.85; H, 5.84; P, 5.33; S, 5.57.

Example 40

3-Phenoxy- α -phosphonobenzenebutanesulfonic acid,

15

tripotassium salt

A. (E)-3-(3-Phenoxyphenyl)-2-propenoic acid, ethyl ester

Triethyl phosphonoacetate (6.5 mL, 32.8 mmol) was added dropwise to a suspension of sodium hydride (0.73 g, 30.2 mmol) in THF (40 mL) at 0°C under argon. The ice bath was removed and the suspension was stirred at RT for 20 min, at which time a clear colorless solution resulted. The reaction solution was recooled to -78°C and a solution of 3-phenoxybenzaldehyde (5.0 g, 25.2 mmol) in THF (10 mL) was added dropwise. The reaction mixture was stirred at -78°C for 45 min. After warming to RT, the reaction was quenched with saturated ammonium chloride solution. Diethyl ether (200 mL) was added, the organic layer was washed with H₂O (50 mL), brine (50 mL) and dried over MgSO₄. Evaporation gave 4.0 g of title ester (96%) as a colorless oil.

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B. 3-Phenoxybenzenepropanoic acid,
ethyl ester

A mixture of Part A ester (6.5 g, 24.3 mmol)
5 and palladium on carbon (10%, 300 mg) in ethyl
acetate (50 mL) was stirred under a hydrogen
atmosphere (balloon) overnight at RT. The reaction
mixture was filtered through Celite. Evaporation
of filtrate gave a crude oil. Purification was
10 performed by flash chromatography on 400 g silica
gel, loaded and eluted with 10% ethyl acetate in
hexane. Pure fractions were combined and
evaporation gave 5.45 g of title ester (84%) as a
colorless oil.

15

C. 3-Phenoxybenzenepropanol

Lithium aluminum hydride solution (20.5 mL,
1M in THF, 20.5 mmol) was added dropwise to a
solution of Part B ester (5.45 g, 20.5 mmol) in THF
20 (50 mL) at 0°C under argon. Stirring was continued
for 10 min. Ethyl acetate (5 mL) was added until
bubbling ceased. Ethyl ether (300 mL) was added
and the organic layer was washed with 1N HCl
solution (2 x 150 mL), H₂O (150 mL), saturated
25 sodium bicarbonate (150 mL), and brine (150 mL),
then dried over MgSO₄. Evaporation gave a pale
yellow oil. Purification was performed by flash
chromatography on 500 g silica gel, loaded and
eluted with 15% ethyl acetate in hexane. Pure
30 fractions were combined and evaporated to give 4.2
g of title alcohol (90%) as a colorless oil.

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D. 1-(3-Iodopropyl)-3-phenoxybenzene

Iodine (1.80 g, 7.24 mmol) in THF (5 mL) was added to a mixture of Part C alcohol (1.5 g, 6.58 mmol), triphenylphosphine (1.90 g, 7.24 mmol) and
5 imidazole (0.89 g, 13.2 mmol) in THF (15 mL). The reaction mixture was stirred at RT for 20 min, then diluted with hexane (200 ml). The organic layer was washed with 10% sodium bisulfite (50 mL), saturated sodium bicarbonate (50 mL), brine (50 mL)
10 and dried over MgSO₄. The solvent was evaporated to 100 ml volume, 10 g silica gel was added and the mixture was evaporated to dryness. Flash chromatography was performed on 100 g silica gel, loaded and eluted with hexane. Pure fractions were
15 combined and evaporated to give 1.70 g of title iodide (76%) as a colorless oil.

E. 3-Phenoxy- α -(diethoxyphosphinyl)-benzenebutanesulfonic acid, cyclohexyl ester

20 To a stirred suspension of sodium hydride (241 mg, 10.1 mmol) in DMF (10 mL) at 0°C under argon, Example 1A Part B sulfonate (3.95 g, 12.6 mmol) in DMF (4 mL) was added dropwise over 15 min. The ice bath was removed and the reaction mixture
25 was stirred at RT for 30 min. The reaction mixture was recooled to 0°C and a DMF solution (10 mL) of Part D iodide (1.7 g, 5.03 mmol) was added dropwise over 15 min. The mixture was stirred at 0°C for 2 h. The ice bath was removed and the reaction
30 mixture was stirred at RT overnight. The mixture was diluted with 300 ml of Et₂O and washed with H₂O (150 ml), brine (150 mL) and dried over MgSO₄. Evaporation gave a crude oil. Purification was performed by flash chromatography on 100 g silica

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gel, loaded and eluted with 25% ethyl acetate in hexane. The pure fractions were combined and evaporated to provide 1.5 g of title compound (57%) as a colorless oil.

5

F. 3-Phenoxy- α -phosphonobenzenebutane-
sulfonic acid, tripotassium salt

Ammonia gas was bubbled through a solution of Part E compound (1.20 g, 2.23 mmol) in methanol
10 (20 mL) until the solution was saturated. The sealed tube was heated at 70°C overnight. The reaction mixture was cooled to RT, evaporated to dryness and azeotroped with toluene. To a stirred solution of the resulting residue in dichloro-
15 methane (10 mL) at RT under argon was added bromotrimethylsilane (2.6 mL, 19.6 mmol). The mixture was stirred at RT for 20 h. The solvent was evaporated and the residue was pumped at high vacuum for 2 h. The residue was dissolved in 1 M
20 potassium hydroxide (10 mL, 10 mmol) and the reaction mixture was stirred for 2 h. The solution was lyophilized to give a white solid. The crude product was purified by chromatography on CHP20P gel (2.5 x 20 cm), loaded and eluted with water and
25 followed by a gradient created by the gradual addition of CH₃CN to a reservoir of water. The combined pure fractions were concentrated to about 5 mL volume then lyophilized to provide 780 mg (47%) of title compound as a white solid.

30

IR (KBr) 2957, 1613, 1595, 1489, 1250, 1202, 1074, 966 cm⁻¹

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Mass Spec (FAB, + ions) m/z 463 (M-K+2H), 501 (M+H), 539 (M+K).

Anal. Calc'd for $C_{16}H_{16}K_3O_7PS \cdot 1.8$ equiv H_2O :

5 C, 36.05; H, 3.71; P, 5.81; S, 6.01.

Found: C, 36.05; H, 3.97; P, 5.58; S, 6.06.

Example 41

10 (E,E)-1-[Bis[(2,2-Dimethyl-1-oxopropoxy)methoxy]-phosphinyl]-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, cyclohexyl ester

A. 2,2-Dimethylpropanoic acid, iodomethyl ester

15 Sodium iodide (dried) (15.0 g, 100 mmol) was added in one portion to a solution of 2,2-dimethylpropanoic acid, chloromethyl ester (10.0 g, 66.7 mmol) in dry acetonitrile (80 mL) at RT under argon. The heterogeneous reaction was stirred at
20 RT for 6 h, then concentrated in vacuo. The residue was partitioned between toluene (150 mL) and 5% sodium bisulfite (40 mL). The organic layer was washed with 5% sodium bisulfite (40 mL) and water (20 mL), then dried over $MgSO_4$. Evaporation
25 gave title iodide (12.1 g, 75%) as a pale yellow oil.

B. (E,E)-1-Phosphono-6,10,14-trimethyl-pentadecatriene-1-sulfonic acid, cyclohexyl ester, disilver salt

30 Bromotrimethylsilane (1.45 mL, 11.0 mmol) was added dropwise to a solution of Example 1A Part C sulfonate (1.50 g, 2.75 mmol) and allyltrimethylsilane (4.36 mL, 27.5 mmol) in CH_2Cl_2 (5 mL) at RT



under argon. The clear yellow reaction was stirred at RT for 52 h, concentrated in vacuo, then pumped at high vacuum overnight to give an orange oil.

The crude silyl ester prepared above was
5 dissolved in 1N KOH (6.05 mL, 6.05 mmol) over 15 min, then added dropwise over 5 min to a solution of silver nitrate (1.17 g, 6.88 mmol) in water (100 mL) under argon in the dark (Al foil). The resultant tan suspension was stirred at RT for 10
10 min, then the reaction mixture was lyophilized to give a tan solid. The lyophilate was partitioned between toluene (50 mL) and water (50 mL). The aqueous layer was extracted with toluene (3 x 50 mL). The combined organic extracts were washed
15 with water containing a few drops of brine (20 mL), then dried over Na₂SO₄. Evaporation followed by pumping under high vacuum for 30 min gave title compound (1.91 g, 99%) as a brown gum.

20 C. (E,E)-1-[Bis[(2,2-Dimethyl-1-oxo-propoxy)methoxy]phosphinyl-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, cyclohexyl ester

A solution of Part B compound (1.91 g, 2.71
25 mmol) in toluene (20 mL) was cooled to 0°C under argon. A solution of Part A ester (1.66 g, 6.88 mmol) in toluene (5 mL) was added to the brown solution over 5 min. After 5 min at 0°C, a solid precipitated out of solution. The reaction was
30 stirred an additional 15 min, then filtered through a 0.45 µm filter. The filtrate was concentrated in vacuo to give a pale yellow oil, which was purified by flash chromatography on silica gel (100 g)

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eluting with 15:85 EtOAc/hexane to provide title compound (1.34 g, 67%) as a colorless oil.

TLC (20:80 EtOAc/hexane): R_f = 0.21

5

IR (neat) 2965, 2936, 1757, 1134, 959 cm^{-1} .

MS (CI, NH_3) m/z 736 ($\text{M}+\text{NH}_4$).

10 Anal. Calc'd for $\text{C}_{36}\text{H}_{63}\text{O}_{10}\text{PS}$:

C, 60.15; H, 8.83; P, 4.31; S, 4.46.

Found: C, 60.08; H, 9.03; P, 4.47; S, 4.18.

Example 42

15 (E,E)-1-[Bis[(2,2-Dimethyl-1-oxopropoxy)methoxy]-phosphinyl]-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, monopotassium salt

Potassium acetate (403 mg, 4.11 mmol) was
20 added to a solution of Example 41 compound (982 mg, 1.37 mmol) in 2,2,2-trifluoroethanol/water (10:1, 10 mL) at RT under argon. After dissolution, the clear colorless reaction was heated at 40°C overnight (18 h), then concentrated in vacuo. The
25 slightly colored oil was dissolved in EtOAc (30 mL) and washed with saturated KHCO_3 (2 x 5 mL) and half-saturated KCl (10 mL). The organic layer was dried over anhydrous KCl. Evaporation followed by pumping under high vacuum overnight gave title salt
30 (893 mg, 97%) as a colorless oil.

TLC (10:90 MeOH/ CH_2Cl_2): R_f = 0.18

IR (neat) 2969, 2920, 1755, 1248, 1136, 1005 cm^{-1} .

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MS (FAB, + ions) m/z 713 (M+K), 675 (M+H).

Anal. Calc'd for $C_{30}H_{52}KO_{10}PS$:

5 C, 53.39; H, 7.77; P, 4.59; S, 4.75.

Found: C, 53.30; H, 7.81; P, 4.84; S, 5.19.

Example 43

10 α -Phosphono[1,1':4',1"-terphenyl]-4"-butanesulfonic
acid, tripotassium salt

A. 4-Aminobenzenepropanoic acid, ethyl
ester

15 A 500 mL Parr hydrogenation vessel was
charged with 12.36 g (55.9 mmol) of (E)-3-(4-
nitrophenyl)-2-propenoic acid, ethyl ester, 100 mL
of absolute ethanol, 15 mL of concentrated
hydrochloric acid and 0.75 g of 10% palladium-on-
activated charcoal. The slurry was purged with
20 nitrogen and then agitated under an initial
pressure of 44.5 psi of hydrogen gas. After 16 h,
18.5 psi had been consumed. The flask was
evacuated, purged again with nitrogen and the
contents filtered through Celite and evaporated.
25 The residue was dissolved in water and adjusted to
pH 9 with solid sodium carbonate. The resulting
mixture was extracted thrice with dichloromethane
and the combined organic extracts dried over Na_2SO_4 ,
filtered and evaporated to provide 9.31 g, 86% of
30 title compound as a yellow oil, sufficiently pure
for use in subsequent reactions.

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B. 4-Iodobenzenepropanoic acid, ethyl ester

To a stirred solution of 6.48 g (33.6 mmol) of Part A amine in 10 mL (120 mmol) of diiodomethane under nitrogen at room temperature was added 9 mL (67 mmol) of isoamyl nitrite over 10 min. The orange solution was stirred for 30 min and then heated to 80°C for 2 h. The deep orange solution was diluted with ether and washed once with 2 M HCl, once with water, once with saturated sodium bicarbonate solution and once with saturated sodium bisulfite solution. The organic phase was dried (MgSO₄) and evaporated. Purification by flash chromatography on silica gel (5 x 20 cm column) eluted with 3:2 hexanes/dichloromethane gave title iodide as a colorless oil, 8.65 g, 85% yield.

C. [1,1':4',1''-Terphenyl]-4-propanoic acid, ethyl ester

To a stirred solution of 1.17 g (5.0 mmol) of 4-bromobiphenyl in 10 mL of THF at -75°C under argon was added 5.9 mL (10.0 mmol, 1.7 M in pentane) of t-butyllithium dropwise over 15 min. After an additional 15 min, the blue-green solution was warmed to 0°C, stirred 30 min and a solution of 1.86 g (14 mmol) thrice-fused zinc chloride in 15 mL of THF was added. The resulting colorless, turbid solution was stirred for 1 h and then a solution of 1.00 g (3.3 mmol) of Part B iodide and 0.3 g (0.26 mmol) of tetrakis(triphenylphosphine)-palladium(0) in 5 mL of THF was added. The reaction was stirred for 16 h, diluted with ether and washed once with 10% citric acid. The organic phase was dried (MgSO₄) and evaporated.

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Purification by flash chromatography on silica gel (5 x 15 cm column) eluted with 11:9 hexanes/dichloromethane gave title ester as an off-white solid, 1.07 g, 98% yield, mp 172-174°C.

5

D. [1,1:4',1']-Terphenyl]-4-propanol

To a stirred solution of 1.00 g (3.0 mmol) of Part C ester in 5 mL of THF under nitrogen at room temperature was added 3 mL (3 mmol) of 1 M lithium aluminium hydride in THF. The reaction was stirred for 1 h, quenched with brine and brought to pH 1 with 2 N H₂SO₄. Extracted thrice with 100 mL portions of ethyl acetate. The organic extracts were combined, dried (MgSO₄) and evaporated to give title alcohol as gray flakes, mp 210-212°C, 740 mg, 86% yield. The compound was used without further purification.

20

E. 4-(3-Iodopropyl)[1,1':4',1']-terphenyl

To a stirred solution of 720 mg (2.50 mmol) of Part D title alcohol, 660 mg (2.51 mmol) of triphenylphosphine, and 375 mg (5.5 mmol) of imidazole in 20 mL of THF under argon at room temperature was added a solution of 640 mg (2.5 mmol) of iodine in 5 mL of THF, dropwise over 20 min. After addition was complete, the reaction was diluted with hexanes and washed once with saturated sodium bisulfite solution. The organic phase was dried (MgSO₄) and evaporated. Purification by flash chromatography on silica gel (5 x 10 cm column) eluted with CH₂Cl₂ gave title iodide as a white solid, 860 mg, 86% yield.

25

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F. α -(Diethoxyphosphinyl)[1,1':4',1''-terphenyl]-4-butanesulfonic acid, cyclohexyl ester

To a stirred slurry of 145 mg (3.6 mmol, 60%
5 mineral oil dispersion) of sodium hydride in 3 mL
of DMF under argon at -10°C was added a solution
of 1.26 g (4.0 mmol) of Example 1A Part B sulfonate
in 2 mL of DMF. After addition was complete, the
reaction was warmed to room temperature and stirred
10 for 30 min. To the resulting solution was added
800 mg (2.00 mmol) of Part E title iodide as a
powdered solid. The reaction mixture was diluted
with 1.5 mL of THF to form a turbid slurry. The
reaction was stirred for 16 h, diluted with 100 mL
15 of ether and washed once with 10% citric acid and
thrice with water. The organic phase was dried
(MgSO₄) and evaporated. Purification by flash
chromatography on silica gel (5 x 15 cm column)
eluted with 1:19 ether/dichloromethane gave title
20 compound as a colorless oil, 620 mg, 53% yield.

G. α -Phosphono[1,1':4',1''-terphenyl]-4''-butanesulfonic acid, tripotassium salt

To a stirred solution of 590 mg (1 mmol) of
25 Part F compound in 7 mL of dichloromethane under
argon at room temperature was added 420 μ L (3 mmol)
of bromotrimethylsilane. After 24 h, the resulting
clear solution was evaporated at 25°C and the
residue dissolved in 10 mL of THF. To this stirred
30 solution was added 550 mg (3.3 mmol) of dried,
finely ground potassium iodide and 5 mg (0.015
mmol) of 18-crown-6. The resulting slurry was
heated to reflux for 24 h, evaporated and then
stirred for 1 h with 6 mL (3 mmol) of 0.5 M



potassium hydroxide solution. The solution was lyophilized and then purified by MPLC (2.5x20 cm column of Mitsubishi Kasei Sepabeads CHP20P resin): 11.5 mL fractions, 7 mL/min flow rate, eluted with 140 mL water and then a gradient of 500 mL 3:2 acetonitrile/H₂O into 450 mL H₂O). Fractions 41-49 were collected and lyophilized to give title compound as a white solid, 480 mg, 78% yield.

10 IR (KBr pellet) 3407, 3092, 2932, 2864, 1634, 1485, 1198, 1078, 1049, 966 cm⁻¹.

Anal. Calc'd for C₂₂H₂₀K₃O₈PS·3.1 H₂O:

C, 42.83; H, 4.29; P, 5.02; S, 5.20

15 Found: C, 42.83; H, 4.19; P, 5.03; S, 5.18.

MS (FAB, + ions) m/e 561 (M+H), 523 (M-K+2H), 485 (M-2K+3H).

20 Example 44

4-(2-Methylphenoxy)-α-phosphonobenzenebutane-sulfonic acid, tripotassium salt

The title compound was prepared as described herein and has the following properties.

TLC (n-propanol/NH₄OH/H₂O=5:4:1)(silica gel)
(R_f=0.26)

30 IR (KBr) 2951, 2932, 1653, 1507, 1240, 1204, 1076, 966, 878 cm⁻¹

MS (FAB, + ions) m/z 477 (M-K+2H), 515 (M+H), 553 (M+K).

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Anal. Calcd for $C_{17}H_{18}K_3O_7PS \cdot 2.3 \text{ equiv } H_2O$:

C, 36.72; H, 4.10; P, 5.57; S, 5.77.

Found: C, 36.72; H, 3.91; P, 5.51; S, 5.54.

5

Example 45

3-(3-Propylphenoxy)- α -phosphonobenzenebutane-
sulfonic acid, tripotassium salt

10

A. 3-Iodobenzenepropanoic acid, ethyl ester

(1). (E)-3-(3-Nitrophenyl)-2-propenoic
acid, ethyl ester

A mixture of 3-nitrocinnamic acid (11.7 g,
15 60.6 mmol), concentrated sulfuric acid (0.16 mL,
3.03 mmol) and absolute ethanol (120 mL) was
refluxed overnight. The reaction mixture was
poured into ice water (400 mL). The mixture was
extracted with ethyl ether (500 mL x 2). The
20 organic layer was washed with saturated sodium
bicarbonate solution (100 mL x 2), water (100 mL x
2), brine (100 mL x 2) and dried over magnesium
sulfate. Evaporation gave title compound (12.0 g,
99%) as a colorless oil.

25

(2) 3-Aminobenzenepropanoic acid,
ethyl ester

A Parr hydrogenation vessel was charged with
Part (1) compound (12.0 g, 54.3 mmol), concentrated
30 HCl (15 mL, 0.15 mmol), 10% palladium on carbon
(750 mg) and absolute ethanol (75 mL). The slurry
was purged with nitrogen and agitated under an
initial pressure of 45 psi of hydrogen gas. After
16 h, the flask was evacuated and the contents

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filtered through Celite and evaporated. The residue was dissolved in water and adjusted to pH 9 with solid sodium carbonate. The resulting mixture was extracted with dichloromethane (250 mL x 2).

- 5 The combined extracts were evaporated to give the title compound (8.7 g, 86%) as an oil.

(3) 3-Iodobenzenepropanoic acid, ethyl ester

- 10 To a solution of Part (2) compound (7.2 g, 32 mmol) in diiodomethane (10.3 mL, 128 mmol) under argon at RT was added isoamyl nitrite (6.5 mL, 64 mmol) over 10 min. The brownish solution was stirred at RT for 40 min and then heated to 80°C
15 for 2 h. Ethyl ether (300 mL) was added to the reaction and the organic layer was washed with 1N hydrochloric acid (70 mL x 2), water (70 mL), saturated sodium bicarbonate (70 mL x 2), 10% sodium bisulfite solution (30 mL) and dried over
20 magnesium sulfate. Purification was performed by flash chromatography on 800 g silica gel, loaded and eluted with 7% ethyl acetate in hexane. Pure fractions were combined and evaporated to give the title compound (4.1 g, 42%) as a colorless oil.

25

B. 3-Propylphenol

(1) 3-(1-Propenyl)phenol

- To a suspension of (ethyl)triphenylphosphonium bromide (35 g, 94.3 mmol) in THF (95 mL)
30 was added potassium bis(trimethylsilyl)amide (180 ml, 0.5 M in toluene, 90.2 mmol) dropwise. The reaction was stirred at 0°C for 30 min, then a solution of 3-hydroxy-benzaldehyde (5 g, 41.0 mmol)



in THF (5 mL) was added dropwise. After addition the reaction was stirred at 0°C for 1h. Ethyl ether (200 mL) was added to dilute the reaction. The organic layer was washed with water (50 mL x 5 2), brine (50 mL x 2) and dried over magnesium sulfate. Purification was performed by flash chromatography on 600 g silica gel, loaded and eluted with 10% ethyl acetate in hexane. Pure fractions were combined and evaporated to give the 10 title compound (5.1 g, 93%) as a colorless oil.

(2) 3-Propylphenol

To a mixture of Part B(1) compound (3 g, 22.4 mmol) and 10 % palladium on carbon (150 mg) in 15 THF (25 mL) was connected a hydrogen balloon. Hydrogenation was maintained at RT overnight. The mixture of reaction was filtered through Celite. The resulting clear solution was evaporated to give the title compound (2.97 g, 100%) as a yellowish 20 oil.

C. 3-(3-Propylphenoxy)benzenepropanoic acid, ethyl ester

To a suspension of sodium hydride (155 mg, 25 6.44 mmol) in pyridine (25 mL) was added a solution of Part B compound (1.5 g, 11.0 mmol) in pyridine (2.5 mL) at 0°C under argon. Stirring was continued until the solution was clear (15 min). The reaction was warmed to RT, and a solution of 30 Part A compound (2.5 g, 8.27 mmol) in pyridine (2.5 mL) was added to the reaction followed by copper bromide-dimethyl sulfide complex (2.27 g, 11.0 mmol). The reaction was refluxed for 24 h. The reaction was cooled to RT. The mixture of reaction

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was filtered and evaporated to dryness. Ethyl ether (250 mL) was added to the resulting residue, and the organic layer was washed with 1N HCl (2 x 50 mL), water (2 x 50 mL), saturated sodium bicarbonate solution (50 mL), brine (50 mL) and dried over MgSO₄. Purification was performed by flash chromatography on 200 g silica gel, loaded and eluted with 10% ethyl acetate in hexane. Pure fractions were combined and evaporated to give the title compound (1.68 g, 65%) as a colorless oil.

D. 3-(3-Propylphenoxy)benzenepropanol

Lithium aluminum hydride solution (5.29 mL, 1M in THF, 5.29 mmol) was added dropwise to a solution of Part C compound (1.65 g, 5.29 mmol) in THF (10 mL) at 0°C under argon. Stirring was continued for 10 min. Ethyl acetate (5 mL) was added to destroy excess LAH. Ethyl ether (200 mL) was added and the organic layer was washed with 1N HCl solution (2 x 50 mL), H₂O (50 mL), saturated sodium bicarbonate solution (50 mL), and brine (50 mL), then dried over MgSO₄. Evaporation gave the title compound (1.3 g, 91%) as a colorless oil.

E. 1-(3-Iodopropyl)-3-((3-propylphenoxy)-benzene

A solution of iodine (1.35 g, 5.3 mmol) in THF (5 mL) was added to a mixture of Part D compound (1.3g, 1.43 mmol), triphenylphosphine (1.39 g, 5.3 mmol) and imidazole (655 mg, 9.64 mmol) in THF (15 mL). The reaction mixture was stirred at RT for 10 min, then diluted with hexane (200 mL). The organic layer was washed with 10% sodium bisulfite (50 mL), saturated sodium

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bicarbonate (50 mL), brine (50 mL) and dried over MgSO_4 . The solvent was evaporated to 100 mL volume, 6 g silica gel was added, and the mixture was evaporated to dryness. Flash chromatography
5 was performed on 200 g silica gel, loaded and eluted with hexane. Pure fractions were combined and evaporated to give the title compound (1.6 g, 88%) as a colorless oil.

10 F. α -(Diethoxyphosphinyl)benzenebutane-
sulfonic acid, cyclohexyl ester

To a stirred suspension of sodium hydride (126 mg, 5.26 mmol) in DMF (5 mL) at 0°C under argon, Exaple 1A Part B sulfonate (2.1 g, 6.58
15 mmol) in DMF (2 mL) was added dropwise over 15 min. The ice bath was removed and the reaction mixture was stirred at RT for 30 min. The reaction mixture was recooled to 0°C and a solution of Part E
20 compound (1.0 g, 2.63 mmol) in DMF (2 mL) was added dropwise over 15 min. The mixture was stirred at 0°C for 2 h. The ice bath was removed and the reaction mixture was stirred at RT overnight. The mixture was diluted with ethyl ether (250 mL) and washed with H_2O (50 mL), brine (50 mL) and dried
25 over MgSO_4 . Evaporation gave a crude oil. Purification was performed by flash chromatography on 150 g silica gel, loaded and eluted with 30% ethyl acetate in hexane. The pure fractions were combined and evaporated to provide the title
30 compound (1.1 g, 74%) as a colorless oil.

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G. 3-(3-Propylphenoxy)- α -phosphonobenzene-
butanesulfonic acid, tripotassium salt

Ammonia gas was bubbled through a solution
of Part F compound (800 mg, 2.19 mmol) in methanol
5 (10 mL) until the solution was saturated. The
sealed tube containing the reaction was heated at
70°C overnight. The reaction mixture was cooled to
RT, evaporated to dryness and azeotroped with
toluene (2 x 20 mL). To a stirred solution of the
10 resulting residue in dichloromethane (10 mL) at RT
under argon was added bromotrimethylsilane (2.22
mL, 15.3 mmol). The mixture was stirred at RT for
20 h. The solvent was evaporated and the residue
was pumped at high vacuum for 2 h. The residue was
15 dissolved in 1 M potassium hydroxide (8 mL, 8 mmol)
and the reaction mixture was stirred for 2 h. The
resulting clear solution was purified by
chromatography on CHP20P gel (2.5 x 20 cm), loaded
and eluted with water followed by a gradient
20 created by the gradual addition of CH₃CN to a
reservoir of water. The combined pure fractions
were concentrated to about 5 mL volume then
lyophilized to provide the title compound (500 mg,
42%) as a white solid.

25

IR (KBr) 2959, 2932, 1605, 1578, 1254, 1200, 1157,
1076, 966, 696 cm⁻¹

30

MS (FAB, + ions) m/z 505 (M-K+2H), 543 (M+H),
581 (M+K).

Anal. Calcd for C₁₉H₂₂K₃O₇PS · 1.7 equiv H₂O:

C, 39.80; H, 4.47; P, 5.40; S, 5.59.

Found: C, 39.85; H, 3.43; P, 5.25; S, 5.68.

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Example 46

6-Methyl- α -phosphonobenzeneoctanesulfonic acid,
tripotassium salt

5

The title compound was prepared as
described herein and has the following properties.

TLC Silica gel (6:3:1 n-propanol/conc. NH_3 /water)
10 R_f =0.17.

IR (KBr) 3427, 3065, 3027, 2926, 2859, 1636, 1497,
1377, 1209, 1148, 1084, 1044, 968, 698 cm^{-1} .

15 Mass Spec (FAB, + ions) m/e 517 (M+K), 479 (M+H),
441 (M-K+2H).

Anal. Calc'd for $\text{C}_{15}\text{H}_{22}\text{O}_6\text{SPK}_3 + 0.54 \text{ H}_2\text{O}$:

C, 36.89; H, 4.76; P, 6.34; S, 6.56

20 Found: C, 36.59; H, 5.10; P, 6.01; S, 6.83.

Example 47

3-(2-Butylphenoxy)- α -phosphonobenzenepropane-
sulfonic acid, tripotassium salt

25

A. Tetrahydro-2-phenoxy-2H-pyran

Phenol (10 g, 106 mmol) was dissolved in
3,4-dihydro-2H-pyran (29 mL, 318 mmol) and one drop
concentrated HCl was added at RT. The reaction was
30 stirred at RT overnight. Ethyl ether (500 mL) was
added to dilute the reaction. The organic layer was
washed with water (2 x 100 mL), saturated sodium
bicarbonate (2 x 100 mL), brine (2 x 100 mL) and

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dried over MgSO_4 . Evaporation gave title compound (17 g, 100%) as a colorless oil.

B. 2-(2-Butylphenoxy)tetrahydro-2H-pyran

5 To a solution of Part A compound (5 g, 31.3 mmol) in THF (69 mL) and ethyl ether (37 mL) was added dropwise a solution of 2.5 M n-butyllithium in hexane (15.5 mL, 38.8 mmol) at 0°C over 10 min. After an additional 30 min at 0°C , the reaction was
10 allowed to warm to RT for 5 h. The reaction was recooled to 0°C and iodobutane (7.55 mL, 66.4 mmol) was added. After 10 min at 0°C , the reaction was allowed to warm to RT and stirring was continued overnight. Ethyl ether (300 mL) was added to dilute
15 the reaction, and the organic layer was washed with 1N HCl (2 x 50 mL), saturated sodium bicarbonate (2 x 50 mL), brine (2 x 50 mL) and dried over MgSO_4 . Evaporation gave title compound (6.0 g, 89 %) as a crude oil.

20

C. 2-Butylphenol

To a solution of Part B compound (6.0 g, 27.8 mmol) in dioxane (250 mL) was added 10% HCl solution (100 mL) at RT. The reaction was stirred
25 at RT for 3.5 h. Ethyl ether (200 mL) was added to dilute the reaction. The organic layer was washed with saturated sodium bicarbonate solution (2 x 100 mL), brine (2 x 100 mL) and dried over MgSO_4 . Purification was performed by flash chromatography
30 on silica gel (500 g), loaded and eluted with 10 % ethyl acetate in hexane. Pure fractions was combined and evaporated to give title compound (3.0 g, 70%) as a colorless oil.

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D. 3-(2-Butylphenoxy)benzenepropanoic acid, ethyl ester

To a suspension of potassium hydride (572 mg, 14.3 mmol) [obtained by washing a 35 wt.% suspension of KH in mineral oil with hexane several times followed by evaporation of excess hexane] in pyridine (20 mL) was added a solution of Part C compound (2.2 g, 14.3 mmol) in pyridine (2.5 mL) at 0 °C under argon. Stirring was continued until the solution was clear (15 min). The reaction was warmed to RT, and a solution of Example 45 Part A iodide (2.9 g, 9.53 mmol) in pyridine (2.5 mL) was added to the reaction followed by copper bromide-dimethyl sulfide complex (2.94 g, 14.3 mmol). The reaction was refluxed for 16 h. Ethyl ether (150 mL) was added to dilute the reaction. The resulting mixture was filtered through Celite, the filtrate was evaporated to dryness. Ethyl ether (200 mL) was added and the organic layer was washed with 1N HCl (2 x 50 mL), water (2 x 50 mL), 1N potassium hydroxide solution (2 x 50 mL), brine (50 mL) and dried over MgSO₄. Purification was performed by flash chromatography on 200 g silica gel, loaded and eluted with 7% ethyl acetate in hexane. Pure fractions were combined and evaporated to give title compound (1.2 g, 38%) as a colorless oil.

E. 3-(2-Butylphenoxy)benzenepropanol

Lithium aluminum hydride (LAH) solution (2.52 mL, 1M in THF, 2.52 mmol) was added dropwise to a solution of Part D compound (820 mg, 2.52 mmol) in THF (8 mL) at 0°C under argon. Stirring was continued for 10 min. Methanol (5 mL) was added to destroy excess LAH. Ethyl ether (150 mL) was

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added and the organic layer was washed with 1N HCl solution (2 x 50 mL), H₂O (50 mL), saturated sodium bicarbonate solution (50 mL), and brine (50 mL), then dried over MgSO₄. Evaporation gave title
5 compound (620 mg, 87%) as a colorless oil.

F. 1-(2-Butylphenoxy)-3-(3-iodopropyl)-benzene

A solution of iodine (589 mg, 2.32 mmol) in
10 THF (2 mL) was added to a mixture of Part E alcohol (600 mg, 2.11 mmol), triphenylphosphine (607 mg, 2.32 mmol) and imidazole (287 mg, 4.22 mmol) in THF (10 mL). The reaction mixture was stirred at RT for 10 min, then diluted with hexane (150 ml). The
15 organic layer was washed with 10% sodium bisulfite (50 mL), saturated sodium bicarbonate (50 mL), brine (50 mL) and dried over MgSO₄. The solvent was evaporated to 100 ml volume, 5 g silica gel was added, and the mixture was evaporated to dryness.
20 Flash chromatography was performed on 100 g silica gel, loaded and eluted with hexane. Pure fractions were combined and evaporated to give title compound (720 mg, 87%) as a colorless oil.

25 G. 3-(2-Butylphenoxy)- α -(diethoxyphosphinyl)benzenebutanesulfonic acid, cyclohexyl ester

To a stirred suspension of sodium hydride (45.2 mg, 1.89 mmol) in DMF (2 mL) at 0°C under
30 argon, Example 1A Part B sulfonate (642 mg, 2.04 mmol) in DMF (2 mL) was added dropwise over 15 min. The ice bath was removed and the reaction mixture was stirred at RT for 30 min. The reaction mixture was recooled to 0°C and a solution of Part F



compound (620 mg, 1.57 mmol) in DMF (2 mL) was added dropwise over 15 min. The mixture was stirred at 0°C for 2 h. The ice bath was removed and the reaction mixture was stirred at RT overnight. The mixture was diluted with ethyl ether (150 mL) and washed with H₂O (50 mL), brine (50 mL) and dried over MgSO₄. Evaporation gave a crude oil. Purification was performed by flash chromatography on 150 g silica gel, loaded and eluted with 25% ethyl acetate in hexane. The pure fractions were combined and evaporated to provide title compound (650 mg, 71%) as a colorless oil.

H. 3-(2-Butylphenoxy)- α -phosphonobenzene-butanesulfonic acid, tripotassium salt

Ammonia gas was bubbled through a solution of Part G compound (650 mg, 1.12 mmol) in methanol (10 mL) until the solution was saturated. The sealed tube was heated at 70°C overnight. The reaction mixture was cooled to RT, evaporated to dryness and azeotroped with toluene (2 x 20 mL). To a stirred solution of the resulting residue in dichloromethane (10 mL) at RT under argon was added bromotrimethylsilane (1.10 mL, 7.84 mmol). The mixture was stirred at RT for 20 h. The solvent was evaporated and the residue was pumped at high vacuum for 2 h. The residue was dissolved in 1 M potassium hydroxide (8 mL, 8 mmol) and the reaction mixture was stirred for 2 h. The solution was lyophilized to give a white solid. The crude product was purified by chromatography on CHP20P gel (2.5 x 20 cm), loaded and eluted with water and followed by a gradient created by the gradual addition of CH₃CN to a reservoir of water. The

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combined pure fractions were concentrated to about 5 mL volume then lyophilized to provide title compound (350 mg, 56%) as a white solid.

5 IR (KBr) 2957, 2932, 1613, 1578, 1485, 1248, 1219, 1072, 964, 557 cm^{-1} .

MS (FAB, + ions) m/z 557 (M+H), 595 (M+K).

10 Anal. Calc'd for $\text{C}_{20}\text{H}_{24}\text{K}_3\text{O}_7\text{PS}$ + 1.8 equiv H_2O :
C, 40.77; H, 4.72; P, 5.26; S, 5.44.
Found: C, 40.84; H, 4.87; P, 5.10; S, 5.38.

Example 48

15 (E,E)-1-Fluoro-6,10,14-trimethyl-1-phosphono-5,9,13-pentadecatriene-1-sulfonic acid, tripotassium salt

20 A. (E,E)-1-(Diethoxyphosphinyl)-1-fluoro-5,9,13-pentadecatriene-1-sulfonic acid, cyclohexyl ester

To a suspension of 81 mg (2.0, mmol, 1.1 eq) of sodium hydride (as a 60% mineral oil dispersion) in 1 mL of THF at 0°C was added a solution of 1.0 g (1.8 mmol, 1 eq) of Example 1A Part C compound in 3 mL of THF. The bubbling solution was warmed to RT and stirred for 30 min, then cooled to -78°C. A solution of 721 mg (2.3 mmol, 1.25 eq) of N-fluorobenzenesulfonimide in 2 mL of THF was added over 2 min and the reaction was stirred at -78°C for 1 h, then warmed to RT and stirred for 2 h. The reaction was quenched by the addition of saturated ammonium chloride, then diluted with ether. The aqueous layer was extracted with ether

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and the combined organic solutions were stirred with 10% sodium thiosulfate for 30 min. The organic layer was washed with 10% KOH, dried and concentrated. Flash chromatography of the crude
5 product on silica gel (75 g) eluting with 25% ethyl acetate in hexane afforded 674 mg (65%) of title compound as a clear colorless oil.

TLC Silica gel (10% ether in CH_2Cl_2) $R_f=0.78$.

10

B. (E,E)-1-Fluoro-6,10,14-trimethyl-1-phosphono-5,9,13-pentadecatriene-1-sulfonic acid, tripotassium salt

To a solution of 660 mg (1.2 mmol, 1 eq) of
15 Part A compound in 10 mL of methanol at 0°C in a thick-walled, sealable tube was bubbled ammonia until the solution was saturated. The reaction tube was then sealed and heated at 75°C for 19 h. The reaction mixture was allowed to cool to RT and
20 concentrated. The oily residue was coevaporated once with toluene, then with 10% hexamethyldisilazane in toluene (2 x 10 mL) to afford a clear oil.

To a solution of the oil in 5 mL of dry
25 CH_2Cl_2 at RT was added 986 μL (4.7 mmol, 4 eq) of hexamethyldisilazane followed by 771 μL (5.8 mmol, 5 eq) of bromotrimethylsilane (TMSBr) dropwise over 1 min. After 22 h at RT, the reaction was concentrated and the resulting semisolid was placed
30 on high vacuum (0.25 mm Hg) for 1 h. The residue was dissolved by adding 4.7 mL (4 eq) of 1 M potassium hydroxide followed by 5 mL of water, frozen and lyophilized to afford an off-white lyophilate. The lyophilate was purified by MPLC on



a column of CHP20P (2.5 cm x 25 cm) eluting initially with 150 mL of water followed by a gradient formed by gradual addition of 400 mL of 50% acetonitrile in water to a reservoir containing 400 mL of water. Fractions containing pure product were pooled, concentrated, filtered, frozen and lyophilized. The lyophilate was dissolved in a minimum amount of water and concentrated. The resulting semisolid residue was triturated with acetone to afford, after high vacuum (0.025 mm Hg) removal of acetone remnants, 236 mg (60%) of a white solid.

TLC silica gel (5 : 4 : 1 n-propanol:ammonium hydroxide:water): $R_f=0.43$.

IR (KBr): 3426(br), 2969, 2926, 2857, 1663, 1451, 1213, 1101, 982 cm^{-1} .

Mass Spec (FAB, + ions): m/z 541 (M + H), 503 (M + 2H - K).

Anal. Calcd for $\text{C}_{18}\text{H}_{29}\text{O}_6\text{FPSK}_7 + 1.13 \text{ H}_2\text{O}$:

C, 38.53; H, 5.62; S, 5.71; P, 5.52

Found: C, 38.53; H, 5.87; S, 5.40; P, 5.38.

Example 49

(E,E)-1-[Bis[1-(1-Oxopropoxy)ethoxy]phosphinyl]-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, monopotassium salt

A. Propanoic acid, 1-chloroethyl ester

To freshly fused zinc chloride (50 mg) was added CH_2Cl_2 (20 mL) followed by propionyl chloride



(10.0 g, 108 mmol). The mixture was cooled to 10°C and acetaldehyde (6.0 mL, 108 mmol) was added over 5 min. The brown reaction was allowed to warm to RT, then stirred at that temperature overnight.

5 The reaction was diluted with CH₂Cl₂ (50 mL) and washed with 20% aqueous sodium acetate (20 mL). The organic layer was dried over MgSO₄ and evaporated to give a brown oil, which was distilled under high vacuum (0.5 torr) to give title compound

10 (1.48 g, 10%) in the form of a clear, colorless liquid. bp 28-31°C

B. (E,E)-1-[Bis[1-(1-Oxopropoxy)ethoxy]-phosphinyl]-6,10,14-trimethyl-5,9,13-

15 pentadecatriene-1-sulfonic acid, monopotassium salt.

A solution of Example 1B tripotassium salt (500 mg, 0.953 mmol) in water (3 mL) was added dropwise slowly via syringe pump at a rate of 0.24

20 mL/min to a solution of silver nitrate (586 mg, 3.44 mmol) in water (2 mL) at RT under argon. A white precipitate began to form immediately upon addition. The reaction was stirred at RT for 10 min, then filtered. The solid obtained was washed

25 with water (2 x 2 mL) and diethyl ether (2 mL), then pumped under high vacuum for 7 h to give 567 mg of a silver salt in the form of a white solid.

To a suspension of the silver salt prepared above in CH₂Cl₂ (2 mL) under argon in the dark at RT

30 was added 2,4,6-collidine (110 µL, 0.836 mmol) followed by a solution of Part A compound (568 mg, 4.18 mmol) in CH₂Cl₂ (1 mL). The reaction was stirred at RT for 6 h, filtered through Celite with the aid of CH₂Cl₂, then concentrated in vacuo to

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give an opaque oil. The crude material was dissolved in EtOAc (10 mL) and washed with 1N HCl (5 x 2 mL), saturated KHCO_3 (2 x 2 mL), and saturated KCl (2 mL), then dried over anhydrous KCl. Evaporation gave a pale yellow oil, which was chromatographed (2.5 x 20 cm CHP20P gel, 10 mL fractions, water elution followed by a gradient of acetonitrile in water). The product-containing fractions were combined and evaporated to give an opaque gum, which was dissolved in CH_2Cl_2 and dried over anhydrous KCl. Evaporation gave title compound (369 mg, 68%) as a colorless oil as a mixture of four diastereomers.

15 TLC (silica gel) (15:85 MeOH/ CH_2Cl_2): $R_f = 0.42$.

IR (neat) 2940, 2924, 1751, 1256, 1209, 1107, 1084, 1047, 978, 949 cm^{-1} .

20 Mass Spec (FAB, + ions) m/z 685 (M+K).

Anal. Calcd for $\text{C}_{28}\text{H}_{48}\text{KO}_{10}\text{PS}$:

C, 51.99; H, 7.48; P, 4.79; S, 4.96.

Found: C, 51.69; H, 7.49; P, 4.44; S, 5.92.

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The following additional examples may be prepared employing procedures set out hereinbefore including in the working Examples.

- 5 50. (E)-6-methyl-10-phenyl-1-phosphono-5-decene-1-sulfonic acid, tripotassium salt;
Mas Spec (FAB, + ions) m/z 519 (M+H), 481
(M+2H-K).
Anal. Calcd for $C_{18}H_{26}O_6SPK_3+1.3 H_2O$:
10 C, 39.82; H, 5.33; P, 5.70; S, 5.90
Found: C, 39.82; H, 5.63; P, 5.49; S, 5.65.
51. (E)-9-cyclopentyl-6-methyl-1-phosphono-5-nonene-1-sulfonic acid, tripotassium salt;
15 Mass Spec (Ion Spray, + ions) m/z 445 (M-K+2H), 483
(M+H).
Anal. Calcd for $C_{15}H_{26}O_6SPK_3+0.70 H_2O$:
 C, 36.39; H, 5.57; P, 6.26; S, 6.48
Found: C, 36.60; H, 5.98; P, 5.92; S, 6.23.
- 20 52. α -phosphono-4'-methyl[1,1'-biphenyl]-4-butanesulfonic acid, tripotassium salt;
Mass Spec (electrospray, CH_3CN , NH_3 , + ions) m/z
508
25 (M-3K+4H+3 CH_3CN), 467 (M-3K+4H+2 CH_3CN), 461
(M-K+2H), 443 (M-3K+3H+ NH_4 + CH_3CN), 426
(M-3K+4H+ CH_3CN), 423 (M+H-2K), 402 (M-3K+3H+ NH_4),
385 (M-3K+4H).
Anal. Calcd for $C_{17}H_{18}K_3O_6PS+1.4 H_2O$:
30 C, 38.98; H, 4.00; P, 5.91; S, 6.12
Found: C, 39.32; H, 4.03; P, 6.12; S, 5.73.
53. α -phosphono-4-(3-propylphenoxy)-benzene-butanesulfonic acid, tripotassium salt;



Mass Spec (FAB, + ions) m/z 429 (M+4H-3K), 467 (M+3H-2K), 505 (M+2H-K), 543 (M+H).

Anal. Calcd for $C_{19}H_{22}K_3O_7PS+0.5 H_2O$:

C, 41.36; H, 4.20; P, 5.61; S, 5.81

5 Found: C, 41.17; H, 3.96; P, 5.40; S, 5.98.

54. 4'-ethyl- α -phosphono[1,1'-biphenyl]-4-butanesulfonic acid, tripotassium salt;

10 Mass Spec (FAB, + ions) m/z 551 (M+K), 513 (M+H), 475 (M-K+2H).

Anal. Calcd for $C_{18}H_{20}K_3O_6PS+1.2 H_2O$:

C, 40.48; H, 4.22; P, 5.80; S, 6.00

Found: C, 40.17; H, 4.32; P, 5.97; S, 6.45.

15 55. 4'-chloro- α -phosphono[1,1'-biphenyl]-4-butanesulfonic acid, tripotassium salt;

Mass Spec (FAB, + ions) m/z 557/9 (M+K), 519/21 (M+H), 481/3 (M-K+2H).

Anal. Calcd for $C_{16}H_{15}ClK_3O_6PS+0.75 H_2O$:

20 C, 36.10; H, 3.12; Cl, 6.66; P, 5.82; S, 6.02

Found: C, 35.88; H, 3.02; Cl, 6.88; P, 5.62; S, 6.42.

25 56. 14-methyl-1-phosphono-13-pentadecene-1-sulfonic acid, tripotassium salt;

Mass Spec (FAB, + ions) m/z 537 (M+K), 499 (M+H), 461 (M-K+2H).

Anal. Calcd for $C_{16}H_{30}O_6SPK_3 + 2.3 H_2O$:

30 C, 35.63; H, 6.45; P, 5.74; S, 5.94

Found: C, 35.63; H, 6.27; P, 5.71; S, 6.14.

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57. 4-(phenylthio)- α -phosphonobenzene-
butane-sulfonic acid, tripotassium salt;

Mass Spec (FAB, + ions) m/z 441 (M+3H-2K), 479
(M+2H-K), 517 (M+H).

5 Anal. Calcd for $C_{16}H_{16}K_3O_6PS_2+1.6 H_2O$:

C, 35.23; H, 3.55; P, 5.68; S, 11.76

Found: C, 34.89; H, 3.79; P, 5.46; S, 12.19.

58. α -phosphono-4-propylbenzeneoctane-
10 sulfonic acid, tripotassium salt;

Mass Spec (electrospray, + ions) m/z 427 [(M+3H-
3K)+NH₃+NH₄], 448 [(M+2H-2K)+NH₄], 469 (M+2H-K).

Anal. Calcd for $C_{17}H_{26}K_3O_6PS+1.0 H_2O$:

C, 38.91; H, 5.38; P, 5.90; S, 6.11

15 Found: C, 39.22; H, 5.27; P, 5.50; S, 6.14.

59. α -phosphono-3-(4-propylphenoxy)-
benzene-butanefulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 505 (M-K+2H), 543
20 (M+H), 581 (M+K).

Anal. Calcd for $C_{19}H_{22}K_3O_7PS+1.4 H_2O$:

C, 40.18; H, 4.40; P, 5.45; S, 5.65

Found: C, 40.16; H, 4.72; P, 5.42; S, 6.06.

25 60. 4-[3-(2-methyl-1-propenyl)phenoxy]- α -
phosphonobenzenefulfonic acid, tripotassium
salt;

Mass Spec (FAB, + ions) m/z 517 (M-K+2H), 555
(M+H), 593 (M+K).

30 Anal. Calcd for $C_{20}H_{22}K_3O_7PS+1.0 H_2O$:

C, 41.94; H, 4.22; P, 5.42; S, 5.60

Found: C, 42.01; H, 4.10; P, 5.53; S, 5.57.

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61. (10S)-10,14-dimethyl-1-phosphono-13-pentadecene-1-sulfonic acid, dipotassium salt;
Mass Spec (FAB, + ions) m/z 513 (M+H), 457 (M+2H-K), 437 (M+3H-2K).

5 Anal. Calcd for $C_{17}H_{33}O_6PSK_2 + 2.0 H_2O$:

C, 39.98; H, 7.30; P, 6.06; S, 6.28

Found: C, 39.92; H, 6.99; P, 5.89; S, 6.27.

10 62. (E,E)-1-phosphono-3-[(3,7,11-trimethyl-2,6,10-dodecatrienyl)oxy]-1-propanesulfonic acid, tripotassium salt;

Mass Spec (FAB), + ions) m/z 577 (M+K), 539 (M+H).

Anal. Calcd for $C_{18}H_{30}O_7PSK_3 + 1.25 H_2O$:

C, 38.51; H, 5.84; P, 5.52; S, 5.94

15 Found: C, 38.51; H, 5.95; P, 5.18; S, 5.52.

63. (E,E)-6,10,14-trimethyl-1-phosphono-5,9,13-pentadecatriene-1-sulfonic acid, 4-(methylthio)phenyl ester, dipotassium salt;

20 Mass Spec (FAB, + ions) m/z 645 (M+K), 607 (M+H).

Anal. Calcd for $C_{25}H_{37}O_6PS_2K_2 + 4.6 H_2O$:

C, 43.53; H, 6.75; P, 4.49; S, 9.30

Found: C, 43.16; H, 6.25; P, 4.26; S, 9.53.

25 64. 4-(3-methylphenoxy)- α -phospho-benzenebutanesulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 515 (M+H), 553 (M+K).

Anal. Calcd for $C_{17}H_{18}K_3O_7PS + 2.1 H_2O$:

C, 36.96; H, 4.05; P, 5.61; S, 5.80

30 Found: C, 36.94; H, 4.40; P, 5.49; S, 5.94.

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65. (E,E)-1-[bis[[(cyclohexylacetyl)oxy]-methoxy]phosphinyl]-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, monopotassium salt;

5 Mass Spec (FAB, + ions) m/z 793 (M+K).

Anal. Calcd for $C_{36}H_{60}KO_{10}PS$:

C, 57.27; H, 8.01; P, 4.10; S, 4.25

Found: C, 57.06; H, 8.03; P, 4.01; s, 4.56.

10 66. (E,E)-1-[bis[(benzoyloxy)methoxy]phosphinyl]-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, monopotassium salt;

Mass Spec (FAB, + ions) m/z 753 (M+K).

Anal. Calcd for $C_{34}H_{44}PSO_{10}K+0.53 H_2O$:

15 C, 56.37; H, 6.27; P, 4.28; S, 4.43

Found: C, 56.37; H, 6.32; P, 4.37; S, 4.32.

67. 4-(benzoylphenylamino)- α -phosphonobenzene-butanesulfonic acid, tripotassium salt;

20 Mass Spec (FAB, + ions) m/z 642 (M+K), 604 (M+H), 566 (M-K+2H).

Anal. Calcd for $C_{23}H_{21}NO_7SPK_3+4.0 H_2O$:

C, 40.88; H, 4.33; N, 2.07; P, 4.58;

S, 4.74

25 Found: C, 40.71; H, 4.28; N, 2.12; P, 4.76; S, 4.87.

68. 3-(benzoylphenylamino)- α -phosphonobenzene-butanesulfonic acid, tripotassium salt;

30 Mass Spec (FAB, + ions) m/z 642 (M+K), 604 (M+H), 566 (M-K+2H).

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Anal. Calcd for $C_{23}H_{21}NO_7SPK_3 + 2.50 H_2O$:

C, 42.58; H, 4.04; N, 2.16; P, 4.77;
S, 4.94

Found: C, 42.73; H, 4.24; N, 2.47; P, 4.56;
S, 4.88.

5

69. 4-(phenylamino)- α -phosphonobenzene-
butanesulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 538 (M+K), 500 (M+H),
462 (M-K+2H).

Anal. Calcd for $C_{16}H_{17}NO_6SPK_3 + 2.0 H_2O$:

C, 35.87; H, 3.95; N, 2.61; P, 5.78

Found: C, 36.08; H, 3.96; N, 2.47; P, 5.61.

10

15

70. 3-(phenylamino)- α -phosphonobenzene-
butane-sulfonic acid, tripotassium salt;
Mass spec (FAB, + ions) m/z 538 (M+K), 500 (M+H),
462 (M-K+2H).

Anal. Calcd for $C_{16}H_{17}NO_6SPK_3 + 1.0 H_2O$:

C, 37.12; H, 3.70; N, 2.71; P, 5.98;
S, 6.19

Found: C, 36.97; H, 3.99; N, 2.47; P, 5.98;
S, 6.14

20

25

71. 4-(phenylsulfinyl)- α -phosphonobenzene-
butanesulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 457 (M-2K+3H), 495
(M-K+2H), 533 (M+H).

Anal. Calcd for $C_{16}H_{16}K_3O_7PS_2 + 1.2 H_2O$:

C, 34.67; H, 3.35; P, 5.59; S, 11.57

Found: C, 34.68; H, 3.23; P, 5.27; S, 11.41

30

72. 4-(2-methylphenoxy)- α -phosphono-
benzenebutanesulfonic acid, tripotassium salt;

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Mass Spec (FAB, + ions) m/z 477 (M-K+2H), 515
(M+H), 553 (M+K).

Anal. Calcd for $C_{17}H_{18}K_3O_7PS+2.3 H_2O$:

C, 36.72; H, 4.10; P, 5.57; S, 5.77

5 Found: C, 36.72; H, 3.91; P, 5.51; S, 5.54

73.4-phenoxy- α -phosphonobenzenepentane-
sulfonic acid, tripotassium salt;

10 Mass Spec (FAB, + ions) m/z 476 (M-K+2H), 515
(M+H), 553 (M+K).

Anal. Calcd for $C_{17}H_{18}K_3O_7PS+1.3 H_2O$:

C, 37.95; H, 3.86; P, 5.76; S, 5.96

Found: C, 38.15; H, 4.26; P, 5.63; S, 6.48

15 74. 4-(2-Fluorophenoxy)- α -phosphono-
benzenebutanesulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 481 (M-K+2H), 519
(M+H), 557 (M+K).

Anal. Calcd for $C_{16}H_{15}FK_3O_7PS+2.6 H_2O$:

20 C, 33.99; H, 3.60; P, 5.48; S, 5.67

Found: C, 34.14; H, 3.34; P, 5.53; S, 5.27

75. 4-(2-methoxyphenoxy)- α -phosphono-
benzenebutanesulfonic acid, tripotassium salt;
25 Mass Spec (FAB, + ions) m/z 493 (M-K+2H), 531
(M+H), 569 (M+K).

Anal. Calcd for $C_{17}H_{18}K_3O_8PS+2.6 H_2O$:

C, 35.36; H, 4.05; P, 5.36; S, 5.55

Found: C, 35.37; H, 3.81; P, 5.46; S, 5.47

30 76. (E,E)-1-[bis[[(1-oxoheptyl)oxy]-
methoxy]-phosphinyl]-6,10,14-trimethyl-5,9,13-
pentadecatriene-1-sulfonic acid, monopotassium
salt;



Mass Spec (FAB, + ions) m/z 769 (M+K), 731 (M+H).

Anal. Calcd for $C_{34}H_{60}PSO_{10}K+0.06 H_2O$:

C, 55.79; H, 8.28; P, 4.23; S, 4.38

Found: C, 55.79; H, 8.38; P, 4.31; S, 4.00

5

77. 4-[(4-bromophenyl)thio]- α -phosphono-benzenebutanesulfonic acid, tripotassium salt;

Mass Spec HRMS (FAB, + ions) calcd for

$C_{16}H_{17}^{79}BrK_2O_6PS_2$: 556.8662 (M-K+2H)

10 Found: 556.8691

Anal. Calcd for $C_{16}H_{15}BrK_3O_6PS_2+1.8 H_2O$:

C, 30.60; H, 2.99; P, 4.93; S, 10.21

Found: C, 30.89; H, 3.06; P, 4.54; S, 10.16

15

78. 4-(phenylsulfonyl)- α -phosphonobenzene-butanesulfonic acid, tripotassium salt;

Mass Spec (FAB, + ions) m/z 473 (M-2K+3H), 511

(M-K+2H), 549 (M+H), 587 (M+K).

Anal. Calcd for $C_{16}H_{16}K_3O_8PS_2+2.6 H_2O$:

20 C, 32.27; H, 3.59; P, 5.20; S, 10.77

Found: C, 32.63; H, 3.54; P, 4.80; S, 9.55

79. 4-phenoxy- α -phosphonobenzenepropane-sulfonic acid, tripotassium salt;

25 Mass Spec (FAB, + ions) m/z 449 (M-K+2H), 487

(M+H), 525 (M+K).

Anal. Calcd for $C_{15}H_{14}K_3O_7PS+1.3 H_2O$:

C, 35.34; H, 3.28; P, 6.08; S, 6.29

Found: C, 35.34; H, 3.49; P, 5.92; S, 6.48

30

80. 6-methyl-9-phenyl- α -phosphono-5-nonene-1-sulfonic acid, tripotassium salt;

Mass Spec (FAB, + ions) m/z 529 (M+K), 491 (M+H).

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Anal. Calcd for $C_{16}H_{22}PSO_6K_3 + 3.6 H_2O$:

C, 34.62; H, 5.29; P, 5.58; S, 5.78

Found: C, 34.29; H, 5.01; P, 5.60; S, 5.74

5 81. (E,E)-1-[bis[(2-methyl-1-oxopropoxy)-methoxy]phosphinyl]-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, monopotassium salt; Mass Spec (FAB, + ions) m/z 685 (M+K).

Anal. Calcd for $C_{28}H_{48}PSO_{10}K + 1.0 H_2O$:

10 C, 50.54; H, 7.58; P, 4.51; S, 4.82

Found: C, 50.54; H, 7.47; P, 4.51; S, 4.85

 82. 4-(2-butylphenoxy)- α -phosphonobenzene-butan-sulfonic acid, tripotassium salt;

15 Mass Spec (FAB, + ions) m/z 519 (M-K+2H), 557 (M+H), 595 (M+K).

Anal. Calcd for $C_{20}H_{24}K_3O_7PS + 1.3 H_2O$:

C, 41.36; H, 4.63; P, 5.33; S, 5.52

Found: C, 41.36; H, 4.98; P, 5.04; S, 5.54

20 83. (E)-6-methyl-7-(4-methylphenoxy)-1-phosphono-5-heptene-1-sulfonic acid, tripotassium salt; Mass Spec (FAB, + ions) m/z 531 (M+K), 493 (M+H), 455 (M-K+2H).

25 Anal. Calcd for $C_{15}H_{20}O_7PSK_3 + 2.1 H_2O$:

C, 33.96; H, 4.60; P, 5.84; S, 6.04

Found: C, 34.34; H, 5.00; P, 6.11; S, 5.81

 84. (E)-6-methyl-8-(4-methylphenyl)-1-phosphono-5-octenyl-1-sulfonic acid, tripotassium salt;

30 Mass Spec (FAB, + ions) m/z 529 (M+K), 491 (M+H), 453 (M-K+2H).

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Anal. Calcd for $C_{16}H_{22}O_6PSK_3 + 1.74 H_2O$:

C, 36.82; H, 4.92; P, 5.93; S, 6.14

Found: C, 36.82; H, 5.35; P, 5.98; S, 6.11

- 5 85. (E)-6-methyl-7-(3-methylphenoxy)-1-phosphono-5-heptene-1-sulfonic acid, tripotassium salt;

Mass Spec (FAB, + ions) 531 (M+K), 493 (M+H), 455 (M-K+2H).

- 10 Anal. Calcd for $C_{15}H_{20}O_7PSK_3 + 0.85 H_2O$:

C, 35.47; H, 4.30; P, 6.10; S, 6.31

Found: C, 35.91; H, 4.73; P, 6.34; S, 6.42

- 15 86. 4-(1-naphthalenyl)- α -phosphonobenzene-butan-sulfonic acid, tripotassium salt;

Mass Spec (FAB, + ions) m/z 535 (M+H), 497 (M-K+2H), 459 (M-2K+3H).

Anal. Calcd for $C_{20}H_{18}K_3O_6PS + 2.24 H_2O$:

C, 41.77; H, 3.94; S, 5.58; P, 5.39

- 20 Found: C, 42.17; H, 4.38; S, 5.24; P, 5.50

- 25 87. 4-(2,6-dimethylphenoxy)- α -phospho-benzenebutanesulfonic acid, tripotassium salt;

Mass Spec (FAB, + ions) m/z 491 (M-K+2H), 529 (M+H), 567 (M+K).

Anal. Calcd for $C_{18}H_{20}K_3O_7PS + 2.9 H_2O$:

C, 37.17; H, 4.48; P, 5.32; S, 5.51

Found: C, 37.17; H, 4.44; P, 5.12; S, 5.91

- 30 88. 3-(3-methylphenoxy)- α -phospho-benzenebutanesulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 553 (M+K), 515 (M+H).

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Anal. Calcd for $C_{17}H_{18}K_3O_7PS + 1.5 H_2O$:

C, 37.69; H, 3.91; P, 5.72; S, 5.92

Found: C, 37.74; H, 3.92; P, 5.78; S, 6.24

- 5 89. (E)-6,10-dimethyl-1-phosphono-5,9-pentadecadiene-1-sulfonic acid, tripotassium salt; Mass Spec (FAB, + ions) m/z 549 (M+K), 511 (M+H), 473 (M+2H-K).

Anal. Calcd for $C_{17}H_{30}O_6PSK_3 + 0.35 H_2O$:

10 C, 39.49; H, 5.98; P, 5.99; S, 6.20

Found: C, 39.51; H, 6.16; P, 5.17; S, 5.98

90. 4-(2-benzofuranyl)- α -phosphonobenzene-butanefulfonic acid, tripotassium salt; Mass Spec m/z (FAB, + ions) 525 (M+H), 487 (M-K+2H), 449 (M-2K+3H).

Anal. Calcd for $C_{18}H_{16}K_3PO_7PS + 4.5 H_2O$:

C, 35.66; H, 4.17; P, 5.11; S, 5.29

Found: C, 35.66; H, 4.18; P, 4.83; S, 4.95

- 20 91. α -phosphono-4'-propyl[1,1'-biphenyl]-4-pentanesulfonic acid, tripotassium salt; Mass Spec (FAB, + ions) m/z 541 (M+H), 503 (M+2H-K), 465 (M+3H-2K).

25 Anal. Calcd for $C_{20}H_{24}O_6PSK_3 + 1.26 H_2O$:

C, 42.64; H, 4.47; P, 5.50; S, 5.69

Found: C, 42.64; H, 5.11; P, 5.20; S, 5.90

92. 3-(2-methylphenoxy)- α -phospho-benzenebutanefulfonic acid, tripotassium salt; Mass Spec (FAB, + ions) m/z 515 (M+H), 553 (M+K) Anal. Calcd for $C_{17}H_{18}K_3O_7PS + 1.7 H_2O$:

C, 37.45; H, 3.96; P, 5.68; S, 5.88

Found: C, 37.49; H, 4.07; P, 5.66; S, 6.00

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93. α -[bis[(2,2-dimethyl-1-oxopropoxy)-methoxy]phosphinyl]-3-phenoxybenzenebutanesulfonic acid, monopotassium salt;
- 5 Mass Spec (FAB, + ions) m/z 653 (M+H), 691 (M+K).
Anal. Calcd for $C_{28}H_{38}KO_{10}PS$:
C, 51.52; H, 5.87; P, 4.75; S, 4.91
Found: C, 51.33; H, 5.62; P, 4.54; S, 4.75
- 10 94. 11-phenyl-1-phosphono-1-undecane-sulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 545 (M+K), 507 (M+H), 469 (M+2H-K).
Anal. Calcd for $C_{17}H_{26}K_3O_6PS+0.5 H_2O$:
15 C, 39.59; H, 5.28; P, 6.01; S, 6.22
Found: C, 39.61; H, 5.44; P, 5.77; S, 6.46
95. α -phosphonobenzeneoctanesulfonic acid, tripotassium salt;
- 20 Mass Spec (FAB, + ions) m/z 503 (M+K), 465 (M+H).
Anal. Calcd for $C_{14}H_{20}K_3O_6PS+2.2 H_2O$:
C, 33.34; H, 4.88; P, 6.14; S, 6.36
Found: C, 33.34; H, 4.94; P, 5.99; S, 6.17
- 25 96. 1-phosphono-7-(4-pentylphenoxy)-1-heptanesulfonic acid, tripotassium salt;
Mass Spec (ion spray, + ions) m/z 464 (M+4H-3K+CH₃CN), 461 (M+3H-2K), 423 (M+4H-3K).
Anal. Calcd for $C_{18}H_{28}K_3O_7PS+1.34 H_2O$:
30 C, 38.55; H, 5.51; P, 5.52; S, 5.72
Found: C, 38.55; H, 5.66; P, 5.11; S, 6.01
97. α -phosphono-3'-propyl[1,1'-biphenyl]-4-butanesulfonic acid, tripotassium salt;



Mass Spec (FAB, + ions) m/z 565 (M+K), 527 (M+H),
489 (M-K+2H), 451 (M-2K+3H)

Anal. Calcd for $C_{19}H_{22}O_6PSK_3+1.0 H_2O$:

C, 41.84; H, 4.45; S, 5.88; P, 5.68

5 Found: C, 41.84; H, 4.74; S, 6.14; P, 5.30

98. 4-(4-methylphenoxy)- α -phosphonobenzene-
butanesulfonic acid, tripotassium salt;

Mass Spec (FAB, + ions) m/z 553 (M+K), 515 (M+H),

10 477 (M+2H-K)

Anal. Calcd for $C_{17}H_{18}K_3O_7PS+1.7 H_2O$:

C, 37.45; H, 3.96; P, 5.68; S, 5.88

Found: C, 37.38; H, 3.79; P, 5.38; S, 6.24

15 99. (E,E)-4,8,12-trimethyl-1-phosphono-
3,7,11-tridecatriene-1-sulfonic acid, tripotassium
salt;

Mass Spec (FAB, + ions) m/z 533 (M+K), 495 (M+H),
457 (M+2H-K)

20 Anal. Calcd for $C_{16}H_{26}PSO_6K_3+1.00 H_2O$:

C, 37.49; H, 5.50; P, 6.04; S, 6.25

Found: C, 37.40; H, 5.54; P, 6.08; S, 6.69

25 100. (E)-6-methyl-7-phenoxy-1-phosphono-5-
heptenyl-1-sulfonic acid, tripotassium salt;

Mass Spec (FAB, + ions) m/z 517 (M+K), 479 (M+H),
441 (M-K+2H)

Anal. Calcd for $C_{14}H_{18}O_7PSK_3+2.0 H_2O$:

C, 32.67; H, 4.31; P, 6.02; S, 6.23

30 Found: C, 32.28; H, 4.25; P, 5.78; S, 6.11

101. (E)-6-methyl-7-(4-propylphenoxy)-1-
phosphono-5-heptene-1-sulfonic acid, tripotassium
salt;

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Mass Spec (FAB, + ions) m/z 521 (M+H), 483
(M-K+2H), 445 (M-2K+3H)

Anal. Calcd for $C_{17}H_{25}O_7PSK_2+1.85 H_2O$:

C, 39.57; H, 5.61; P, 6.00; S, 6.21

5 Found: C, 39.18; H, 5.23; P, 6.14; S, 6.41

102. (E)-6-methyl-8-(3-methylphenyl)-1-phosphono-5-octenyl-1-sulfonic acid, tripotassium salt;

10 Mass Spec (FAB, + ions) m/z 529 (M+K), 491 (M+H),
453 (M-K+2H)

Anal. Calcd for $C_{16}H_{22}O_6PSK_3+1.03 H_2O$:

C, 37.74; H, 4.76; P, 6.08; S, 6.30

Found: C, 37.99; H, 5.21; P, 5.90; S, 6.60

15

103. (E)-6-methyl-1-phosphono-7-(3-propylphenoxy)-5-heptene-1-sulfonic acid, tripotassium salt;

20 Mass Spec (FAB, + ions) m/z 521 (M+H), 483 (M-K+2H), 445 (M-2K+3H), 407 (M-3K+4H)

Anal. Calcd for $C_{17}H_{24}O_7PSK_3+0.64 H_2O$:

C, 38.37; H, 4.79; P, 5.82; S, 6.02

Found: C, 38.37; H, 5.12; P, 5.83; S, 5.81

25

104. (E)-6-methyl-7-(2-methylphenoxy)-1-phosphono-5-heptene-1-sulfonic acid, tripotassium salt;

Mass Spec (FAB, + ions) m/z 531 (M+K), 493 (M+H),
455 (M-K+2H)

30 Anal. Calcd for $C_{15}H_{20}O_7PSK_3+1.46 H_2O$:

C, 34.72; H, 4.45; P, 5.97; S, 6.18

Found: C, 34.72; H, 4.90; P, 5.58; S, 5.92

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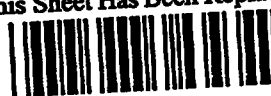


105. (E,E)-6,10,14-trimethyl-1-phosphono-5,9-pentadecadiene-1-sulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 563 (M+K), 525 (M+H),
5 487 (M+2H-K)
Anal. Calcd for $C_{18}H_{32}O_6PSK_3+2.0 H_2O$:
C, 38.55; H, 6.47; P, 5.52; S, 5.72
Found: C, 38.93; H, 6.87; P, 5.62; S, 5.49
- 10 106. 4'-phenoxy- α -phosphono[1,1'-biphenyl]-butanesulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 577 (M+H), 539 (M-K+2H), 501 (M-2K+3H)
Anal. Calcd for $C_{22}H_{30}K_3O_7PS+1.6 H_2O$:
15 C, 43.64; H, 3.86; P, 5.11; S, 5.29
Found: C, 43.73; H, 3.97; P, 4.71; S, 5.30
107. α -phosphono-4'-propyl[1,1'-biphenyl]-4-propanesulfonic acid, tripotassium salt;
20 Mass Spec (FAB, + ions) m/z 551 (M+K), 513 (M+H), 475 (M-K+2H)
Anal. Calcd for $C_{18}H_{20}K_3O_6PS+4.1 H_2O$:
C, 36.90; H, 4.84; P, 5.29; S, 5.47
Found: C, 36.90; H, 4.68; P, 5.05; S, 5.67
- 25 108. 3-(4-methylphenoxy)- α -phospho-benzenebutanesulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 477 (M-K+2H), 515 (M+H), 553 (M+K)
30 Anal. Calcd for $C_{17}H_{18}K_3O_7PS+2.1 H_2O$:
C, 36.96; H, 4.05; P, 5.61; S, 5.80
Found: C, 37.27; H, 4.42; P, 5.43; S, 5.42



109. (E)-8-phenyl-1-phosphono-5-octene-1-sulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 501 (M+K), 463 (M+H), 425 (M-K+2H)
- 5 Anal. Calcd for $C_{14}H_{18}O_6PSK_3+3.0 H_2O$:
C, 32.50; H, 4.69; P, 5.99; S, 6.20
Found: C, 32.50; H, 4.73; P, 6.03; S, 6.40
110. 2'-methoxy- α -phosphono-4'-propyl[1,1'-biphenyl]-4-butanesulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 519 (M+2H-K), 481 (M+3H-2K)
- 10 Anal. Calcd for $C_{20}H_{24}K_3O_7PS+2.3 H_2O$:
C, 40.16; H, 4.82; P, 5.18; S, 5.36
15 Found: C, 40.14; H, 4.83; P, 4.79; S, 5.44
111. (E,E)-6,10-dimethyl-12-phenyl-1-phosphono-5,9-dodecadiene-1-sulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 583 (M+K), 545 (M+H), 507 (M+2H-K)
- 20 Anal. Calcd for $C_{20}H_{28}O_6PSK_3+0.8 H_2O$:
C, 42.96; H, 5.34; P, 5.54; S, 5.73
Found: C, 42.96; H, 5.74; P, 5.65; S, 5.72
- 25 112. (E)-6-methyl-7-(phenylthio)-1-phosphono-5-heptenyl-1-sulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 533 (M+K), 495 (M+H), 457 (M-K+2H), 419 (M-2K+3H)
- 30 Anal. Calcd for $C_{14}H_{18}O_6PS_2K_3+3.8 H_2O$:
C, 29.87; H, 4.58; P, 5.50; S, 11.39
Found: C, 29.87; H, 4.73; P, 5.48; S, 11.52

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113. 3-phenoxy- α -phosphonobenzenepropane-sulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 499 (M+2H-K), 487 (M+H), 525 (M+K)
5 Anal. Calcd for $C_{15}H_{14}K_3O_7PS+1.6 H_2O$:
C, 34.95; H, 3.36; P, 6.01; S, 6.22
Found: C, 34.91; H, 3.31; P, 5.93; S, 6.23
114. 2'-(methoxymethoxy)- α -phosphono-4'-propyl[1,1'-biphenyl]-4-butanesulfonic acid, tripotassium salt;
10 Mass Spec (FAB, + ions) m/z 625 (M+K), 586 (M+H), 549 (M+2H-K)
Anal. Calcd for $C_{21}H_{26}K_3O_8PS+2.4 H_2O$:
15 C, 40.03; H, 4.93; P, 4.92; S, 5.09
Found: C, 40.03; H, 5.03; P, 4.80; S, 5.42
115. 2'-hydroxy- α -phosphono-4'-propyl[1,1'-biphenyl]-4-butanesulfonic acid, tripotassium salt;
20 Mass Spec (FAB, + ions) m/z 581 (M+K), 543 (M+H), 467 (M+2H-K)
Anal. Calcd for $C_{19}H_{22}PSO_7K_3+2.7 H_2O$:
C, 38.59; H, 4.67; P, 5.24; S, 5.42
Found: C, 38.59; H, 4.58; P, 5.07; S, 5.56
25
116. α -phosphono-4'-(2-pyridinyl)[1,1'-biphenyl]-butanesulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 562 (M+H), 524 (M-K+2H), 486 (M-2K+3H)
30 Anal. Calcd for $C_{21}H_{19}NO_6PSK_3+2.5 H_2O$:
C, 41.57; H, 3.99; N, 2.31; P, 5.10; S, 5.28
Found: C, 41.48; H, 3.90; N, 2.40; P, 4.78; S, 5.27



117. (E)-6-methyl-7-phenyl-1-phosphono-5-heptene-1-sulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 501 (M+K), 463 (M+H), 425 (M-K+2H)

5 Anal. Calcd for $C_{14}H_{18}O_6PSK_3+2.9 H_2O$:

C, 32.67; H, 4.66; P, 6.02; S, 6.23

Found: C, 32.67; H, 4.63; P, 6.13; S, 6.02

118. α -fluoro-3-phenoxy- α -phosphonobenzene-
10 butanesulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 519 (M+H), 481 (M+2H-K), 440 (M+3H-2K)

Anal. Calcd for $C_{16}H_{15}FO_7PSK_3+1.4 H_2O$:

C, 35.33; H, 3.30; P, 5.69; S, 5.89

15 Found: C, 35.73; H, 3.71; P, 5.77; S, 6.09

119. (E)-6 methyl-8-(2-methylphenyl)-1-phosphono-5-octene-1-sulfonic acid, tripotassium salt;
20 Mass Spec (FAB, + ions) m/z 529 (M+K), 491 (M+H), 453 (M-K+2H)

Anal. Calcd for $C_{16}H_{22}PSO_6K_3+2.2 H_2O$:

C, 36.21; H, 5.02; P, 5.84; S, 6.04

Found: C, 36.29; H, 4.96; P, 5.44; S, 6.40

25

120. 3-(2-naphthalenyloxy)- α -phosphonobenzenebutanesulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 513 (M-K+2H), 551 (M+H), 589 (M+K)

30 Anal. Calcd for $C_{20}H_{18}K_3O_7PS+3.8 H_2O$:

C, 38.80; H, 4.17; P, 5.00; S, 5.18

Found: C, 38.69; H, 4.04; P, 5.10; S, 4.96

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121. (E)-6-methyl-1-phosphono-8-(4-propyl-phenyl)-5-octene-1-sulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 557 (M+K), 519 (M+H),
5 481 (M-K+2H)
Anal. Calcd for $C_{18}H_{26}PSO_6K_3 + 3.36 \text{ mol } H_2O$:
C, 37.32; H, 5.69; P, 5.35; S, 5.53
Found: C, 37.32; H, 5.68; P, 5.46; S, 5.66
- 10 122. (E)-8-(3-methoxyphenyl)-6-methyl-1-phosphono-5-octene-1-sulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 545 (M+K), 507 (M+H),
469 (M-K+2H)
15 Anal. Calcd for $C_{16}H_{22}PSO_7K_3 + 2.3 \text{ } H_2O$:
C, 35.04; H, 4.90; P, 5.65; S, 5.85
Found: C, 35.04; H, 5.19; P, 5.54; S, 5.41
- 20 123. α -phosphono-4'-(1-piperidinyl)[1,1'-biphenyl]-4-butanesulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 606 (M+K), 568 (M+H),
530 (M-K+2H), 492 (M-2K+3H)
Anal. Calcd for $C_{21}H_{25}K_3NO_6PS + 2.7 \text{ } H_2O$:
C, 40.92; H, 4.97; N, 2.27; P, 5.02; S, 5.20
25 Found: C, 40.93; H, 4.96; N, 2.00; P, 4.93; S, 5.53
124. ζ -methyl- α -phosphono-4-propylbenzene-octanesulfonic acid, tripotassium salt;
Mass Spec (Electrospray, - ions) m/z 405 (M-3K+2H)
30 Anal. Calcd for $C_{18}H_{28}O_6PSK_3 + 1.92 \text{ } H_2O$:
C, 38.93; H, 5.78; P, 5.58; S, 5.77
Found: C, 38.93; H, 6.05; P, 5.45; S, 5.90

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125. ζ ,2-dimethyl- α -phosphonobenzeneoctane-sulfonic acid, tripotassium salt;

Mass Spec (Electrospray, - ions) m/z 377 (M-3K+2H)

Anal. Calcd for $C_{16}H_{24}O_6PSK_3+1.2 H_2O$:

5 C, 37.37; H, 5.17; P, 6.23; S, 6.02

Found: C, 37.87; H, 5.65; P, 6.10; S, 5.80

126. 3-(1-naphthalenyloxy)- α -phosphonobenzenebutanesulfonic acid, tripotassium salt;

10 Mass Spec (FAB, + ions) m/z 475 (M-2K+3H), 513 (M-K+2H), 551 (M+H), 589 (M+K)

Anal. Calcd for $C_{20}H_{18}K_3O_7PS+2.5 H_2O$:

C, 40.32; H, 3.89; P, 5.20; S, 5.38

Found: C, 40.42; H, 4.17; P, 5.41; S, 5.09

15

127. 3-(cyclohexyloxy)- α -phosphonobenzenebutanesulfonic acid, tripotassium salt;

Mass Spec (FAB, + ions) m/z 545 (M+K), 507 (M+H), 469 (M-K+2H).

20 Anal. Calcd for $C_{16}H_{22}O_7PSK_3+4.2 H_2O$:

C, 32.98; H, 5.27; P, 5.32; S, 5.50

Found: C, 32.98; H, 5.25; P, 5.65; S, 5.18.

128. 3-(3-ethylphenoxy)- α -phosphonobenzenebutanesulfonic acid, tripotassium salt;

25 Mass Spec (FAB, + ions) m/z 491 (M-K+2H), 529 (M+H), 567 (M+K).

Anal. Calcd for $C_{18}H_{20}K_3O_7PS+1.6 H_2O$:

C, 38.78; H, 4.19; P, 5.56; S, 5.75

30 Found: C, 38.94; H, 4.47; P, 5.32; S, 5.31.

129. α -phosphono-3-[3-(trifluoromethyl)-phenoxy]benzenebutanesulfonic acid, tripotassium salt;



Mass Spec (FAB, + ions) m/z 431 (M-K+2H), 569
(M+H), 607 (M+K)

Anal. Calcd for $C_{17}H_{15}F_3K_3O_7PS+1.6 H_2O$:

C, 34.18; H, 3.07; F, 9.54; P, 5.18; S, 5.37

5 Found: C, 34.21; H, 3.15; F, 9.20; P, 5.02; S, 5.51

130. (E)-6-methyl-1-phosphono-8-[3-(trifluoromethyl)phenyl]-5-octene-1-sulfonic acid, tripotassium salt;

10 Mass Spec (Ion Spray, - ions) m/z 429 (M-3K+2H),
411 (M-3K+2H-H₂O).

Anal. Calcd for $C_{16}H_{19}F_3K_3PSO_6+2.3 H_2O$:

C, 32.78; H, 4.06; P, 5.28; S, 5.47

Found: C, 32.78; H, 4.41; P, 5.55; S, 5.86.

15

131. 3-phenoxy- α -phosphonobenzenepentane-sulfonic acid, tripotassium salt;

Mass Spec (FAB, + ions) m/z 477 (M+2H-K), 515
(M+H), 553 (M+K)

20 Anal. Calcd for $C_{17}H_{18}K_3O_7PS+1.3 H_2O$:

C, 37.95; H, 3.86; P, 5.76; S, 5.96

Found: C, 37.95; H, 4.24; P, 5.56; S, 5.97.

132. 3-[2-(3-methylbutyl)phenoxy]- α -phosphonobenzenebutanesulfonic acid, tripotassium salt;
25 Mass Spec (FAB, + ion) m/z 533 (M-K+2H), 571 (M+H),
609 (M+K)

Anal. Calcd for $C_{21}H_{26}K_3O_7PS+1.5 H_2O$:

C, 42.19; H, 4.89; P, 5.18; S, 5.36

30 Found: C, 42.33; H, 5.15; P, 4.96; S, 5.02.

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133. 3-[2-(3-methyl-2-butenyl)phenoxy]- α -phosphonobenzenebutanesulfonic acid, tripotassium salt;

Mass Spec (FAB, + ion) m/z 569 (M+H), 607 (M+K)

5 Anal. Calcd for $C_{21}H_{24}K_3O_7PS+2.2 H_2O$:

C, 41.46; H, 4.71; P, 5.09; S, 5.27

Found: C, 41.64; H, 4.73; P, 5.11; S, 4.77.

10 134. α -[bis[1-(1-oxopropoxy)ethoxy]phosphinyl]-3-phenoxybenzenebutanesulfonic acid, monopotassium salt;

Mass Spec (FAB, + ions) 663 (M+K)

Anal. Calcd for $C_{26}H_{34}KO_{11}PS$:

C, 49.99; H, 5.49; P, 4.96; S, 5.13

15 Found: C, 49.93; H, 5.54; P, 5.08; S, 5.44.

135. (E)-8-([1,1'-biphenyl]-4-yl)-6-methyl-1-phosphono-5-octene-1-sulfonic acid, tripotassium salt;

20 Mass Spec (FAB, + ions) m/e 591 (M+K), 553 (M+H), 515 (M-K+2H)

Anal. Calcd for $C_{21}H_{24}PSO_6K_3 + 1.34 \text{ mol } H_2O$:

C, 43.72; H, 4.66; P, 5.37; S, 5.56

Found: C, 43.72; H, 4.97; P, 5.31; S, 5.59.

25

136. 3-(2-cyclohexen-1-yloxy)- α -phosphonobenzenebutanesulfonic acid, tripotassium salt;

Mass Spec (FAB, + ions) m/e 543 (M+K), 505 (M+H), 467 (M-K+2H)

30 Anal. Calcd for $C_{26}H_{20}O_7PSK_3 + 5.22 H_2O$:

C, 32.10; H, 5.12; P, 5.17; S, 5.36

Found: C, 32.10; H, 4.84; P, 4.90; S, 5.71.

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137. (E)-6-methyl-8-(2-naphthalenyl)-1-phosphono-5-octene-1-sulfonic acid, tripotassium salt;

Mass Spec (FAB, + ions) m/e 565 (M+K), 527 (M+H)

5 Anal. Calcd for $C_{19}H_{22}PSO_6K_3 + 4.10 \text{ mol } H_2O$:

C, 38.00; H, 5.07; P, 5.16; S, 5.34

Found: C, 38.39; H, 4.87; P, 5.31; S, 4.94.

138. 3-(phenylmethoxy)- α -phosphonobenzene-
10 butanesulfonic acid, tripotassium salt;

Mass Spec 515 (M+H), 477 (M-K+2H), 439 (M-2K+3H)

Anal. Calcd for $C_{17}H_{18}O_7PSK_3 + 3.5 H_2O$:

C, 35.34; H, 4.36; P, 5.36; S, 5.55

Found: C, 35.34; H, 4.40; P, 5.03; S, 5.26.

15

139. 6-([1,1'-biphenyl]-4-yl)- α -phosphono-
3-pyridinebutanesulfonic acid, tripotassium salt;

Mass Spec (FAB, + ions) 600 (M+K), 562 (M+H), 524 (M-K+2H), 486 (M-2K+3H)

20 Anal. Calcd for $C_{21}H_{19}NO_6PSK_3 + 2.3 H_2O$:

C, 41.82; H, 3.94; N, 2.32; P, 5.14;

S, 5.32

Found: C, 42.21; H, 4.34; N, 2.30; P, 5.02;

S, 5.34.

25

140. 3-(4-chlorophenoxy)- α -phosphonobenzenebutanesulfonic acid, tripotassium salt;

Mass Spec (FAB, + ions) m/z 573 (M+K), 535 (M+H), 497 (M-K+2H), 463 (M-K-Cl+3H)

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Anal. Calcd for $C_{16}H_{15}ClO_7PS \cdot 3K + 0.89 H_2O$:

C, 34.87; H, 3.07; P, 5.62; S, 5.82;
Cl, 6.43

Found: C, 35.28; H, 3.51; P, 5.48; S, 5.97;
Cl, 6.25.

5

141. 3-(3-chlorophenoxy)- α -phosphonoben-
zenebutanesulfonic acid, tripotassium salt;

Mass Spec (FAB, + ion) m/z 459 (M-2K+3H), 497

10 (M-K+2H), 535 (M+H)

Anal. Calcd for $C_{16}H_{15}ClK_3O_7PS + 1.5 H_2O$:

C, 34.19; H, 3.23; P, 5.51; S, 5.70

Found: C, 34.23; H, 3.66; P, 5.25; S, 5.91.

15

142. (E)-6-methyl-1-phosphono-8-(2-
pyridinyl)-5-octene-1-sulfonic acid, tripotassium
salt;

Mass Spec (FAB, + ions) m/z 516 (M+K), 478 (M+H),
440 (M-K+2H)

20 Anal. Calcd for $C_{14}H_{19}NPSO_6K_3 + 1.30 H_2O$:

C, 33.58; H, 4.34; N, 2.80; P, 6.19
S, 6.40

Found: C, 33.54; H, 4.41; N, 2.84; P, 6.05
S, 6.07

25

143. 2-methoxy-5-phenoxy- α -phosphonoben-
zenebutanoic acid, tripotassium salt;

Mass Spec (FAB, + ions) m/z 569 (M+K), 531 (M+H),
493 (M-K+2H), 455 (M-2K+3H)

30 Anal. Calcd for $C_{17}H_{18}K_3O_8PS + 1.2 H_2O$:

C, 36.94; H, 3.73; P, 5.60; S, 5.80

Found: C, 37.37; H, 4.17; P, 5.36; S, 5.38.

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144. (E,E)-1-[bis[2-methyl-1-(1-oxopropoxy)propoxy]phosphinyl]-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, monopotassium salt;
- 5 Mass Spec (FAB, + ions) 703 (M+H), 741 (M+K)
Anal. Calcd for $C_{32}H_{56}KO_{10}PS$:
C, 54.68; H, 8.03; P, 4.41; S, 4.56
Found: C, 54.66; H, 8.07; P, 4.37; S, 4.37.
- 10 145. ζ -methyl- α -phosphono[1,1'-biphenyl]-4-octanesulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/e (M+K), 555 (M+H), 517 (M-K+2H)
Anal. Calcd for $C_{21}H_{26}PSO_6K_3 + 2.47 \text{ mol } H_2O$:
15 C, 42.09; H, 5.20; P, 5.17; S, 5.35
Found: C, 42.09; H, 5.18; P, 4.77; S, 5.02.
146. 4-(2-phenyl-5-pyridinyl)- α -phosphonobenzenebutanesulfonic acid, tripotassium salt;
20 Mass Spec (FAB, +ions) m/z 600 (M+K), 562 (M+H), 524 (M-K+2H)
Anal. Calcd for $C_{21}H_{19}NO_6PSK_3 + 1.9 \text{ } H_2O$:
C, 42.32; H, 3.86; N, 2.35; S, 5.38
P, 5.20
25 Found: C, 42.32; H, 4.21; N, 2.37; S, 5.27
P, 5.22.
147. α -[bis[1-(2,2-dimethyl-1-oxopropoxy)ethoxy]phosphinyl]-3-phenoxybenzenebutanesulfonic acid, monopotassium salt;
30 Mass Spec (FAB, + ions) m/z 719 (M+K)
Anal. Calcd for $C_{30}H_{42}KO_{11}PS + 0.5 \text{ } H_2O$:
C, 52.24; H, 6.28; P, 4.49; S, 4.65
Found: C, 52.42; H, 6.21; P, 4.65; S, 5.39.



148. 5-phenoxy- α -phosphono-2-thiophene-
butanesulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 507 (M+H), 469
5 (M-K+2H), 431 (M-2K+3H)
Anal. Calcd for $C_{14}H_{14}O_7PS_2K_3 + 2.04 H_2O$:
C, 30.95; H, 3.35; P, 5.70; S, 11.80
Found: C, 30.95; H, 3.37; P, 5.33; S, 11.99.
- 10 149. 3-[2-(2-methoxyethyl)phenoxy]- α -phos-
phonobenzenesulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 597 (M+K), 559 (M+H),
543 (M-K+Na+H), 521 (M-K+2H), 483 (M-2K+3H)
Anal. Calcd for $C_{19}H_{22}O_8PS \cdot 3K + 1.15 H_2O$:
15 C, 39.38; H, 4.23; P, 5.34; S, 5.53
Found: C, 39.38; H, 4.51; P, 4.93; S, 5.34.
- 20 150. (E,E)-1-[bis[1-(benzoyloxy)ethoxy]-
phosphinyl]-6,10,14-trimethyl-5,9,13-penta-
decatriene-1-sulfonic acid, monopotassium salt;
Mass Spec (FAB, + ions) 781 (M+K)
Anal. Calcd for $C_{36}H_{48}KO_{10}PS + 0.3 H_2O$:
C, 57.80; H, 6.54; P, 4.14; S, 4.29
Found: C, 57.80; H, 6.43; P, 4.00; S, 3.23.
- 25 151. (E,E)- α -[bis[2-methyl-1-(1-oxopro-
poxy)propoxy]phosphinyl]-3-phenoxybenzenesulfonic
acid, monopotassium salt;
Mass Spec (FAB, + ions) m/z 719 (M+K)
30 Anal. Calcd for $C_{30}H_{42}KO_{11}PS$:
C, 52.93; H, 6.22; P, 4.55; S, 4.71
Found: C, 52.86; H, 6.33; P, 4.28; S, 5.10.

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152. 3-[2-(2-propenyl)phenoxy]- α -phosphono-
benzenebutanesulfonic acid, tripotassium salt;
Mass Spec (FAB, + ion) m/z 465 (M-2K+3H), 503
(M-K+2H), 541 (M+H), 579 (M+K)
5 Anal. Calcd for $C_{19}H_{20}K_3O_7PS + 2.7 H_2O$:
C, 38.72; H, 4.34; P, 5.26; S, 5.44
Found: C, 38.79; H, 4.45; P, 5.00; S, 5.08.

153. 2-(methoxymethoxy)-5-phenoxy- α -phos-
10 phonobenzenebutanoic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 599 (M+K), 561 (M+H),
523 (M-K+2H)
Anal. Calcd for $C_{18}H_{20}K_3O_9PS + 2.9 H_2O$:
C, 35.24; H, 4.25; P, 5.05; S, 5.23
15 Found: C, 35.24; H, 4.13; P, 4.84; S, 5.57.

154. α -phosphono-3-(2-pyridinyloxy)benzene-
butanesulfonic acid, tripotassium salt;
Mass Spec m/z 540 (M+K), 502 (M+H), 464 (M-K+2H)
20 Anal. Calcd for $C_{15}H_{15}NO_7PSK_3 + 2.63 H_2O$:
C, 32.82; H, 3.72; N, 2.55; P, 5.64;
S, 5.84
Found: C, 32.87; H, 4.12; N, 2.50; P, 5.38;
S, 6.22.

25 155. 3-[2-phenylmethyl)phenoxy]- α -phos-
phonobenzenebutanesulfonic acid, tripotassium salt;
Mass Spec 629 (M+K), 591 (M+H), 553 (M-K+2H),
515 (M-2K+3H)
30 Anal. Calcd for $C_{23}H_{22}K_3O_7PS$:
C, 45.32; H, 3.98; N, 0.00; S, 5.26;
P, 5.08
Found: C, 45.32; H, 4.25; N, 0.24; S, 5.54;
P, 4.84.

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156. δ -methyl-3-phenoxy- α -phosphonobenzene-
butanesulfonic acid, tripotassium salt;
Mass Spec. (FAB, + ions) m/z 515 (M+H), 553 (M+K)
5 Anal. Calcd for $C_{17}H_{18}K_3O_7PS + 2.5 H_2O$:
C, 36.48; H, 4.14; P, 5.53; S, 5.73
Found: C, 36.50; H, 3.98; P, 5.37; S, 5.47.
157. 3-(3-fluorophenoxy)- α -phosphonoben-
10 zenebutanesulfonic acid, tripotassium salt;
Mass Spec (FAB, + ion) m/z 481 (M-K+2H), 519 (M+H),
557 (M+K)
Anal. Calcd for $C_{16}H_{15}FK_3O_7PS \cdot 2.4 H_2O$:
C, 34.20; H, 3.55; P, 5.51; S, 5.71
15 Found: C, 34.21; H, 3.45; P, 5.36; S, 6.04.
158. 3-(4-fluorophenoxy)- α -phosphonoben-
zenebutanesulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) 557 (M+K), 519 (M+H), 481
20 (M-K+2H), 443 (M+2K+3H)
Anal. Calcd for $C_{16}H_{15}FO_7PSK_3 + 2.0 H_2O$:
C, 34.65; H, 3.45; S, 5.78; P, 5.58;
F, 3.43
Found: C, 34.92; H, 3.88; S, 6.12; P, 5.59;
25 F, 3.48.
159. α -[bis[1-(2-methyl-1-oxopropoxy)-
ethoxy]phosphinyl]-3-phenoxybenzenebutanesulfonic
acid, monopotassium salt;
30 Mass Spec (FAB, + ions) m/z 691 (M+K)
Anal. Calcd for $C_{28}H_{38}KO_{11}PS$:
C, 51.52; H, 5.87; P, 4.75; S, 4.91
Found: C, 51.65; H, 5.93; P, 4.63; S, 5.89.

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160. 4-(2-benzoxazolyl)- α -phosphinylbenzenebutanesulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) 526 (M+K), 488 (M+H), 450 (M-K+2H)

5 Anal. Calcd for $C_{17}H_{15}NO_7PSK_3 \cdot 2.22 H_2O$:

C, 36.10; H, 3.46; N, 2.48; S, 5.67;
P, 5.48

Found: C, 35.98; H, 3.66; N, 2.60; S, 5.46;
P, 5.53.

10

161. α -[bis[2-methyl-1-(2-methyl-1-oxopropoxy)propoxy]phosphinyl]-3-phenoxybenzenebutanesulfonic acid, monopotassium salt;

Mass Spec (FAB, + ions) m/z 709 (M+K)

15 Anal. Calcd for $C_{32}H_{46}KO_{11}PS$:

C, 54.22; H, 6.54; P, 4.37; S, 4.52

Found: C, 53.98; H, 6.57; P, 3.86; S, 5.31.

162. α -[bis[1-(1-oxopropoxy)propoxy]phosphinyl]-3-phenoxybenzenebutanesulfonic acid, monopotassium salt;

20

Mass Spec (FAB, + ions) m/z 691 (M+K)

Anal. Calcd for $C_{28}H_{38}KO_{11}PS$:

C, 51.52; H, 5.87; P, 4.75; S, 4.91

25 Found: C, 51.75; H, 5.85; P, 4.54; S, 5.84.

163. 3-(3,4-dichlorophenoxy)- α -phosphonobenzenebutanesulfonic acid, tripotassium salt;

30

Mass Spec (FAB, + ion, for ^{35}Cl) m/z 531 (M-K+2H), 569 (M+H), 607 (M+K), (Cl isotope pattern)

Anal. Calcd for $C_{16}H_{14}Cl_2K_3O_7PS \cdot 1.6 H_2O$:

C, 32.12; H, 2.90; P, 5.18; S, 5.36

Found: C, 32.10; H, 3.15; P, 5.16; S, 5.71.

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164. 3-(2,3-dichlorophenoxy)- α -phosphono-
benzenebutanesulfonic acid, tripotassium salt;
Mass Spec (FAB, + ion, for ^{35}Cl) m/z 533 (M-K+2H),
569 (M+H), 607 (M+K), (Cl isotope pattern)
5 Anal. Calcd for $\text{C}_{16}\text{H}_{14}\text{Cl}_2\text{O}_7\text{PS}\cdot 2.2 \text{ H}_2\text{O}$:
C, 31.55; H, 3.04; P, 5.09; S, 5.26
Found: C, 31.54; H, 3.17; P, 4.75; S, 5.51.
165. 3-(2-phenoxyphenoxy)- α -phosphonoben-
10 zenebutanesulfonic acid, tripotassium salt;
Mass Spec (FAB, + ion) m/z 555 (M-K+2H), 593 (M+H),
631 (M+K)
Anal. Calcd for $\text{C}_{22}\text{H}_{20}\text{K}_3\text{O}_8\text{PS} + 1.8 \text{ H}_2\text{O}$:
C, 42.27; H, 3.81; P, 4.95; S, 5.13
15 Found: C, 42.25; H, 3.91; P, 5.25; S, 4.88.
166. 3-(2-benzoylphenoxy)- α -phosphonoben-
zenesulfonic acid, tripotassium salt;
Mass Spec (FAB, + ion) m/z 567 (M-K+2H), 605 (M+H),
20 643 (M+K)
Anal. Calcd for $\text{C}_{23}\text{H}_{20}\text{K}_3\text{O}_8\text{PS} + 3.1 \text{ H}_2\text{O}$:
C, 41.82; H, 4.00; P, 4.69; S, 4.85
Found: C, 41.86; H, 3.88; P, 4.69; S, 4.86.
- 25 167. (Z)-6-methyl-8-phenyl-1-phosphono-5-
octene-1-sulfonic acid, tripotassium salt;
Mass Spec (FAB, + ions) m/z 515, (M+K), 477 (M+H)
Anal. Calcd for $\text{C}_{15}\text{H}_{20}\text{PSO}_6\text{K}_3 + 1.8 \text{ H}_2\text{O}$:
C, 35.36; H, 4.68; P, 6.08; S, 6.29
30 Found: C, 35.36; H, 4.67; P, 5.89; S, 6.00.
168. (E)-8-(2-fluorophenyl)-6-methyl-1-
phosphono-5-octene-1-sulfonic acid, tripotassium
salt;

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Mass Spec (FAB, + ions) m/z 533 (M+K), 495 (M+H),
457 (M-K+2H)

Anal. Calcd for $C_{15}H_{19}FPO_6K_3 + 3.50 H_2O$:

C, 32.35; H, 4.69; P, 5.56; S, 5.76

5 Found: C, 32.35; H, 4.69; P, 5.63; S, 5.76.

169. 3-(4-methoxyphenoxy)- α -phosphonoben-
zenebutanesulfonic acid, tripotassium salt;

10 Mass Spec (FAB, + ions) m/z 569 (M+K), 531 (M+H),
493 (M-K+2H), 455 (M-2K+3H)

Anal. Calcd for $C_{17}H_{18}O_8PS \cdot 3K + 1.71 H_2O$:

C, 36.36; H, 3.85; P, 5.52; S, 5.71

Found: C, 36.78; H, 4.00; P, 5.13; S, 5.54.

15 170. 3-(3-methoxyphenoxy)- α -phosphonoben-
zenebutanesulfonic acid, tripotassium salt;

Mass Spec (FAB, + ion) m/z 531 (M+H), 569 (M-K)

Anal. Calcd for $C_{17}H_{18}K_3O_8PS + 1.7 H_2O$:

C, 36.38; H, 3.84; P, 5.52; S, 5.71

20 Found: C, 36.43; H, 4.16; P, 5.43; S, 5.66.

171. 3-(2-propoxyphenoxy)- α -phosphonoben-
zenebutanoic acid, tripotassium salt;

25 Mass Spec (FAB, + ions) m/z 597 (M+K), 559 (M+H),
521 (M-K+2H)

Anal. Calcd for $C_{19}H_{22}K_3O_8PS + 1.1 H_2O$:

C, 39.50; H, 4.21; P, 5.36; S, 5.55

Found: C, 39.50; H, 4.49; P, 5.09; S, 5.31.

30 172. α -phosphono-3-(2-propylphenoxy)ben-
zenebutanesulfonic acid, tripotassium salt;
Mass Spec (FAB, + ion) m/z 505 (M-K+2H), 543 (M+H),
581 (M+K)



Anal. Calcd for $C_{19}H_{22}K_3O_7PS + 2.0 H_2O$:

C, 39.43; H, 4.53; P, 5.35; S, 5.54

Found: C, 39.44; H, 4.42; P, 5.21; S, 5.85.

5 173. 3-[2-(2-ethoxymethyl)phenoxy]- α -phosphonobenzenebutanesulfonic acid, tripotassium salt; Mass Spec (FAB, + ions) m/z 597 (M+K), 559 (M+H), 543 (M-K+Na+H), 521 (M-K+2H), 1041 (2M+K), 1079 (2M+2K-H), 1117 (2M+3K-2H)

10 Anal. Calcd for $C_{19}H_{22}O_8PS \cdot 3K + 1.43 H_2O$:

C, 39.05; H, 4.29; P, 5.30; S, 5.49

Found: C, 39.05; H, 4.31; P, 5.11; S, 5.10.

Example 174

15 α -[Bis[(2,2-Dimethyl-1-oxopropoxy)methoxy]phosphinyl]-3-phenoxybenzenebutanesulfonic acid, monopotassium salt

20 A. α -[Bis[2,2-dimethyl-1-oxopropoxy)-methoxy]phosphinyl]-3-phenoxybenzenebutanesulfonic acid, cyclohexyl ester

25 Bromotrimethylsilane (3.61 g, 23.63 mmol, 4 eq.) was added dropwise to a solution of Example 40, Part E ester (3.10 g, 5.90 mmol) and allyltrimethylsilane (4.71 g, 41.3 mmol) in dichloromethane (20 mL) at RT under argon. The clear reaction mixture was stirred at RT for 48 h, concentrated and pumped at high vacuum for 4 h to give a colorless oil.

30 The crude silyl ester prepared above (3.55 g, $\approx$ 5.88 mmol) was dissolved in 1 N KOH (12.7 mL, 12.7 mmol) over 10 min, then added slowly with vigorous stirring to a solution of silver nitrate (2.17 g, 12.76 mmol) in water (40 mL) under argon

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- in the dark. The resulting white gum was diluted with 40 mL of water, extracted with toluene (4x75 mL) and dried over Na₂SO₄. The organics were filtered and concentrated to a thick gum. The gum was diluted with 80 mL of toluene, cooled to 0°C and treated with 2,2-dimethylpropanoic acid, iodomethyl ester (3.87 g, 16.00 mmol) in 20 mL of toluene over 15 min. After 5 min. at 0°C, a solid precipitated out of the solution. The reaction was stirred an additional 0.5 h and warmed to room temperature. The mixture was stirred with Celite (4 g) for 6 min., filtered through a pad of Celite and concentrated to provide a yellow oil. The oil was purified by flash column chromatography on silica gel (200 g) eluting with (1.5 L) 20:80 ethyl acetate/hexane followed by (0.5 L) 40:60 ethyl acetate/hexane to provide 2.60 g (65%) of title compound as a colorless oil.
- TLC Silica gel (3:7 ethyl acetate/hexanes) R_f=0.50.

B. α -[Bis[(2,2-Dimethyl-1-oxopropoxy)-methoxy]phosphinyl]-3-phenoxybenzenebutane-sulfonic acid, monopotassium salt

- To a mixture of 1.07 g (11.00 mmol) of KOAc in 40 mL of a 9:1 trifluoroethanol/water (v/v) solution was added 2.50 g (3.59 mmol) of Part A compound. After a homogeneous solution was obtained ($\approx$ 15 min.), the solution was heated to 40°C (bath temp.) for 20 h and the solvent removed under reduced pressure. The remainder was diluted with water (5 mL) and concentrated. The residue was diluted with ethyl acetate, washed with solutions of KHCO₃ (2x8 mL) and KCl (1x10 mL),

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dried over anhydrous KCl and evaporated to provide a pale yellow oil. The oil was diluted with 15 mL of water (a soapy slurry formed) and freeze dried to provide 2.02 g (86%) of title compound as a
5 white lyophilate.

TLC Silica gel (1:9 methanol/dichloromethane)
R_f=0.60.

10 IR (KBr) 3488, 3063, 2974, 1753, 1584, 1485, 1460, 1447, 1397, 1370, 1250, 1215, 1163, 1140, 1069, 1045, 1022, 1003, 963 cm⁻¹.

Mass Spec (FAB, + ions) m/z 691 (M+K), 615 (M-
15 K+2H), 445 (M-C₁₂H₂₂O₅+K).

Anal. Calcd for C₂₈H₃₈O₁₁SPK:

C, 51.52; H, 5.87; P, 4.75; S, 4.91

Found: C, 51.38; H, 5.93; P, 4.65; S, 4.90.

20

Example 175

(S)-(-)-3-Phenoxy- α -phosphonobenzenebutanesulfonic
acid, tripotassium salt

25

A. (1R,2R)-N,N'-Dimethyl-1,2-cyclo-
hexanediamine

Preparation of the title compound was carried out as described by Hanessian, S. et. al. J. Amer. Chem. Soc. 1984, 106, 5754-5756, and

30

Alexakis, A. et. al. J. Org. Chem. 1992, 57, 1224-1237, Galsbol, F. et al., Acta Chem. Scand. 1972, 26, 3605 and Onuma, K. et. al., Bull. Chem. Soc. Jpn. 1980, 53, 2012.



$[\alpha_{\text{spec}}]_{\text{D}}^{20} = -150^{\circ} \text{CHCl}_3, (C=1); \text{ Literature}$

$[\alpha_{\text{spec}}]_{\text{D}}^{20} = -147^{\circ}.$

5 B. [3aR-(3a α ,7a β)]-Octahydro-1,2,3-trimethyl-1H-1,3,2-benzodiazaphosphole, 2-oxide

To a solution of 4.0 g (28.1 mmol, 1 eq.) of Part A diamine and 7.92 mL (56.8 mmol, 2.02 eq) of triethylamine in 64 mL of benzene at RT was added a solution of 3.74 g (28.1 mmol, 1 eq.) of methylphosphonic dichloride in 40 mL of benzene over 40 minutes. The heterogeneous mixture was stirred for 90 minutes at RT and then filtered through a pad of Celite, rinsing well with ethyl acetate. Concentration of the organic solution afforded 5.67 g of a yellow oil. Flash chromatography of the oil on silica gel (100 g), eluting with 7% methanol in ethyl acetate, afforded 4.59 g (81%) of the title compound as a white solid, m.p. 61-63°C. TLC Silica gel (10% methanol in ethyl acetate): R_f 0.12.

25 C. [3aR-(3a α ,7a β)]-Octahydro-1,3-dimethyl-2-[4-(3-phenoxyphenyl)butyl]-1H-1,3,2-benzodiazaphosphole, 2-oxide

To a solution of 2.0 g (9.9 mmol, 1 eq.) of Part B compound in 15 mL of THF at -78°C was added dropwise 4.4 mL (10.9 mmol, 1.1 eq.) of 2.5 M n-BuLi in hexane. Addition of the alkyl lithium resulted in a gelatinous mixture to which 5 mL of THF was added. The resulting opaque white solution was stirred for 1 hour at -78°C. A solution of 3.8

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g (11.9 mmol, 1.2 eq.) of 3-(3-phenoxyphenyl)-propyliodide in 10 mL of THF was then added dropwise over 20 minutes. The reaction was stirred at -78°C for 2 hours, 0°C for 1 hour and RT for 19 hours. The reaction was quenched with methanol, diluted with ethyl acetate, washed with water and dried (Na₂SO₄). Concentration of the organic solution afforded 4.81 g of the crude product as a yellow oil. Flash chromatography of the oil on silica gel (200 g), eluting with 5% methanol in ethyl acetate, afforded 3.78 g (92%) of the title compound as a viscous yellow oil. TLC Silica gel (10% methanol in ethyl acetate): R_f 0.29.

15

D. [3aR-[2(R*),3a α ,7a β]]-[1-[[[(Dimethyl-amino)thioxomethyl]thio]-4-(3-phenoxy-phenyl)butyl]octahydro-1,3-dimethyl-2-1H-1,3,2-benzodiazaphosphole, 2-oxide

20 and

E. [3aR-[2(S*),3a α ,7a β]]-[1-[[[(Dimethyl-amino)thioxomethyl]thio]-4-(3-phenoxy-phenyl)butyl]octahydro-1,3-dimethyl-2-1H-1,3,2-benzodiazaphosphole, 2-oxide

25

To a solution of 3.7 g (8.97 mmol, 1 eq) of Part C compound in 60 mL of THF at -75°C (internal temperature) was added dropwise 3.95 mL (9.87 mmol, 1.1 eq) of 2.5 M n-BuLi in hexanes at a rate to keep temperature below -70°C (15 min). The reaction was stirred at -75°C for 2 h. The reaction was cooled to -90°C (liquid nitrogen/methanol slush) and 2.59 g (10.8 mmol, 1.2 eq) of tetramethylthiuram disulfide was added as a solid in small portions over 20 minutes. The

30

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reaction was stirred at -90°C for 1 hour and then warmed to -70°C (dry ice/methanol) and stirred for 2 hours. The reaction was quenched by the addition of methanol (5 mL), warmed to RT and diluted with ether. Concentration of the organic solution afforded 6.65 g of a yellow solid-oil mixture which contained title D α -(R) isomer and title E α -(S) isomer in a 1 : 3 ratio. Flash chromatography on silica gel (200 g), eluting with 2% methanol in ethyl acetate, afforded 0.807 g (17%) of title D α -(R) isomer and 2.66 g (56%) of title E α -(S) isomer, each with >99% d.e. as judged by ^{31}P NMR.

^{31}P NMR (CDCl_3 , 121 MHz, ref. to 10% H_3PO_4 , 0 ppm): title D α -(R) isomer 41.6 ppm; title E α -(S) isomer 39.3 ppm.

TLC Silica gel (10% methanol in ethyl acetate): For title D α -(R) isomer R_f 0.46; for title E α -(S) isomer R_f 0.37.

(10% methanol in t-Butyl methyl ether): For title D α -(R) isomer R_f 0.45; for title E α -(S) isomer R_f 0.33.

F. (S)- α -[[(Dimethylamino)thioxomethyl]-thiol-3-phenoxybenzenebutanephosphonic acid]

To a solution of 1.95 g (3.67 mmol, 1 eq) of title E α -(S) isomer in 35 mL of acetonitrile was added 37 mL (110 mmol, 30 eq) of 3 N hydrochloric acid. The homogeneous solution was stirred at RT for 13 hours. The reaction was concentrated and the residue was dissolved in 20 mL of water and evaporated. A column of Biorad AG-50W-X8 ion exchange resin, H^+ form (22 mL bed volume, 37 meq)



was equilibrated initially with water (50 mL), followed by 50% aqueous isopropanol (50 mL). The residual oil was dissolved in 25 mL of 30% aqueous isopropanol and eluted slowly through the resin
5 with 30% aqueous isopropanol followed by evaporation to afford 1.47 g (94%) of the title compound as a clear viscous oil.

$[\alpha]_{\text{spec}}^{20}_{\text{D}} + 0.8^{\circ}$ (c. 1.0, MeOH)

10

^{31}P NMR (CDCl_3 , 121 MHz, ref. to 10% H_3PO_4 , 0 ppm): 30.5 ppm.

TLC Silica gel (6:3:1 n-propanol:ammonium
15 hydroxide:water): R_f 0.59.

G. (S)-(-)-3-Phenoxy- α -phosphonobenzene-
butanesulfonic acid tripotassium salt

To 1.44 g (3.39 mmol, 1 eq) of Part F α -(S)
20 isomer was added 12 mL of acetic acid and mixture was allowed to stir to effect complete dissolution. A white precipitate formed after 15 minutes. To the heterogeneous reaction was added 1.35 mL of formic acid followed after 5 minutes by 2.08 mL
25 (20.3 mmol, 6 eq) of 30% hydrogen peroxide in water (exothermic: internal temperature increased to 38°C). The reaction became cloudy after 30 sec and a yellow precipitate became visible within 1 min. The reaction was monitored by reverse phase HPLC.
30 After 7 h, excess peroxide was decomposed by the slow addition of 622 μL (8.48 mmol, 2.5 eq) of dimethyl sulfide (exothermic: internal temperature increased to 40°C). The reaction was diluted with water, filtered and concentrated. The residue was

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dissolved in water (25 mL), concentrated, then redissolved in water (10 mL) and the pH of the resulting solution (pH ~ 1.95) was brought to pH 12 with 1 N potassium hydroxide (12 mL). The basic solution was lyophilized. The lyophilate was dissolved in water and chromatographed on CHP-20P gel (2.5 cm x 25 cm) eluting initially with water (1 L) followed by 10% CH₃CN in water. Fractions containing product were analyzed by HPLC, then pooled and concentrated to afford a clear waxy residue which was dissolved in water, filtered and lyophilized to afford 1.42 g (82%) of the title compound as a white lyophilate.

15 TLC Silica gel (6 : 3 : 1 n-propanol : ammonium hydroxide : water): R_f 0.21.

$[\alpha]_{\text{spec}}^{20}_{\text{D}} - 9.9^\circ$ (c. 0.97, H₂O)

20 Chiral HPLC analysis of enantiomeric excess was performed on a ChromTech α -acid glycoprotein (α_1 -AGP) column, eluted with 85% 0.1 M KH₂PO₄, 15% CH₃CN, pH 4.6, in isocratic mode.

For this sample :

25 ret. time 10.3 min, 99.65% (S)-isomer
ret. time 18.8 min, 0.35% (R)-isomer
therefore 99.3% enantiomeric excess.

MS (FAB, + ions): m/z 539 (M + K), 501 (M + H),
30 463 (M - K + 2H).

Anal. Calcd. for C₁₆H₁₆O₇PSK₃ + 0.75 H₂O:

C, 37.38; H, 3.43; P, 6.02; S, 6.24.

Found: C, 37.37; H, 3.44; P, 5.86; S, 6.08

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Example 176

(R)-(+)-3-Phenoxy- α -phosphonobenzenebutanesulfonic
acid, tripotassium salt

5

A. (R)- α -[[(Dimethylamino)thioxomethyl]-
thiol-3-phenoxybenzenebutanephosphonic acid

To a solution of 0.32 g (0.60 mmol, 1 eq) of
Example 175 Part D α -(R)-isomer in 12 mL of
10 acetonitrile was added 18 mL (18 mmol, 30 eq) of 1
N hydrochloric acid. The initially opaque, milky
white solution became homogeneous after 2 min and
was stirred at RT for 14 h. The reaction was
concentrated and the residue was dissolved in
15 methanol and passed through a column of Biorad AG-
50W-X8 ion exchange resin, H⁺ form (60 mL bed
volume, 102 meq) which has been equilibrated with
water (50 mL), 0.1 N HCl (100 mL), water (100 mL ,
pH of eluant ~ 7) and 10% methanol in water prior
20 to use. The column was eluted with methanol to
afford 0.18 g (72%) of title compound as a clear
viscous oil.

$[\alpha]_{\text{spec}}^{20}_{\text{D}} - 2.3^{\circ}$ (c. 2.6, MeOH)

25

^{31}P NMR (CD_3OD , 121 MHz, ref. to 10% H_3PO_4 , 0 ppm):
24.2 ppm.

TLC Silica gel (6:3:1 n-propanol:ammonium
30 hydroxide:water): R_f 0.56

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B. (R)-(+)-3-Phenoxy- α -phosphonobenzene-
butanesulfonic acid, tripotassium salt

- To a solution of 0.18 g (0.59 mmol, 1 eq) of Part A compound in 40 mL of 98% formic acid was added 2.16 mL (21.2 mmol, 50 eq) of 30% hydrogen peroxide in water. The reaction became cloudy after 0.5 min and a precipitate formed after ~1 min. After 45 min, the reaction was concentrated and the residue was dissolved in water. The solution was cooled to 0°C and the excess peroxide was decomposed by the slow addition of 25 mL of 1 N potassium sulfite. The solution was again concentrated and the residue was coevaporated twice with water. The residue was dissolved in 10 mL of water and the pH of the solution (pH ~ 3) was brought to pH 12 with 1 N potassium hydroxide. The solution was then chromatographed on CHP-20P gel (2.5 cm x 25 cm) eluting with water. Fractions containing pure product were pooled and concentrated to afford a clear waxy residue which was dissolved in water, filtered and lyophilized to afford 132 mg (56%) of title compound as a white lyophilate.
- TLC Silica gel (6:3:1 n-propanol:ammonium hydroxide:water): R_f 0.21.
- $[\alpha]_{\text{spec}}^{20}_{\text{D}} + 9.5^\circ$ (c. 0.89 H₂O)
- Chiral HPLC analysis of enantiomeric excess was performed on a ChromTech α -acid glycoprotein (α_1 -AGP) column, eluted with 85% 0.1 M KH₂PO₄, 15% CH₃CN, pH 4.6 in an isocratic mode.



For this sample: ret. time 17.8 min, 97.77% (R)-
enantiomer

ret. time 10.9 min, 2.23% (S)-enantiomer
therefore 95.5% enantiomeric excess.

5

IR (KBr): 3412 (br), 3071, 2936, 2866, 1661, 1489,
1204, 1076, 966 cm^{-1} .

10 MS (FAB, + ions): m/z 539 (M + K), 501 (M + H),
463 (M-K + 2H).

Anal. Calcd for $\text{C}_{16}\text{H}_{16}\text{O}_7\text{PSK}_3 + 3.33 \text{ H}_2\text{O}$:

C, 34.28; H, 4.07; P, 5.52; S, 5.72

15 Found: C, 34.28; H, 3.99; P, 5.14; S, 5.79.

Example 177

[3aR-[2(R*),3a α ,7a β]]-[1-[[(Dimethylamino)thioxo-
methyl]thio]-4-(3-phenoxyphenyl)butyl]octahydro-
20 1,3-dimethyl-2-1H-1,3,2-benzodiazaphosphole, 2-
oxide

and

25 [3aR-[2(S*),3a α ,7a β]]-[1-[[(Dimethylamino)thioxo-
methyl]thio]-4-(3-phenoxyphenyl)butyl]-octahydro-
1,3-dimethyl-2-1H-1,3,2-benzodiazaphosphole, 2-
oxide

30 A. [3aR-(3a α ,7a β)]-2-[[[(Dimethylamino)-
thioxomethyl]thio]]octahydro-1,3-dimethyl-
1H-1,3,2-benzodiazaphosphole, 2-oxide

To a stirred solution of 502 mg (2.48 mmol)
of Example 175 Part B compound in 10 mL of THF

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under argon at -78°C was added 1.09 mL (2.73 mmol) of a 2.5 N solution of n-butyllithium in hexanes dropwise over 10 minutes. After stirring at -78°C for one hour, 87 mg (2.73 mmol) of sulfur was added
5 via a solid addition tube, and temperature of the reaction was raised to -20°C over 1 hour. The reaction mixture was treated with 0.93 mL (6.69 mmol) of triethylamine and 276 mg (2.23 mmol) of dimethylthiocarbamoyl chloride at -20°C , stirred
10 for 5 minutes, then allowed to warm to room temperature. The mixture was diluted with ether and washed with water. The aqueous layer was back extracted with ether and the organics were combined, dried and concentrated to afford 558 mg
15 of an oil. The crude product was purified by flash chromatography on silica gel (50 g) eluted with 96:4 ethyl acetate/methanol. Pure fractions were combined and concentrated to yield 337 mg (47%) of title compound as a clear oil.

20

TLC (Silica gel, 9:1 ethyl acetate/methanol)
 $R_f=0.35$.

MS (CI, + ions) 332 (M+H).

25

^{31}P NMR (CDCl_3 , 121 MHz) 37.7 ppm.

30

B. $3\alpha\text{R}-[2(\text{R}^*), 3\alpha, 7\alpha\beta]]-[1-[(\text{Dimethyl- amino)thioxomethyl}]thio]-4-(3\text{-phenoxy- phenyl)butyl]octahydro-1,3\text{-dimethyl-2-1H-1,3,2-benzodiazaphosphole, 2-oxide}$

To a stirred solution of 89 mg (0.28 mmol) of Part A compound in 1 mL of THF under argon at -78°C was added 122 μL (0.31 mmol) of a 2.5 N



solution of n-butyllithium in hexanes dropwise over 10 minutes. After 90 minutes at -78°C, 0.096 mL (0.55 mmol) of hexamethylphosphoramide was added, followed by 98 mg (0.30 mmol) of 3-(3-phenoxy-phenyl)propyliodide in 1 mL of THF. After 28 hours at -78°C, the reaction was quenched with methanol and allowed to reach room temperature. The mixture was concentrated, then dissolved in ether and washed with water and brine, dried over sodium sulfate, and concentrated to afford 129 mg of a yellow oil. The crude product was purified by flash chromatography on silica gel (15 g) eluted with 98:2 ethyl acetate/methanol. Fractions (#11-19) containing pure material were combined and concentrated to yield 50 mg (34%) of title α -(R)isomer as a clear oil.

TLC (Silica gel, 9:1 ethyl acetate/methanol)
 R_f =0.45.

20

C. [3aR-[2(S*),3a α ,7a β]]-[1-[[(Dimethyl-amino)thioxomethyl]thio]-4-(3-phenoxy-phenyl)butyl]octahydro-1,3-dimethyl-2-lH-1,3,2-benzodiazaphosphole, 2-oxide

25

Fractions #21-30 were combined and concentrated to provide 10 mg (7%) of title isomer as a clear oil.

TLC (Silica gel, 9:1 ethyl acetate/methanol)
 R_f =0.39.

30

MS (CI, + ions) 532 (M+H).

^{31}P NMR (CDCl_3 , 121 MHz) 39.3 ppm.

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The Parts B and C compounds may then be separated and subjected to acid hydrolysis and then oxidation and salt formation as described in Example 175 to form the title compound of Examples 175 and 176.

Example 178

[3aR-[2(R*),3a α ,7a β]]-[1-[[(Dimethylamino)thioxomethyl]thio]-4-(3-phenoxyphenyl)butyl]octahydro-1,3-dimethyl-2-1H-1,3,2-benzodiazaphosphole, 2-oxide

A. [3aR-(3a α ,7a β)]-Octahydro-1,3-dimethyl-1H-1,3,2-benzodiazaphosphole, 2-oxide

To a stirred solution of 497 mg (3.49 mmol) of Example 175 Part A (R,R)-diamine and 1.07 mL (7.89 mmol) of triethylamine in 25 mL of tetrahydrofuran (THF) under argon at -78°C was added dropwise over 5 minutes 335 μ L (3.84 mmol) of phosphorus trichloride. The cloudy solution was allowed to warm to room temperature and was filtered under argon through a pad of celite and magnesium sulfate. The filtrate was chilled to -78°C under argon and treated with 536 μ L of triethylamine and 63 μ L (3.49 mmol) of water. The mixture was allowed to warm to room temperature and was filtered under argon through a pad of celite and magnesium sulfate and concentrated to provide 544 mg (82%) of title compound as a yellow oil.

^{31}P NMR (CDCl_3 , 121 MHz) δ 27.3 ppm.

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B. [3aR-[2(R*),3a α ,7a β)]-Octahydro-1,3-dimethyl-2-[4-(3-phenoxyphenyl)-1-[(trimethylsilyl)oxy]butyl]-1H-1,3,2-benzodiazaphosphole, 2-oxide

5

C. [3aR-[2(S*),3a α ,7a β)]-Octahydro-1,3-dimethyl-2-[4-(3-phenoxyphenyl)-1-[(trimethylsilyl)oxy]butyl]-1H-1,3,2-benzodiazaphosphole, 2-oxide

10

A solution of 544 mg (2.89 mmol) of Part A compound and 534 mg (2.22 mmol) of 3-phenoxybenzenebutanal (Example 180 Part B) in 5 mL of methylene chloride under argon was treated with 814 μ L (3.33 mmol) of bis(trimethylsilyl) acetamide at
15 room temperature and stirred for 17 hours. The reaction was quenched with water and extracted with methylene chloride (3 x 35 mL). The combined organics were washed with brine, dried (sodium sulfate), and concentrated to provide 875 mg of a
20 yellow oil. The crude product mixture was purified by flash chromatography on silica gel (80 g) eluted with 2 L of 9:1 hexane/acetone followed by 2 L of 85:15 hexane/acetone and 1.5 L of 8:2 hexane/acetone. Fractions containing the more
25 polar α -(R) isomer (title B) were combined and concentrated to yield 135 mg (14%) of title B compound as a clear oil.

30

TLC Silica gel (1:1 hexane/acetone) R_f =0.29.

^{31}P NMR (CDCl_3 , 121 MHz) δ 41.1 ppm.

Fractions #85-96 were combined and concentrated to yield 112 mg (12%) of the pure Part C α -(S) isomer.

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TLC Silica gel (1:1 hexane/acetone) $R_f=0.31$.

^{31}P NMR (CDCl_3 , 121 MHz) δ 27.3 ppm.

5

D. [3aR-[2(R*),3a α ,7a β]]-Octahydro-2-[1-hydroxy-4-(3-phenoxyphenyl)butyl]-1,3-dimethyl-1H-1,3,2-benzodiazaphosphole,
2-oxide

10

To a stirred solution of 125 mg (0.20 mmol) of Part B isomer in 1 mL of THF was added 0.29 mL (0.29 mmol) of a 1.0 N solution of tetrabutylammonium fluoride in THF. After stirring for three hours at room temperature, the mixture was diluted with ether, washed with saturated sodium bicarbonate, brine, dried (sodium sulfate), and concentrated to provide 104 mg of a white solid. The crude product was purified by flash chromatography on silica gel (15 g) eluted with 97.5:2.5 ethyl acetate/methanol. Clean fractions (#41-71) were combined and concentrated to yield 100 mg (93%) of title compound as a white solid. m.p. 122-125°C.

15

20

25

TLC Silica gel (1:1 hexane/acetone) $R_f=0.44$.

^{31}P NMR (CDCl_3 , 121 MHz) δ 41.1 ppm.

30

E. [3aR-[2(R*),3a α ,7a β]]-[1-[[[(Dimethylamino)thioxomethyl]thio]-4-(3-phenoxyphenyl)butyl]octahydro-1,3-dimethyl-2-1H-1,3,2-benzodiazaphosphole, 2-oxide]

To a stirred suspension of 56 mg (0.13 mmol) of Part D compound, 30 mg (0.09 mmol) of dimethyl-

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dithiocarbamic acid, zinc salt, and 47 mg (0.18 mmol) of triphenylphosphine in 1 mL of THF at 0°C under argon was added a solution of 52 μ L (0.27 mmol) of diisopropyl azodicarboxylate in 0.5 mL of THF over fifteen minutes. The reaction was stirred at room temperature for 45 hours, then diluted with ether and quenched with water. The organics were washed with brine, dried (sodium sulfate), and concentrated to provide 150 mg of an oil. The crude product was purified by flash chromatography on silica gel (15 g) eluted with ethyl acetate. Pure fractions were combined and concentrated to yield 15 mg (21%) of title compound as a film, the α -(R)-isomer.

TLC Silica gel (1:1 hexane/acetone) R_f =0.20.
Note: This is identical to Example 175 Part D compound and is the precursor to the Example 176 compound.

MS (CI, + ions) 532 (M+H).

 ^{31}P NMR (CDCl_3 , 121 MHz) δ 41.2 ppm.

Example 179

(S)-(-)-3-Phenoxy- α -phosphonobenzenebutanesulfonic acid, tripotassium salt

A. [3aR-(3a α ,7a β)]-2-Chlorooctahydro-1,3-dimethyl-1H-1,3,2-benzodiazaphosphole, 2-oxide

A solution of 4.72 g (33.20 mmol) of Example 175 Part A diamine and 12.63 g (125.0 mmol) of triethylamine in 50 mL of toluene at 0° C was

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treated with 5.00 g (33.20 mmol) of phosphorus oxychloride dropwise over 15 min. The reaction mixture was stirred for 10 min. at 0°C and warmed to RT. After 3 h the solids were filtered off and
5 the filtrate concentrated to a slurry. The slurry was purified by flash chromatography (100 g of silica gel) eluting with 15:85 acetone/toluene to provide 6.50 g (88%) of title chloride as a low melting solid.

10

TLC Silica gel (1:4 acetone/toluene) R_f =0.30.

B. [3aR-(3a α ,7a β)]-Octahydro-1,3-dimethyl-1H-1,3,2-benzodiazaphosphole-2-methane-
15 sulfonic acid, ethyl ester, 2-oxide

To a rapidly stirred solution of 6.20 g (50.0 mmol) of ethyl methanesulfonate in 150 mL of THF at -73 °C (internal temperature) was added 20 mL (50 mmol) of 2.5 M n-butyllithium dropwise over
20 20 min (The internal temperature was not allowed to rise above -69°C throughout the addition of n-BuLi). After an additional 30 min., 5.56 g (25.0 mmol) of freshly prepared Part A chloride in 25 mL of THF was added at a rate to keep the solution
25 temperature below -69°C. The reaction mixture was stirred for 0.3 h at -73°C and for 3 h at -30°C. The reaction mixture was poured into 250 mL of a rapidly stirring mixture of 1:1 saturated aqueous NaHCO₃ solution/ethyl acetate. The mixture was
30 partitioned between ethyl acetate and water (3 X 75 mL). The organic extracts were dried (Na₂SO₄) and concentrated to an oil. The oil was purified by flash chromatography (200 g silica gel) eluting with methylene chloride (600 mL) followed by 93:7

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dichloromethane/isopropanol (1000 mL) to provide 6.60 g (85%) of title compound as a low melting solid.

- 5 TLC Silica gel (1:9 2-propanol/dichloromethane)
R_f=0.58.

IR (KBr) 2947, 2878, 1478, 1451, 1348, 1258, 1236, 1215, 1165, 1123, 1026, 1005, 918 cm⁻¹.

10

Mass Spec (CI-NH₃, + ions) m/e 638 (2M+NH₄), 621 (2M+H), 328 (M+NH₄), 311 (M+H).

Anal. Calc'd for C₁₁H₂₃N₂O₄PS:

- 15 C, 42.57; H, 7.47; N, 9.03; P, 9.89;
S, 10.33

Found: C, 42.95; H, 7.55; N, 9.10; P, 9.81;
S, 10.59.

- 20 $[\alpha]_D^{20} = -79^\circ$ CHCl₃, (c=1)

C. [3aR-(3a α ,7a β)]-Octahydro-1,3-dimethyl-
1H-1,3,2-benzodiazaphosphole-2-methane-
sulfonic acid, tetrabutylammonium salt,
25 2-oxide

- 30 A suspension of 5.00 g (16.12 mmol) of Part B compound and 6.02 g (16.29 mmol) of tetrabutylammonium iodide in 30 mL of anhydrous THF at RT was stirred for 10 min. at 0°C and warmed to RT. After 30 h the clear solution was concentrated to a thick oil. The oil was dried under vacuum (0.009 mm Hg) overnight. The honey-like oil was used without further purification.

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Mass Spec (FAB, + ions) m/e 242 (Bu_4N).

Mass Spec (high res., FAB, - ions)

5 Calcd for $\text{C}_9\text{H}_{18}\text{O}_4\text{N}_2\text{PS}$:

281.0725

Found: 281.0717

$[\alpha]_{\text{D}}^{20} = -33.8^\circ \text{ CH}_3\text{OH}, (c=1)$

10

D. (S)-(-)-3-Phenoxy- α -phosphonobenzene-
butanesulfonic acid, tripotassium salt

To a slurry of 3.29 g (6.29 mmol) of Part C
compound in 20 mL of dry THF at -90°C (internal
15 temperature) under argon was added 3.0 mL (7.50
mmol) of 2.5 M n-BuLi in hexanes to give a yellow
solution. After 0.5 h at -90°C the solution was
treated with 2.10 g (6.29 mmol) of 3-(3-phenoxy-
phenyl)propyl iodide in 6 mL of THF at such a rate
20 to keep the internal temperature below -85°C . The
reaction mixture was stirred at -90°C for 3 h when
it was gradually warmed to -74°C overnight. The
mixture was quenched with 360 μL of acetic acid in
3 mL of THF and allowed to warm to RT. The mixture
25 was concentrated and acidified with 12 mL of 2M HCl
solution (24 mmol). The reaction mass was
extracted with hexane, the aqueous layer was heated
to 80°C for 3 hours and then diluted with 2-
propanol until a clear solution resulted. After
30 heating an additional hour the solvent was
evaporated and the residue pumped (≈ 0.5 mm
pressure) for 0.5 h. The remainder was dissolved
in 30 mL (30 mmol) of 1 M KOH solution and freeze-
dried to provide a cream colored solid. The solid

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was diluted with water and eluted through 24 g of AG50X8 (63 meq, K⁺ form) ion exchange resin. Final purification was accomplished by MPLC on a column of CHP20P gel (125 mL) eluting with water (200 mL) followed by a gradient created by the gradual addition of 500 mL of acetonitrile to a reservoir of 500 mL of water. Approximately 10 mL fractions were collected. Pure fractions were pooled, the acetonitrile was removed under reduced pressure and the aqueous solution lyophilized to provide 1.48 g (47%) of title compound as a white lyophilate.

TLC Silica gel (6:3:1 propanol/ammonium hydroxide/water) R_f=0.2

Chiral HPLC analysis of enantiomeric excess was performed on a ChromTech α -acid glycoprotein (α 1-AGP) column: isocratic 85% 0.1 M KH₂PO₄/15% CH₃CN, (pH 4.6) in isocratic mode.

For this sample title compound (S)-isomer: retention time $\approx$ 10.3 min. 94%

Example 176 compound (R)-isomer: retention time $\approx$ 19.0 min. 6%

Therefore, the enantiomeric excess is 88%.

Anal. Calc'd for C₁₆H₁₆O₇PSK₃ + 2.2 H₂O:

C, 35.54; H, 3.81; P, 5.73; S, 5.93

Found: C, 35.54; H, 3.98; P, 5.42; S, 6.30.

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Example 180

(R)-(+)-3-Phenoxy- α -phosphonobenzenebutanesulfonic
acid, tripotassium salt

5 A. 4-(3-Phenoxyphenyl)butyl alcoholA(1) 3-Phenoxybenzyl alcohol

Sodium borohydride (961 mg, 25.3 mmol) was added in one portion to a solution of 3-phenoxy-
10 benzaldehyde (10.0 g, 50.5 mmol) in methanol (150 mL) at RT under argon. Once the bubbling ceased, the reaction was stirred at RT for 5 min, then adjusted to pH 6 with glacial acetic acid (about 1 mL). The reaction was concentrated in vacuo to
15 give a residue, which was partitioned between EtOAc (200 mL) and saturated NaHCO₃ (50 mL). The organic layer was washed with water and brine (50 mL each), then dried over MgSO₄. Evaporation gave title compound (10.1 g, 100%) as a tan oil.

20

A(2) 3-Phenoxybenzylbromide

Phosphorus tribromide solution (11.0 mL, 1M in CH₂Cl₂, 11.0 mmol) was added over 5 min to a solution of Part 1(A) alcohol (2.00 g, 10.0 mmol)
25 in CH₂Cl₂ (30 mL) under argon at RT. The yellow reaction was stirred at RT for 10 min, diluted with CH₂Cl₂ (100 mL), and washed with saturated NaHCO₃ (2 x 30 mL). The organic layer was dried over MgSO₄. Evaporation gave a pale yellow oil, which
30 was purified by flash chromatography on silica gel (75 g) eluting with 10:90 CH₂Cl₂/hexane to provide title bromide (1.57 g, 60%) as a yellow oil.



A(3) 4-(3-Phenoxyphenyl)butyl alcohol

A Grignard solution of $\text{ClMg}(\text{CH}_2)_3\text{OMgCl}$ (19.2 mL, 0.6M in THF, 11.5 mmol) was added to a mixture of Part A(2) bromide (1.51 g, 5.74 mmol) and
5 copper(I) iodide (11 mg, 0.057 mmol) in THF (10 mL) at 0°C under argon over a period of 5 min. The dark green reaction was stirred at 0°C for 30 min, then quenched by dropwise addition of 2-propanol (2 mL). The reaction was diluted with diethyl ether
10 (100 mL) and washed with 1N KHSO_4 (2 x 50 mL). The aqueous layers were back-extracted with diethyl ether (20 mL). The combined organic layers were dried over MgSO_4 . Evaporation gave a pale yellow oil, which was purified by flash chromatography on
15 silica gel (100 g) eluting with 30:70 EtOAc/hexane to provide title alcohol (1.10 g, 79%) as a colorless oil.

B. 3-Phenoxybenzenebutanal

20 To a stirred solution of 3.4 mL (48.6 mmol) of methyl sulfoxide in 50 mL of CH_2Cl_2 under argon at -78°C was added 3.9 mL (44.5 mmol) of oxalyl chloride dropwise over 5 min. The reaction was stirred at -78°C for 0.5 h at which time 9.8 g
25 (40.4 mmol) of Part A alcohol in 15 mL of CH_2Cl_2 was added dropwise. The reaction was stirred at -78°C for 20 min, warmed to -30°C for 5 min, cooled back down to -78°C and treated with 22.6 mL (162 mmol) of triethylamine. The reaction gradually
30 warmed to -20°C and was quenched with 150 mL of water. The mixture was diluted with a 1:1 mixture of hexanes/ethyl acetate and the layers were separated. The organics were dried over Na_2SO_4 and

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evaporated to dryness to provide 8.8 g (91%) of title compound as a pale yellow oil.

TLC Silica gel (70:30 hexanes/ethyl acetate)

5 $R_f = 0.40$.

C. 4,6-Dimethyl-2-[3-(3-phenoxyphenyl)-propyl]-1,3-dioxane

To a solution of 5.6 g (23.33 mmol) of Part
10 B aldehyde in 25 mL of benzene was added 2.4 g
(23.33 mmol) of (2S,4S)-(+)-pentanediol and a 50 mg
(0.36 mol) of p-toluenesulfonic acid. The reaction
was refluxed for 2 h using a Dean-Stark trap for
the azeotropic removal of water. The reaction was
15 diluted with ethyl acetate, washed with sat. NaHCO_3
solution, water, dried over MgSO_4 and evaporated to
provide a crude yellow oil. Flash chromatography
was performed on 300 g of silica gel eluting with
90:10 hexanes/ethyl acetate. Pure product
20 fractions were combined and evaporated to provide
5.5 g (72%) of title compound as a colorless oil.

TLC Silica gel (90:10 hexanes/ethyl acetate)

$R_f = 0.21$.

25

$[\alpha]_D^{20} - 13.1^\circ$ (c=1, CH_2Cl_2)

MS (CI- NH_3 , + ions) m/e 344 ($\text{M}+\text{NH}_4$), 326 (M).

30

D. [R-[R*[R*(R*)]]]- α -(3-Hydroxy-1-methylbutoxy)-3-phenoxybenzenebutane-phosphonic acid, diethyl ester

(Yokomatsu, T., Shibuya, S., Tetrahedron
Asymmetry 1992, 3, 377-8).

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To a solution of 2.9 mL (16.87 mmol) of triethyl phosphite in 7 mL of CH_2Cl_2 at -78°C under argon was added dropwise 1.5 mL (13.50 mmol) of titanium (IV) chloride. The resulting orange
5 solution was stirred at -78°C for 0.5 h at which time 2.2 g (6.75 mmol) of Part C compound in 5 mL of CH_2Cl_2 was added dropwise over 0.5 h (internal temperature of the reaction maintained at -68°C).
10 The reaction was stirred for 48 h at -78°C at which time the reaction was poured into 200 mL of a 1:1 mixture of NaHCO_3 /ethyl acetate and extracted. The organics were washed with water, brine, dried (MgSO_4) and evaporated to provide 2.0 g of a crude
15 oil. Flash chromatography was performed on 200 g of silica gel eluting with 4:1 dichloromethane/acetone. Pure product fractions were pooled and evaporated to provide 1.5 g (48%) of title compound as a colorless oil.

20 TLC Silica gel (4:1 dichloromethane/acetone) $R_f = 0.24$.

$[\alpha]_D^{20} +15.8$ ($c = 1$, CH_2Cl_2)

25 IR (Film, CH_2Cl_2) 3410, 3040, 2969, 2870, 1584, 1487, 1447, 1385, 1250, 1215, 1163, 1047 cm^{-1} .

^{31}P NMR (CDCl_3 , 121 MHz, ref. to 10% H_3PO_4 , 0 ppm): 24.20 ppm.

30

HRMS (EI, + ions) m/z Calculated for $\text{C}_{25}\text{H}_{37}\text{O}_6\text{P}$: M^+ 464.2328 Found: 464.2316

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E. (R)- α -Hydroxy-3-phenoxybenzene-
butanephosphonic acid, diethyl ester

To a solution of 3 mL (6.00 mmol) of 2.0 M
oxalyl chloride in CH₂Cl₂ in 3.5 mL of CH₂Cl₂,
5 under argon at -70°C, was added dropwise 535 μ L
(7.54 mmol) of DMSO (exothermic). This mixture was
stirred at -70°C for 15 min at which time 1.4 g
(3.02 mmol) of Part D compound in 5 mL of CH₂Cl₂
was added dropwise. The reaction was stirred at
10 -70°C for 1 h, treated with 1.7 mL of triethylamine
and allowed to warm to RT. The reaction was
quenched with water and diluted with a 1:1 mixture
of hexanes/ethyl acetate. The organics were dried
(MgSO₄) and evaporated to provide 1.4 g of a crude
15 oil. The crude oil was treated with 14 mL of
dioxane, 70 mg (0.37 mmol, 5%) of p-toluenesulfonic
acid, 1.4 mL of water and refluxed for 0.5 h then
cooled to RT. The mixture was diluted with a 1:1
mixture of water/NaHCO₃ and extracted 3 times with
20 CH₂Cl₂. The organics were dried (MgSO₄) and
evaporated to provide 1.2 g of a pale yellow oil.
Flash chromatography was performed on 100 g of
silica gel eluting with 4:1 dichloromethane/
acetone. Pure product fractions were combined and
25 evaporated to provide 690 mg (60%) of title
compound as a colorless oil.

$[\alpha]_D^{20}$ -5.9° (c = 1, CHCl₃)

30 TLC Silica gel (4:1 dichloromethane/acetone)
R_f = 0.23.

IR (Film, CH₂Cl₂) 3306, 2982, 1584, 1485, 1445,
1385, 1250, 1215, 1163, 1142, 1096, 1051, 1026,



966 cm^{-1} .

^1H (300 MHz, CDCl_3):

5 δ 7.30-6.70 (m, 9H)
 4.15 (m, 4H)
 3.95 (m, 1H)
 3.87 (m, 1H)
 2.61 (m, 2H)
 1.95 (m, 1H)
10 1.70 (m, 3H)
 1.30 (t, 6H, $J = 7.1 \text{ Hz}$) ppm.

^{31}P NMR (121 MHz, CDCl_3 , ref. to 10% H_3PO_4 ,
0 ppm): 25.28 ppm.

15

HRMS (FAB, + ions) m/z Calculated for $\text{C}_{20}\text{H}_{28}\text{O}_5\text{P}$:

$(\text{M}+\text{H})^+ = 379.1675$

FOUND: 379.1692

20

Anal. Calcd. for $\text{C}_{20}\text{H}_{27}\text{PO}_5 + 0.50 \text{ mol H}_2\text{O}$.

Effective MW = 387.40.

C, 62.00; H, 7.28; P, 7.99

Found: C, 62.00; H, 7.05; P, 8.13.

25

F. (R)- α -[[(Dimethylamino)thioxomethyl]-
thiol-3-phenoxybenzenebutanephosphonic acid

30

To a stirred slurry of 415 mg (1.10 mmol) of
Part E compound, 585 mg (2.23 mmol) of
triphenylphosphine and 252 mg (0.82 mmol) of
dimethyldithiocarbamic acid, zinc salt, in 3 mL of
THF at 0°C under argon was added 446 mg (2.21 mmol)
of diisopropyl diazodicarboxylate in 2 mL of THF
over the course of 20 minutes. The resulting light
yellow solution was allowed to warm to room

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temperature and stirred for 16 hours. The reaction mixture was then evaporated and immediately purified by flash chromatography (5 x 15 cm column, eluting with 1:3 ether/dichloromethane). Fractions
5 containing both the product and an impurity were collected, concentrated and re-chromatographed (5 x 15 cm column, 85:15 ethyl acetate/hexane). The resulting yellow oil still contained ca. 8-10% of diisopropyl dicarbazide as an impurity. The yield
10 of title compound was 490 mg (82% of 91% pure material).

$$[\alpha]_D^{20} = 24.5^\circ \quad (c = 0.99, \text{CHCl}_3)$$

15 G. (R)-(+)-3-Phenoxy- α -phosphonobenzene-
butanesulfonic acid, tripotassium salt

To a stirred solution of 410 mg (0.851 mmol) of Part F compound in 3 mL of CH_2Cl_2 at room temperature under argon was added 0.7 mL (5.3 mmol)
20 of bromotrimethylsilane. The nearly colorless solution was stirred for 16 hours and then evaporated at less than 25°C. The residue was dissolved in 10 mL of dry methanol and stirred for 1 hour. Re-evaporation gave 358 mg (99%) of the
25 diacid as a colorless glass.

To a solution of 0.326 g (0.77 mmol, 1 eq) of the diacid in 50 mL of 98% formic acid was added 4.2 mL (38 mmol, 50 eq) of 30% hydrogen peroxide in water. The reaction became cloudy after 0.5 min
30 and a precipitate formed after ~2 min. After 1 h, the reaction was cooled to 0°C and the excess peroxide was decomposed by the slow addition of 40 mL of 1 N potassium sulfite. The solution was concentrated and the residue was coevaporated twice

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with water. The residue was dissolved in 10 mL of water and the pH of the solution (pH ~ 3) was brought to pH 12 with 1 N potassium hydroxide. The solution was then chromatographed on CHP-20P gel
5 (2.5 cm x 25 cm) eluting with water. Fractions containing product were analyzed by HPLC, then pooled and concentrated to afford a clear waxy residue which was dissolved in water, filtered and lyophilized to afford 201 mg (48%) of title
10 compound.

TLC Silica gel (6:3:1 n-propanol:ammonium hydroxide:water): R_f 0.21.

15 Chiral HPLC analysis of enantiomeric excess was performed on a ChromTech α -acid glycoprotein (α_1 -AGP) column, eluted with 85% 0.1 M KH_2PO_4 , 15% CH_3CN , pH 4.6 in isocratic mode.

20 For title compound: ret. time 18.5 min, 98.95% (R)-enantiomer
ret. time 11.2 min, 1.05% (S)-enantiomer
therefore 97.9% enantiomeric excess of the (R)-isomer.

25

Anal. Calc'd for $\text{C}_{16}\text{H}_{16}\text{O}_7\text{PSK}_3 + 2.5 \text{ H}_2\text{O}$:

C, 35.19; H, 3.88; P, 5.67; S, 5.87

Found: C, 35.19; H, 3.54; P, 5.32; S, 6.27.

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Example 181

(S)-(-)-3-Phenoxy- α -phosphonobenzenebutanesulfonic
acid, 1-adamantanamine (1:2) salt

5 A sample of the (R)-(-)-trisalt (94:6,
 (S):(R)) prepared in Example 179 (70 mg, 0.14 mmol)
 was stirred with 3 g of Ag50-X8 ion exchange resin
 (7.5 meq, H⁺ form) for 1 h in 5 mL of water and 3
 mL of methanol. The mixture was slowly eluted
10 through an additional column of Ag50-X8 ion
 exchange resin (1 g, 2.5 meq, H⁺ form) with 1:1
 methanol/water. Approximately 3 mL fractions were
 collected. Fractions # 2 to 7 were pooled, the
 methanol was removed under reduced pressure and the
15 aqueous solution lyophilized to provide 54 mg
 (100%) of the free acid form of the title salt as a
 thin film.

 The free acid (54 mg, 0.14 mmol) in 3 mL of
 a 1:1 methanol/water solution was treated with 39
20 mg (0.28 mmol, 2 eq) of adamantanamine and the
 mixture stirred for 0.5 h. The mixture was
 concentrated to a white solid. The solid was
 recrystallized from hot water and 2-propanol. The
 white granules were collected to yield 79 mg (85 %)
25 of title salt as a 97:3 mixture of (S):(R)
 enantiomers. The recrystallization procedure was
 repeated to provide 66 mg (85 %) of title salt, as
 a white solid, mp 248-252°C. The two
 recrystallizations from hot 2-propanol/water
30 improved the ratio of (S):(R) enantiomers from 94:6
 to 98:2 determined by HPLC as described on the α -
 acid glycoprotein column.

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TLC Silica gel (6:3:1 n-propanol/conc.
ammonia/water) $R_f=0.30$.

IR (KBr) 3426, 3086, 3065, 3036, 2915, 2855, 1609,
5 1582, 1485, 1233, 1215, 1175, 1022, 882 cm^{-1} .

Mass Spec (FAB, + ions) m/e 689 (M+H);
(FAB, - ions) m/e 385 (M-2(C₉H₁₇N)+H).

10 Anal. Calc'd for C₃₆H₅₃O₇N₂PS + 1.00 H₂O:
C, 61.17; H, 7.84; N, 3.96; P, 4.38;
S, 4.54.
Found: C, 61.26; H, 7.90; N, 4.00; P, 4.27;
S, 4.74.

15

Regeneration of Metal Salt

Title salt (60 mg, 0.08 mmol) was stirred
with 1.5 mL of Ag50-X8 ion exchange resin (2.5 meq,
20 K⁺ form) for 2 h in 3 mL of water and 1 mL of
methanol (pH = 7). The mixture was slowly eluted
through an additional column of Ag50-X8 ion
exchange resin (1.5 mL, 2.5 meq, K⁺ form) with 1:1
methanol/water. Product containing fractions were
25 pooled, the methanol was removed under reduced
pressure and the aqueous solution lyophilized to
provide 38 mg (95 %) of the tripotassium salt as a
white lyophilate.

30 Chiral HPLC analysis of enantiomeric excess was
performed on a ChromTech α -acid glycoprotein (α 1-
AGP) column eluted with isocratic 85% 0.1 M KH₂PO₄,
15% CH₃CN, pH 4.6.

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For this sample,

Example 181 (S)-isomer: retention time $\approx$ 9.5 min.

98%

Example 180 (R)-isomer: retention time $\approx$ 19.0 min.

5 2%, therefore a 96% enantiomeric excess of the (S)-
isomer.

Example 182

10 (S)-(-)-3-Phenoxy- α -phosphonobenzenesulfonic
acid, (S)- α -methylbenzylamine (1:2) salt

A sample of the (-)-isomer (Example 175) (70
mg, 0.14 mmol) was stirred with 3 g of Ag50-X8 ion
exchange resin (7.5 meq, H⁺ form) for 1 h in 5 mL
15 of water and 3 mL of methanol. The mixture was
slowly eluted through an additional column of Ag50-
X8 ion exchange resin (1 g, 2.5 meq, H⁺ form) with
1:1 methanol/water. Approximately 3 mL fractions
were collected. Fractions # 2 to 7 were pooled,
20 the methanol was removed under reduced pressure and
the aqueous solution lyophilized to provide 54 mg
(100%) of the free acid form of the title salt as a
thin film. The free acid was used without further
characterization.

25

The free acid in 3 mL of a 1:1
methanol/water solution was treated with 36 μ L
(0.28 mmol, 2 eq) of (S)-(-)- α -methylbenzylamine
under argon. The mixture was stirred for 0.5 h and
30 concentrated to an oil. Recrystallization from 3
mL of hot acetonitrile and 3 drops of water
followed by slow evaporation to dryness provided 60
mg (73%) of title diamine salt as needles.
mp 160-163°C.

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$[\alpha]_D^{20} = -8.0^\circ$ (methanol, $c=1$)

IR (KBr) 3447, 3050, 3038, 2938, 2762, 1613, 1582,
5 1566, 1489, 1242, 1213, 1182, 1163, 1072, 1044,
1022, 924, 702 cm^{-1} .

Mass Spec (FAB, + ions) m/e 629 ($M+H$);
(FAB, - ions) m/e 385 ($M-2(\text{C}_8\text{H}_{11}\text{N})+H$).

10

The needles were subjected to X-ray
crystallographic studies, which demonstrated that
the (-)-isomer had the (S)-stereochemistry at the
 α -carbon.

15

Example 183

(S)- α -[Bis[(2,2-dimethyl-1-oxopropoxy)methoxy]phos-
phanyl]-3-phenoxybenzenebutanesulfonic acid, mono-
potassium salt

20

A. (S)-3-Phenoxy- α -phosphonobenzenebutane-
sulfonic acid, trisilver salt

A solution of Example 175 product (1.66 g,
3.32 mmol) in water (17 mL) was added over 30 min
25 via syringe pump to a vigorously stirred solution
of silver nitrate (2.02 g, 11.9 mmol) in water (17
mL) under argon at RT in the dark. A white
precipitate resulted immediately upon addition.
Following addition, additional water (5 mL) was
30 added to aid stirring, and the thick slurry was
stirred vigorously at RT for 15 min then filtered
through a porosity D (10-20 μm) glass fritted
funnel. The solid was washed with water (2 x 40
mL) and diethyl ether (2 x 40 mL) then air-dried

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for 15 min. The product was further dried by pumping under high vacuum in the dark overnight to give title compound (2.28 g, 97%) as a beige solid.

5 B. (S)- α -[Bis[(2,2-dimethyl-1-oxopropoxy)-methoxy]phosphinyl]-3-phenoxybenzenebutane-sulfonic acid, monopotassium salt

10 A suspension of Part A compound (2.12 g, 3.00 mmol) and activated 4A molecular sieves (2.1 g) in CH_2Cl_2 (25 mL) was stirred at RT in the dark under argon for 45 min. Anhydrous anisole (1.6 mL, 15.0 mmol) was added and the reaction was placed in a 20 °C water bath. To the suspension was added a solution of 2,2-dimethylpropanoic acid, iodomethyl
15 ester (2.18 g, 9.00 mmol) in CH_2Cl_2 (5 mL) dropwise slowly over 15 min via syringe pump ensuring that the reaction temperature remained below 30°C. The reaction turned bright yellow during addition. The heterogeneous reaction was stirred vigorously at RT
20 in the dark for 40 min, then filtered through Celite with the aid of CH_2Cl_2 (200 mL). Evaporation of the filtrate gave 3.3 g of the crude triester α -[bis[(2,2-dimethyl-1-oxopropoxy)-methoxy]phosphinyl]-3-phenoxybenzenebutanesulfonic
25 acid, (2,2-dimethyl-1-oxopropoxy)methyl ester as a yellow liquid.

30 The crude triester was dissolved in CH_3CN /water (4:1, 40 mL) to give an opaque solution containing a small amount of yellow precipitate. The reaction was stirred at RT and progress of the solvolysis was monitored by ^1H NMR (disappearance of the $t\text{-BuCO}_2\text{CH}_2\text{-sulfonate}$ signal at 5.8 ppm [in $d_6\text{-DMSO}$]). When no sulfonate ester remained (8 h)

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the reaction was partitioned between EtOAc (150 mL) and saturated KCl (20 mL). The resultant biphasic mixture was filtered to remove the yellow precipitate. The organic layer was washed with 1M
5 potassium phosphate (pH=6.0, 2 x 20 mL) and saturated KCl (5 mL), then dried over anhydrous KCl. Evaporation followed by pumping under high vacuum for 1.5 h gave 2.0 g of a colorless oil.

10 CHP20P gel was stirred with 0.5M potassium phosphate buffer (pH=5.0, 1000 mL) for 4 h, then packed (5 x 25 cm column) and flushed with water (500 mL). The column was equilibrated with 5:95 CH₃CN/water (1.5 L).

15 The crude product was dissolved in CH₃CN (5 mL), then water (10 mL) was added. The solution was adjusted to pH 5.0 with 1M potassium phosphate buffer (pH=7.0). The product solution was
20 chromatographed on CHP20P gel prepared above (25 mL fractions), eluted with 5:95 CH₃CN/H₂O (250 mL) followed by a gradient created by the gradual addition of 80:20 CH₃CN/H₂O (1200 mL) to a reservoir of 5:95 CH₃CN/H₂O (1200 mL)). Fractions
25 55-62 were combined and concentrated to a volume of 100 mL consisting almost entirely of water. The aqueous solution (pH=3.2) was adjusted slowly to pH=5.0 with 1M potassium phosphate (pH=7.0), then concentrated to dryness. The resultant residue was
30 dissolved in CH₃CN/H₂O (1:4, 10 mL) and lyophilized to give title compound (1.12 g, 57%) as a white lyophilate.

TLC (silica gel) (10:90 MeOH/CH₂Cl₂) R_f 0.25

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Chiral purity was determined by HPLC on a Chrom
Tech α -acid glycoprotein column, with isocratic
elution of 10 mM KH_2PO_4 /iPrOH/MeOH buffer

5 (78:16:6). This sample was 99.2% (S)-isomer
(retention time = 23.5 min) and 0.8% (R)-isomer
(retention time = 17.0 min) and therefore had a
98.4% enantiomeric excess favoring the (S)-isomer.

10 IR (KBr) 2974, 1755, 1584, 1485, 1250, 1215, 1140,
1024, 1003, 963 cm^{-1} .

MS (FAB, + ions) 653 (M+H), 691 (M+K)

15 Anal. Calcd. for $\text{C}_{28}\text{H}_{38}\text{KO}_{11}\text{PS} + 0.60 \text{ KH}_2\text{PO}_4$:

C, 45.69; H, 5.38; P, 6.75

Found: C, 45.64; H, 5.43; P, 7.12.

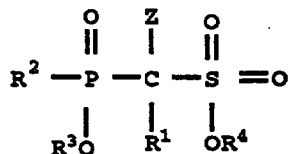
The compounds of Examples 42, 93, 174, 175
20 and 183 are particularly preferred.

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What we claim is:

1. A compound having the structure



wherein R² is OR⁵ or R^{5a},

R³ and R⁵ are independently H, alkyl, arylalkyl, aryl, cycloalkyl, metal ion or other pharmaceutically acceptable salt, or prodrug ester;

R^{5a} is H, alkyl, arylalkyl or aryl;

R⁴ is H, alkyl, aryl, cycloalkyl, arylalkyl, metal ion, or other pharmaceutically acceptable salt, or prodrug ester;

R¹ is a lipophilic group containing at least 7 carbons;

Z is H, halogen, lower alkyl or lower alkenyl.

2. The compound as defined in Claim 1 wherein R¹ is alkyl containing 7 to 25 carbons in the chain; alkenyl containing from 7 to 25 carbon atoms in the chain and from 1 to 6 double bonds; alkynyl containing 1 to 6 triple bonds; mixed alkenyl-alkynyl containing 1 to 5 double bonds and 1 to 5 triple bonds; or aryl; and where in the above groups alkenyl, alkynyl and/or aryl may be substituted or unsubstituted; cycloheteroalkyl

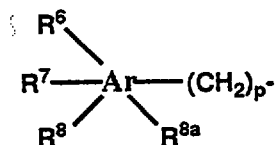
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* C L M S *



linked through a carbon on the ring or a heteroatom; cycloalkyl; heteroarylalkyl; cycloalkylalkyl; heteroaryl; cycloheteroalkylalkyl; or a group of the structure



wherein Ar is aryl or heteroaryl, and Ar may include one to three additional rings fused to Ar, and wherein $(\text{CH}_2)_p$ contains from 1 to 15 carbons in the chain and may include 0, 1, 2 or 3 double bonds and/or 0, 1, 2 or 3 triple bonds in the normal chain, and may contain an ether or amino function in the chain, and/or may include 0, 1, 2 or 3 substituents as defined below for R^6 ; and R^6 , R^7 , R^8 and R^{8a} are the same or different and are H, alkyl containing 1 to 40 carbons, alkoxy containing 1 to 40 carbons, alkenyl containing 2 to 40 carbons, alkenyloxy containing 2 to 40 carbons, alkynyl containing 2 to 40 carbons, alkynyloxy containing 2 to 40 carbons, hydroxy, halogen, nitro, amino, thiol, alkylthio, alkyl-sulfinyl, alkylsulfonyl, carboxy, alkoxycarbonyl, aminocarbonyl, alkylcarbonyloxy, alkylcarbonyl-amino, cycloheteroalkyl, cycloheteroalkylalkyl, heteroaryl, cycloalkyl, cycloalkylalkyl, Ar-alkyl, ArO, Ar-amino, Ar, Ar-thio, Ar-sulfinyl, Ar-sulfonyl, cyano, Ar-carbonyloxy, or Ar-carbonylamino.

3. The compound as defined in Claim 1 wherein Z is H and one or more of R^3 , R^4 and R^5 (where present) are an alkali metal ion or an



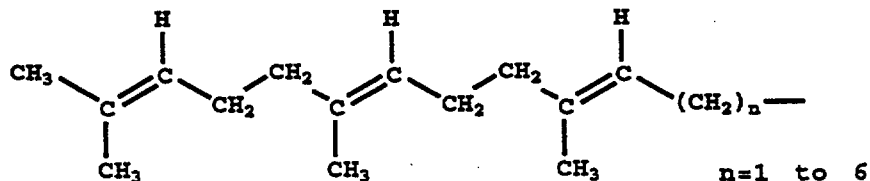
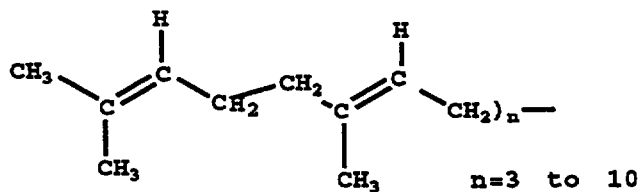
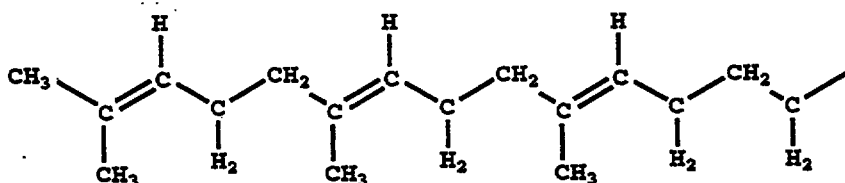


alkaline earth metal ion, or other pharmaceutically acceptable cation, or one or more of R^3 , R^4 and R^5 (where present) are H or R^3 and R^5 (where present) are lower alkyl and/or H.

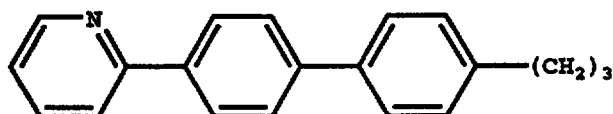
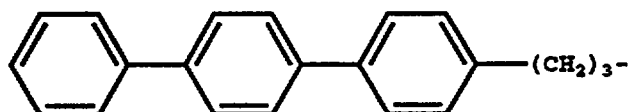
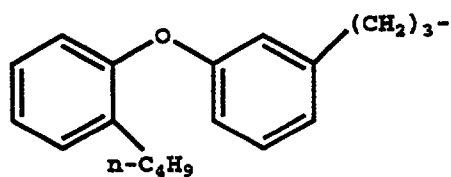
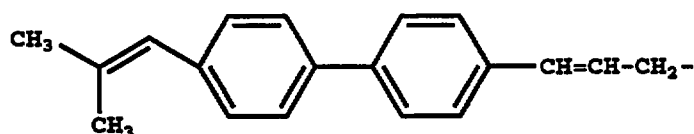
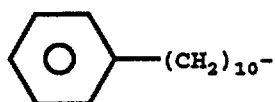
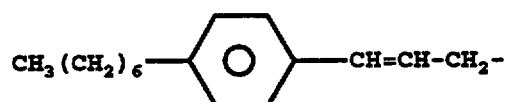
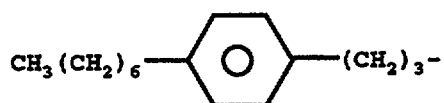
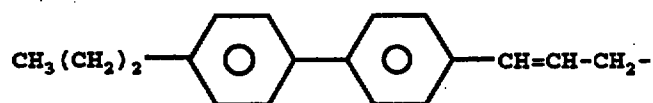
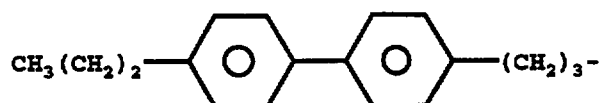
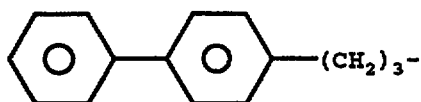
4. The compound as defined in Claim 1 wherein one or more of R^3 , R^4 and R^5 is a prodrug ester.

5. The compound as defined in Claim 1 wherein R^1 is alkenyl, alkyl, phenylalkyl, biphenylalkyl, biphenylalkenyl, terphenylalkyl, terphenylalkenyl, phenylalkenyl, 2-naphthalenyl-alkyl, 2-naphthalenyl-4-phenylalkyl, phenoxyalkyl, phenoxyphenylalkyl, phenoxyphenylalkenyl, pyridylbiphenylalkyl and pyridylbiphenylalkenyl.

6. The compound as defined in Claim 5 wherein R^1 is

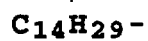
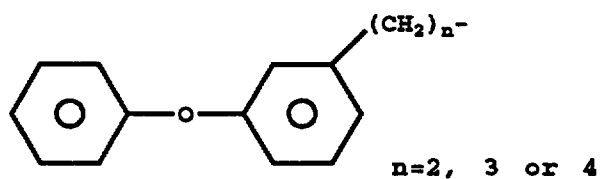
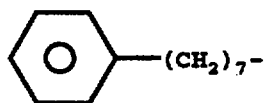
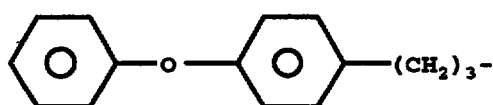
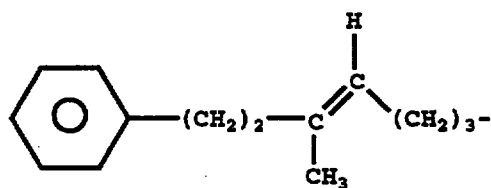
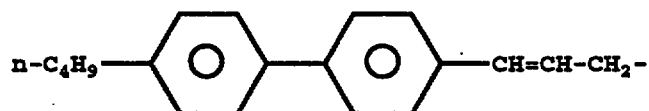
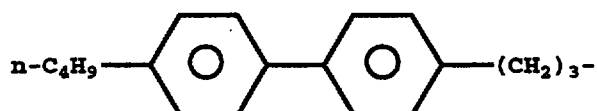
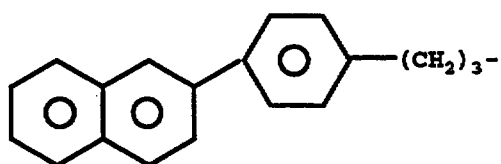
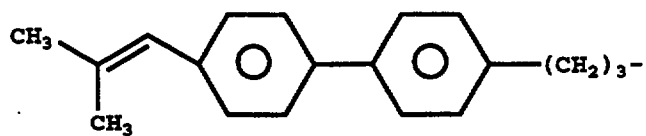
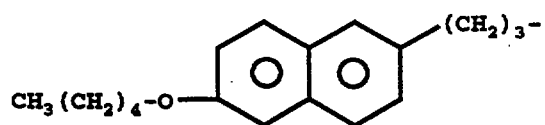


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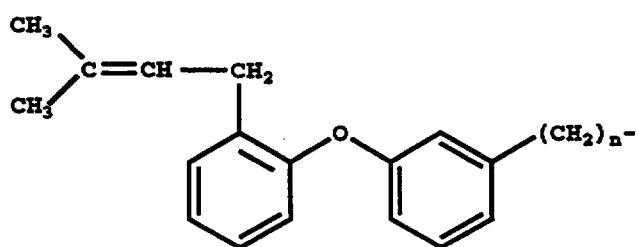
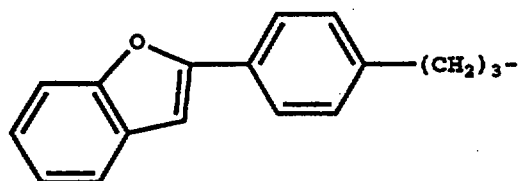
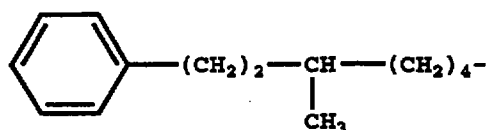


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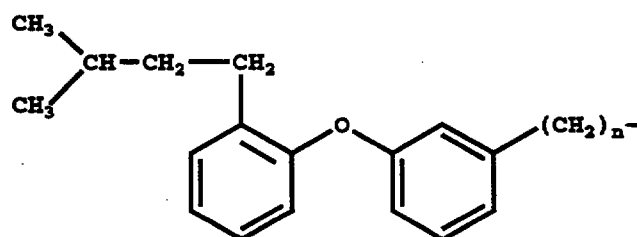
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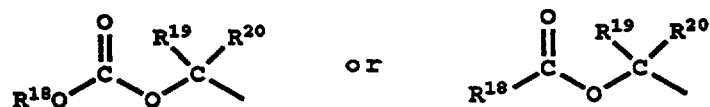


n=2, 3 or 4



n=2, 3 or 4

7. The compound as defined in Claim 1 where the prodrug ester is



wherein R¹⁸, R¹⁹ and R²⁰ are independently H, alkyl, aryl or arylalkyl, with the proviso that R¹⁸O cannot be HO.





8. The compound as defined in Claim 1 which is (E,E)-6,10,14-trimethyl-2-phosphono-5,9,13-pentadecatriene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the trisodium salt or tripotassium salt;

(E)-6,10-dimethyl-1-phosphono-5,9-undecadiene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the trisodium salt;

α -phosphono-[1,1'-biphenyl]-4-butane-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the trisodium salt;

(E)-4-(4-heptylphenyl)-1-phosphono-3-butene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the tripotassium salt;

4-heptyl- α -phosphonobenzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the tripotassium salt;

(E)-4-(4'-propyl[1,1'-biphenyl]-4-yl)-1-phosphono-3-butene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the tripotassium salt;

α -phosphono-4'-propyl[1,1'-biphenyl]-4-butanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the tripotassium salt;

4-(2-phenylethoxy)- α -phosphonobenzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the dipotassium salt;

6-(hexyloxy)- α -phosphono-2-naphthalenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the dipotassium salt;

4-[(5-methyl-4-hexenyl)oxy]- α -phosphonobenzenebutanesulfonic acid, ester thereof, salt





thereof, mixed ester-salt thereof or the tripotassium salt;

1-phosphono-1-pentadecanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the tripotassium salt;

(E)-10,14-dimethyl-1-phosphono-9,13-pentadecadiene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the dipotassium salt;

(E,E)-6,10,14-trimethyl-1-phosphono-5,9,13-pentadecatriene-1-sulfonic acid, ester thereof, or the phenyl ester, salt thereof, mixed ester-salt thereof, or the dipotassium salt, trisodium salt or tripotassium salt;

(E,E)-9,13,17-trimethyl-1-phosphono-8,12,16-octadecatriene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the tripotassium salt;

(E,E)-1-(ethoxyhydroxyphosphinyl)-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, ester thereof, salt thereof mixed ester-salt thereof or the dipotassium salt;

(E)-8,12-dimethyl-1-phosphono-7,11-tridecadiene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the dipotassium salt;

α -phosphono[1,1'-biphenyl]-4-heptanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the tripotassium salt;

(E)-4-(4'-pentyl[1,1'-biphenyl]-4-yl)-1-phosphono-3-butene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the tripotassium salt;





α -phosphono-4'-pentyl[1,1'-biphenyl]-4-butanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the tripotassium salt;

4-(2-naphthalenyl)- α -phosphonobenzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the tripotassium salt;

4-phenoxy- α -phosphonobenzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the tripotassium salt;

1-phosphono-7-(4-propylphenoxy)-1-heptanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the tripotassium salt;

α -phosphono-4-(4-propylphenoxy)benzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the tripotassium salt;

(E,E)-1-(diethoxyphosphinyl)-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the sodium salt;

(E)-6-methyl-10-phenyl-1-phosphono-5-decene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the tripotassium salt;

4-(3-phenylpropyl)- α -phosphonobenzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the tripotassium salt;

(E,E)-1-(hydroxymethylphosphinyl)-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the dipotassium salt;

(E,E)-1-(hydroxyphosphinyl)-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the dipotassium salt;





4-(phenylmethyl)- α -phosphonobenzenebutane-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the tripotassium salt;

(E,E)-1-[hydroxy(methoxymethyl)phosphinyl]-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the dipotassium salt;

α -phosphono-4-propylbenzeneoctanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or the tripotassium salt;

4'-(2-methyl-1-propenyl)- α -phosphono[1,1'-biphenyl]-4-butanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or tripotassium salt;

(E)-6-methyl-1-phosphono-9-(4-propylphenyl)-5-nonene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or tripotassium salt;

(E)-6-methyl-8-phenyl-1-phosphono-5-octene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or tripotassium salt;

(E,E)-1-[hydroxy(hydroxymethyl)phosphinyl]-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or dipotassium salt;

(E,E)-7,11,15-trimethyl-2-phosphono-6,10,14-hexadecatriene-2-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or tripotassium salt;

4'-butyl- α -phosphono[1,1'-biphenyl]-4-butanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof, or tripotassium salt;

(all-E)-7,11,15-trimethyl-1-phosphono-4-(3,7,11-trimethyl-2,6,10-dodecatrienyl)-6,10,14-





hexadecatriene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or tripotassium salt;

(E,E)-4-hydroxy-6,10,14-trimethyl-1-phosphono-5,9,13-pentadecatriene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or tripotassium salt;

3-phenoxy- α -phosphonobenzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or tripotassium salt;

(E,E)-1-[bis[(2,2-dimethyl-1-oxopropoxy)-methoxy]phosphinyl]-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, ester thereof, salt thereof, cyclohexyl ester or monopotassium salt;

4-(2-methylphenoxy)- α -phosphonobenzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or tripotassium salt;

3-(3-propylphenoxy)- α -phosphonobenzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or tripotassium salt;

6-methyl- α -phosphonobenzeneoctanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or tripotassium salt;

α -phosphono[1,1':4',1''-terphenyl]-4'-butanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or tripotassium salt.

3-(2-butylphenoxy)- α -phosphonobenzenepropanesulfonic acid, ester thereof, mixed ester-salt thereof or its tripotassium salt;

(E,E)-1-fluoro-6,10,14-trimethyl-1-phosphono-5,9,13-pentadecatriene-1-sulfonic acid, ester thereof, mixed ester-salt thereof or its tripotassium salt;



(E,E)-1-[bis[1-(1-oxopropoxy)ethoxy]phosphinyl]-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, ester thereof, mixed ester-salt thereof or its monopotassium salt;

(E)-6-methyl-1-phosphono-9-(4-propylphenyl)-5-nonene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

(E)-6-methyl-10-phenyl-1-phosphono-5-decene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

(E)-9-cyclopentyl-6-methyl-1-phosphono-5-nonene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

α -phosphono-4'-methyl[1,1'-biphenyl]-4-butanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

(E,E)-6,10,14-trimethyl-1-phosphono-5,9,13-pentadecatriene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

α -phosphono-4-(3-propylphenoxy)benzene-butanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

4'-ethyl- α -phosphono[1,1'-biphenyl]-4-butanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

4'-chloro- α -phosphono[1,1'-biphenyl]-4-butanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

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14-methyl-1-phosphono-13-pentadecene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

4-(phenylthio)- α -phosphonobenzenebutane-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

(E,E)-7,11,15-trimethyl-1-phosphono-6,10,14-hexadecatriene-1-sulfonic acid, salt thereof, mixed ester-salt thereof or its tripotassium salt;

α -phosphono-4-propylbenzeneoctanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

4-[3-(2-methyl-1-propenyl)phenoxy]- α -phosphonobenzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

α -phosphono-3-(4-propylphenoxy)benzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

(E,E)-1-phosphono-3-[(3,7,11-trimethyl-2,6,10-dodecatrienyl)oxy]-1-propanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

(E,E)-6,10,14-trimethyl-1-phosphono-5,9,13-pentadecatriene-1-sulfonic acid, 4-(methylthio)-phenyl ester, ester thereof, salt thereof, mixed ester-salt thereof or its dipotassium salt;

4-(3-methylphenoxy)- α -phosphonobenzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

(E,E)-1-[bis[(cyclohexylacetyl)oxy]-methoxy]phosphinyl]-6,10,14-trimethyl-5,9,13-

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pentadecatriene-1-sulfonic acid, ester thereof, salt thereof, or its monopotassium salt;

(E,E)-1-bis[benzoyloxy)methoxy]phosphinyl]-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, ester thereof, salt thereof, or its monopotassium salt;

4-(benzoylphenylamino)- α -phosphonobenzene-butanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

3-(benzoylphenylamino)- α -phosphonobenzene-butanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

4-(phenylamino)- α -phosphonobenzenebutane-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

3-(phenylamino)- α -phosphonobenzenebutane-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

4-(phenylsulfinyl)- α -phosphonobenzene-butanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

(10S)-10,14-dimethyl-1-phosphono-13-pentadecene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its dipotassium salt;

4-(2-methylphenoxy)- α -phosphonobenzene-butanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

4-phenoxy- α -phosphonobenzenepentanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

4-(2-fluorophenoxy)- α -phosphonobenzene-butanesulfonic acid ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

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4-(2-methoxyphenoxy)- α -phosphonobenzene-
butanesulfonic acid, ester thereof, salt thereof,
mixed ester-salt thereof or its tripotassium salt;

(E,E)-1-[bis[(1-oxoheptyl)oxy]methoxy]-
phosphinyl]-6,10,14-trimethyl-5,9,13-pentadeca-
triene-1-sulfonic acid, ester thereof, salt
thereof, or its monopotassium salt;

4-[(4-bromophenyl)thio]- α -phosphonobenzene-
butanesulfonic acid, ester thereof, salt thereof,
mixed ester-salt thereof or its tripotassium salt;

4-(phenylsulfonyl)- α -phosphonobenzene-
butanesulfonic acid, ester thereof, salt thereof,
mixed ester-salt thereof or its tripotassium salt;

4-phenoxy- α -phosphonobenzenepropanesulfonic
acid, ester thereof, salt thereof, mixed ester-salt
thereof or its tripotassium salt;

6-methyl-9-phenyl- α -phosphono-5-nonene-1-
sulfonic acid, ester thereof, salt thereof, mixed
ester-salt thereof or its tripotassium salt;

(E,E)-1-bis[(2-methyl-1-oxopropoxy)-
methoxy]phosphinyl]-6,10,14-trimethyl-5,9,13-
pentadecatriene-1-sulfonic acid, ester thereof,
salt thereof, or its monopotassium salt;

4-(2-butylphenoxy)- α -phosphonobenzene-
butanesulfonic acid, ester thereof, salt thereof,
mixed ester-salt thereof or its tripotassium salt;

(E)-6-methyl-7-(4-methylphenoxy)-1-
phosphono-5-heptene-1-sulfonic acid, ester thereof,
salt thereof, mixed ester-salt thereof, or its
tripotassium salt;

(E)-6-methyl-7-(3-methylphenoxy)-1-
phosphono-5-heptene-1-sulfonic acid, ester thereof,
salt thereof, mixed ester-salt thereof or its
tripotassium salt;

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(E)-6-methyl-8-(4-methylphenyl)-1-phosphono-5-octenyl-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

4-(1-naphthalenyl)- α -phosphonobenzene-butanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

4-(2,6-dimethylphenoxy)- α -phosphonobenzene-butanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

3-(3-methylphenoxy)- α -phosphonobenzene-butanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

(E)-6,10-dimethyl-1-phosphono-5,9-pentadecadiene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

α -phosphono-4'-propyl[1,1'-biphenyl]-4-pentanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

3-(2-methylphenoxy)- α -phosphonobenzene-butanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

α -[bis[(2,2-dimethyl-1-oxopropoxy)methoxy]-phosphinyl]-3-phenoxybenzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its monopotassium salt;

4-(2-benzofuranyl)- α -phosphonobenzene-butanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

11-phenyl-1-phosphono-1-undecanesulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

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α -phosphonobenzeneoctanesulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

1-phosphono-7-(4-pentylphenoxy)-1-heptanesulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

α -phosphono-3'-propyl[1,1'-biphenyl]-4-butanesulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

4-(4-methylphenoxy)- α -phosphonobenzenebutanesulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

(E,E)-4,8,12-trimethyl-1-phosphono-3,7,11-tridecatriene-1-sulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

(E)-6-methyl-7-phenoxy-1-phosphono-5-heptenyl-1-sulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

(E)-6-methyl-7-(4-propylphenoxy)-1-phosphono-5-heptene-1-sulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

(E)-6-methyl-8-(3-methylphenyl)-1-phosphono-5-octenyl-1-sulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

(E)-6-methyl-1-phosphono-7-(3-propylphenoxy)-5-heptene-1-sulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

(E)-6-methyl-7-(2-methylphenoxy)-1-phosphono-5-heptene-1-sulfonic acid, ester thereof,



salt thereof, mixed-ester salt thereof or its tripotassium salt;

(E,E)-6,10,14-trimethyl-1-phosphono-5,9-pentadecadiene-1-sulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

4'-phenoxy- α -phosphono[1,1'-biphenyl]-butanesulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

α -phosphono-4'-propyl[1,1'-biphenyl]-4-propanesulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

3-(4-methylphenoxy)- α -phosphono-benzene-butanesulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

(E)-8-phenyl-1-phosphono-5-octene-1-sulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

2'-methoxy- α -phosphono-4'-propyl[1,1'-biphenyl]-4-butanesulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

(E,E)-6,10-dimethyl-12-phenyl-1-phosphono-5,9-dodecadiene-1-sulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

(E)-6-methyl-7-(phenylthio)-1-phosphono-5-heptenyl-1-sulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

3-phenoxy- α -phosphonobenzenepropanesulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

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2'-(methoxymethoxy)- α -phosphono-4'-propyl[1,1'-biphenyl]-4-butanefulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

2'-hydroxy- α -phosphono-4'-propyl[1,1'-biphenyl]-4-butanefulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

(E)-6-methyl-7-phenyl-1-phosphono-5-heptene-1-sulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

α -fluoro-3-phenoxy- α -phosphonobenzene-butanefulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

(E)-6 methyl-8-(2-methylphenyl)-1-phosphono-5-octene-1-sulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

3-(2-naphthalenyloxy)- α -phosphono-benzenebutanefulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

(E)-6-methyl-1-phosphono-8-(4-propylphenyl)-5-octene-1-sulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

α -phosphono-4'-(2-pyridinyl)[1,1'-biphenyl]-butanefulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

(E)-8-(3-methoxyphenyl-6-methyl-1-phosphono-5-octene-1-sulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

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α -phosphono-4'-(1-piperidinyl)[1,1'-biphenyl]-4-butanesulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

ζ -methyl- α -phosphono-4-propylbenzene-octanesulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

ζ ,2-dimethyl- α -phosphonobenzeneoctanesulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

3-(1-naphthalenyloxy)- α -phosphobenzenebutanesulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

3-(cyclohexyloxy)- α -phosphobenzenebutanesulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

3-(3-ethylphenoxy)- α -phosphobenzenebutanesulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

α -phosphono-3-[3-(trifluoromethyl)phenoxy]benzenebutanesulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

(E)-6-methyl-1-phosphono-8-[3-(trifluoromethyl)phenyl]-5-octene-1-sulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

3-phenoxy- α -phosphobenzenepentanesulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

3-[2-(3-methylbutyl)phenoxy]- α -phos-

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phonobenzenebutanesulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

3-[2-(3-methyl-2-butenyl)phenoxy]- α -phosphonobenzenebutanesulfonic acid, ester thereof, salt thereof, mixed-ester salt thereof or its tripotassium salt;

α -[bis[1-(1-oxopropoxy)ethoxy]phosphinyl]-3-phenoxybenzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its monopotassium salt;

(E)-8-([1,1'-biphenyl]-4-yl)-6-methyl-1-phosphono-5-octene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

3-(2-cyclohexene-1-yloxy)- α -phosphonobenzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

(E)-6-methyl-8-(2-naphthalenyl)-1-phosphono-5-octene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

3-(phenylmethoxy)- α -phosphonobenzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

6-([1,1'-biphenyl]-4-yl)- α -phosphono-3-pyridinebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

3-(4-chlorophenoxy)- α -phosphonobenzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

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3-(3-chlorophenoxy)- α -phosphonobenzene-
butanesulfonic acid, ester thereof, salt thereof,
mixed ester-salt thereof or its tripotassium salt;

(E)-6-methyl-1-phosphono-8-(2-pyridinyl)-5-
octene-1-sulfonic acid, ester thereof, salt
thereof, mixed ester-salt thereof or its
tripotassium salt;

2-methoxy-5-phenoxy- α -phosphonobenzene-
butanoic acid, ester thereof, salt thereof, mixed
ester-salt thereof or its tripotassium salt;

(E,E)-1-[bis[2-methyl-1-(1-oxopropoxy)-
propoxy]phosphinyl]-6,10,14-trimethyl-5,9,13-
pentadecatriene-1-sulfonic acid, ester thereof,
salt thereof, mixed ester-salt thereof or its
monopotassium salt;

ζ -methyl- α -phosphono[1,1'-biphenyl]-4-
octanesulfonic acid, ester thereof, salt thereof,
mixed ester-salt thereof or its tripotassium salt;

4-(2-phenyl-5-pyridinyl)- α -phosphono-
benzenebutanesulfonic acid, ester thereof, salt
thereof, mixed ester-salt thereof or its
tripotassium salt;

α -[bis[1-(2,2-dimethyl-1-oxopropoxy)-
ethoxy]phosphinyl]-3-phenoxybenzenebutanesulfonic
acid, ester thereof, salt thereof, mixed ester-salt
thereof or its monopotassium salt;

5-phenoxy- α -phosphono-2-thiophenebutane-
sulfonic acid, ester thereof, salt thereof, mixed
ester-salt thereof or its tripotassium salt;

3-[2-(2-methoxyethyl)phenoxy]- α -phos-
phonobenzenebutanesulfonic acid, ester thereof,
salt thereof, mixed ester-salt thereof or its
tripotassium salt;

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(E,E)-1-[bis[1-(benzoyloxy)ethoxy]phosphinyl]-6,10,14-trimethyl-5,9,13-pentadecatriene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its monopotassium salt;

(E,E)- α -[bis[2-methyl-1-(1-oxopropoxy)propoxy]phosphinyl]-3-phenoxybenzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its monopotassium salt;

3-[2-(2-propenyl)phenoxy]- α -phosphonobenzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

2-(methoxymethoxy)-5-phenoxy- α -phosphonobenzenebutanoic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

α -phosphono-3-(2-pyridinyloxy)benzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

3-[2-phenylmethyl)phenoxy]- α -phosphonobenzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

δ -methyl-3-phenoxy- α -phosphonobenzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

3-(3-fluorophenoxy)- α -phosphonobenzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

3-(4-fluorophenoxy)- α -phosphonobenzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

α -[bis[1-(2-methyl-1-oxopropoxy)ethoxy]phosphinyl]-3-phenoxybenzenebutanesulfonic acid,

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ester thereof, salt thereof, mixed ester-salt thereof or its monopotassium salt;

4-(2-benzoxazolyl)- α -phosphinylbenzene-butanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

α -[bis[2-methyl-1-(2-methyl-1-oxopropoxy)-propoxy]phosphinyl]-3-phenoxybenzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its monopotassium salt;

α -[bis[1-[1-oxopropoxy]propoxy]phosphinyl]-3-phenoxybenzenebutanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its monopotassium salt;

3-(3,4-dichlorophenoxy)- α -phosphonobenzene-butanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

3-(2,3-dichlorophenoxy)- α -phosphonobenzene-butanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

3-(2-phenoxyphenoxy)- α -phosphonobenzene-butanesulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

3-(2-benzoylphenoxy)- α -phosphonobenzene-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

(Z)-6-methyl-8-phenyl-1-phosphono-5-octene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

(E)-8-(2-fluorophenyl)-6-methyl-1-phosphono-5-octene-1-sulfonic acid, ester thereof, salt thereof, mixed ester-salt thereof or its tripotassium salt;

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3-(4-methoxyphenoxy)- α -phosphonobenzene-
butanesulfonic acid, ester thereof, salt thereof,
mixed ester-salt thereof or its tripotassium salt;

3-(3-methoxyphenoxy)- α -phosphonobenzene-
butanesulfonic acid, ester thereof, salt thereof,
mixed ester-salt thereof or its tripotassium salt;

3-(2-propoxyphenoxy)- α -phosphonobenzene-
butanoic acid, ester thereof, salt thereof, mixed
ester-salt thereof or its tripotassium salt;

α -phosphono-3-(2-propylphenoxy)benzene-
butanesulfonic acid, ester thereof, salt thereof,
mixed ester-salt thereof or its tripotassium salt;
or

3-[2-(2-ethoxymethyl)phenoxy]- α -phosphono-
benzenebutanesulfonic acid, ester thereof, salt
thereof, mixed ester-salt thereof or its
tripotassium salt.

9. The compound as defined in Claim 1 which
is α -[bis[(2,2-Dimethyl-1-oxopropoxy)-
methoxy]phosphinyl]-3-phenoxybenzenebutanesulfonic
acid, ester thereof, salt thereof, mixed ester-salt
thereof or its monopotassium salt;

(S)-(-)-3-phenoxy- α -phosphonobenzene-
butanesulfonic acid, or an ester thereof, salt
thereof, mixed ester-salt thereof or its
tripotassium salt;

(R)-(+)-3-phenoxy- α -phosphonobenzenebutane-
sulfonic acid, or an ester thereof, salt thereof,
mixed ester-salt thereof or its tripotassium salt;

(S)-(-)-3-phenoxy- α -phosphonobenzenebutane-
sulfonic acid, or (R)-isomer thereof, or an ester
thereof, salt thereof, mixed ester-salt thereof or
its 1-adamantanamine (1:2) salt;



(S)-(-)-3-phenoxy- α -phosphonobenzenebutane-sulfonic acid, or (R)-isomer thereof, or an ester thereof, salt thereof, mixed ester-salt thereof or its (S)- α -methylbenzylamine (1:2) salt; or

(S)- α -[bis[(2,2-dimethyl-1-oxopropoxy)-methoxy]phosphinyl]-3-phenoxybenzenebutanesulfonic acid, or an ester thereof, salt thereof, mixed ester-salt thereof or its monopotassium salt.

10. Use of a compound as defined in any preceding claim, optionally in prodrug ester form, for the manufacture of a medicament for inhibiting cholesterol biosynthesis, or inhibiting and/or treating hyperlipemia, hyperlipidemia, hyperlipoproteinemia, hypercholesterolemia, and/or hypertriglyceridemia, or inhibiting and/or treating atherosclerosis.

11. The use as defined in Claim 10 wherein said compound is employed in combination with an antihyperlipoproteinemic agent, antihypercholesterolemic agent, antihypertriglyceridemic agent and/or an antiatherosclerotic agent.

12. The use as defined in Claim 11 wherein the antihyperlipoproteinemic agent, antihypercholesterolemic agent, antihypertriglyceridemic agent and/or antiatherosclerotic agent is a fibric acid derivative, an HMG CoA reductase inhibitor, a cholesterol biosynthesis inhibitor, a bile acid sequestrant, another squalene synthetase inhibitor, an antioxidant, and/or other lipid lowering and/or antiatherosclerotic agent.





13. The method as defined in Claim 12 wherein the HMG CoA reductase inhibitor is pravastatin, lovastatin, simvastatin, velostatin, fluvastatin, rivastatin, compactin, SDZ-63,370 (Sandoz), CI-981 (W-L), HR-780, L-645,164, CL274,471, dalvastatin, α -, β -, and γ -tocotrienol,

(3R,5S,6E)-9,9-bis(4-fluorophenyl)-3,5-dihydroxy-8-(1-methyl-1H-tetrazol-5-yl)-6,8-nonadienoic acid, L-arginine salt;

(S)-4-[[2-[4-(4-fluorophenyl)-5-methyl-2-(1-methylethyl)-6-phenyl-3-pyridinyl]ethenyl]-hydroxyphosphinyl]-3-hydroxybutanoic acid, disodium salt; BB-467 (British Biotechnology); dihydrocompactin;

[4R-[4 α ,6 β (E)]]-6-[2-[5-(4-fluorophenyl)-3-(1-methylethyl)-1-(2-pyridinyl)-1H-pyrazol-4-yl]ethenyl]tetrahydro-4-hydroxy-2H-pyran-2-one, and/or

1H-pyrrole-1-heptanoic acid, 2-(4-fluorophenyl)- β , δ -dihydroxy-5-(1-methylethyl)-3-phenyl-4-[(phenylamino)carbonyl]calcium salt[R-(R*,R*)]; the fibric acid derivative is clofibrate, bezafibrate, gemfibrozil; the other cholesterol biosynthesis inhibitor is NB-598, N-(1-oxododecyl)-4 α ,10-dimethyl-8-aza-trans-decal-3 β -ol, or 2,4-undecadienoic acid, 11-[3-(hydroxymethyl)-4-oxo-2-oxetanyl]-3,5,7-trimethyl-, [2R-[2 α (2E,4E,7R*),3 β]]; the bile acid sequestrant is cholestyramine, colestipol, or polidexide (DEAE-Sephadex); the antioxidant is probucol or Vitamin E; the other lipid lowering and/or antiatherosclerotic agent is nicotinic acid or derivatives thereof, neomycin, p-aminosalicylic acid, probucol,



hydroxypropylmethyl cellulose, LS-2904, ethanol 2-[[1-methyl-2-[3-(trifluoromethyl)phenyl]ethyl]-amino]benzoate (ester).

14. A hypocholesterolemic, hypolipemic or hypotriglyceridemic composition comprising a compound as defined in any one of Claims 1-9 and a pharmaceutically acceptable carrier therefor.

15. A combination comprising a compound as defined in any one of Claims 1-9 and a cholesterol lowering agent and/or a triglyceride lowering agent which is an antihyperlipoproteinemic agent, and/or antiatherosclerotic agent .

16. Use of a compound as defined in any one of Claims 1-9, optionally in prodrug ester form, for the manufacture of a medicament for inhibiting and/or treating atherosclerosis resulting from hypertriglyceridemia .

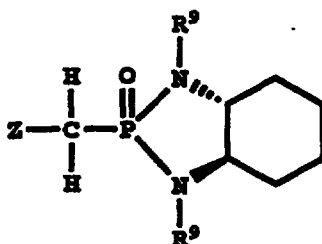
17. Use of a compound as defined in any one of Claims 1-9, optionally in prodrug ester form, for the manufacture of a medicament for treating and/or preventing ras-related tumors, blocking the farnesylation of ras oncogene products, blocking neoplastic transformation induced by ras oncogenes, or preventing prenylation of the cys residue of the CAAX box of a ras protein to prevent ras oncogene activity or treating and/or preventing ras-related tumors or diseases caused by other related CAAX box containing proteins, or preventing prenylation of CAAX box containing proteins to inhibit the disease promoting effects of that protein, by blocking the prenylation of ras oncogene products or related CAAX box containing proteins by blocking the enzyme protein-prenyl



transferase from catalyzing the transfer of the prenyl group from the prenyl pyrophosphate to the cysteine of the CAAX box .

18. Use of a compound as defined in any one of Claims 1-9, optionally in prodrug ester form, for the manufacture of a medicament for preventing or treating hepatitis D.

19. A method for forming an enantiomer of a compound as defined in Claim 1 by any of the following processes: A) ~~which comprises~~ providing a methylphosphondiamide compound of the structure



wherein R^9 is alkyl or arylalkyl,

treating the above diamide with a metalating agent to form an anion of the diamide,

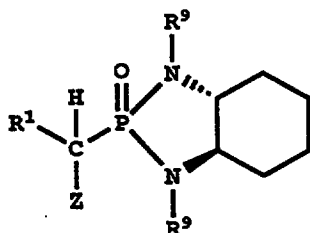
alkylating the anion of the diamide by treating with a halide of the structure



where R^1 is as defined in Claim 1 and X is I, Cl, Br, tosylate, or $CF_3SO_3^-$, to form the alkylated compound

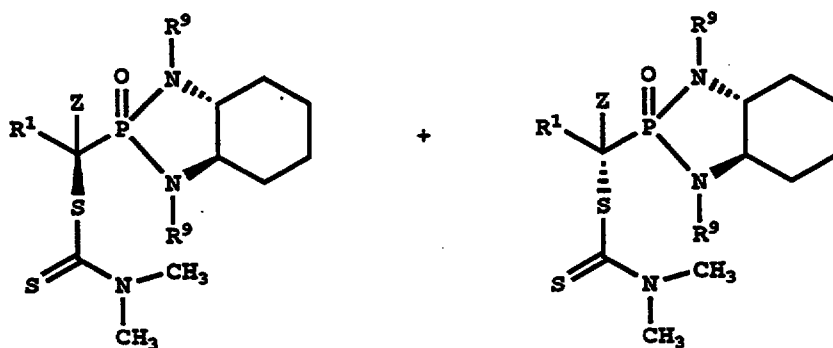
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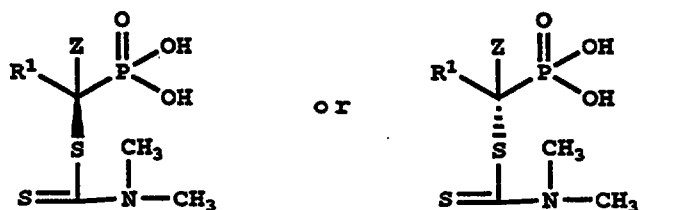
treating the above alkylated diamide with a metalating agent to form the metalated alkylated compound,

subjecting the metalated alkylated compound to sulfuration with tetramethylthiuram disulfide, to form a mixture of isomers of the structures



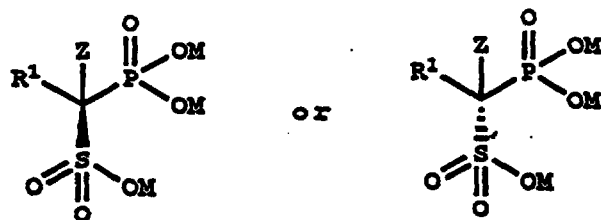
separating the isomers into the α -(S) isomer and α -(R) isomer,

treating the desired isomer with an acid to form the desired diacid



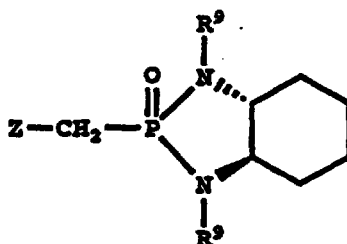
treating the diacid with an oxidizing agent and then with base to form the desired enantiomer





where M is an alkali metal;

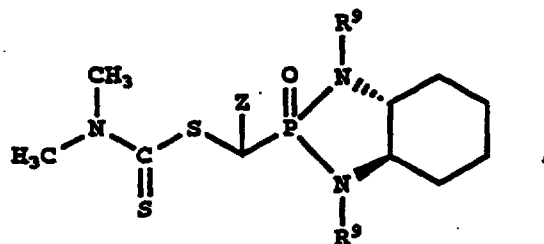
or B) ~~forming an enantiomer of a compound as defined in Claim 1, which comprises~~ providing a methylphosphondiamide of the structure



wherein R⁹ is alkyl or arylalkyl,

treating the above diamide with a metalating agent to form the corresponding anion salt,

treating the anion salt with sulfur and a dialkylthio-carbamoyl halide to form a dithiocarbamoylate of the structure



treating the dithiocarbamoylate with a metalating agent to form the corresponding metalated compound,

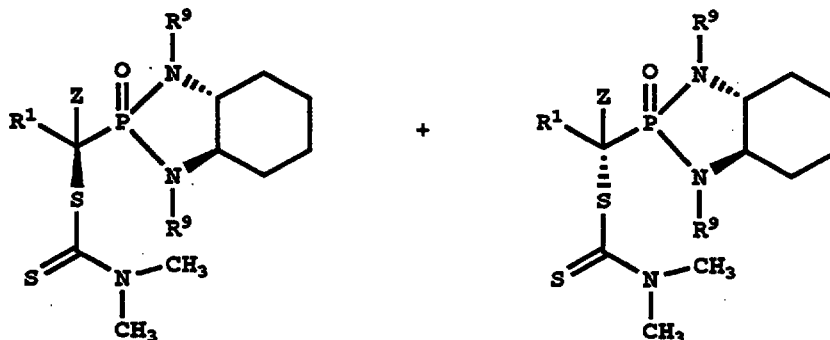




treating the so-formed metalated compound
with an alkylating agent

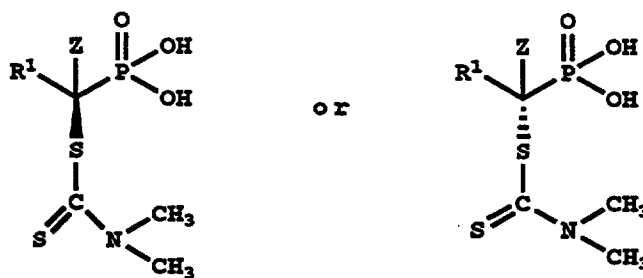


to form a mixture of isomers of the structure

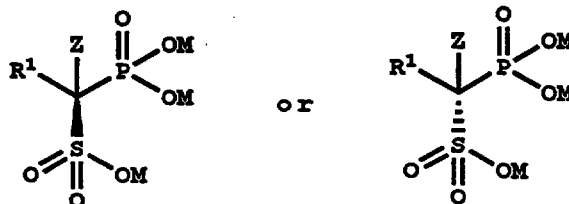


separating the isomers,

treating the desired isomer with an acid to
form the desired diacid

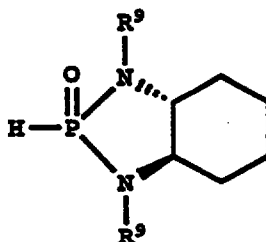


treating the desired diacid with an
oxidizing agent and then with base to form the
desired enantiomer



where M is an alkali metal;

or C) ~~forming an enantiomer of a compound as defined in Claim 1, which comprises~~ providing a phosphorous diamide of the structure

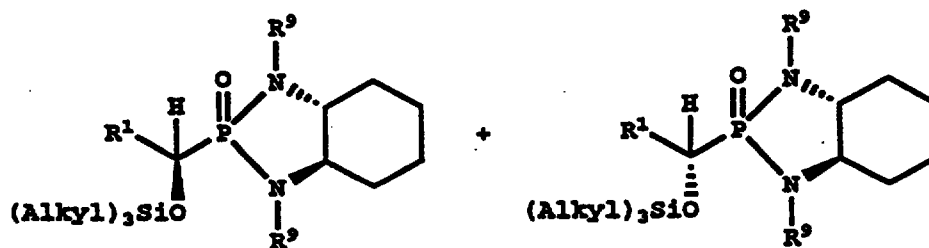


wherein R⁹ is alkyl, aryl or arylalkyl,

treating the diamide with an aldehyde of the structure



and a silylating compound to form a mixture of protected isomers of the structures



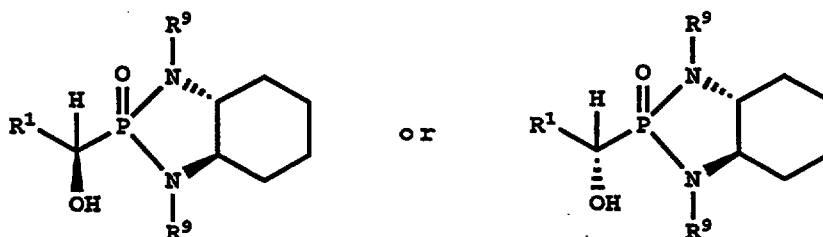
separating the isomers,

reacting the desired isomer with a fluoride source to form a deprotected compound of the structure

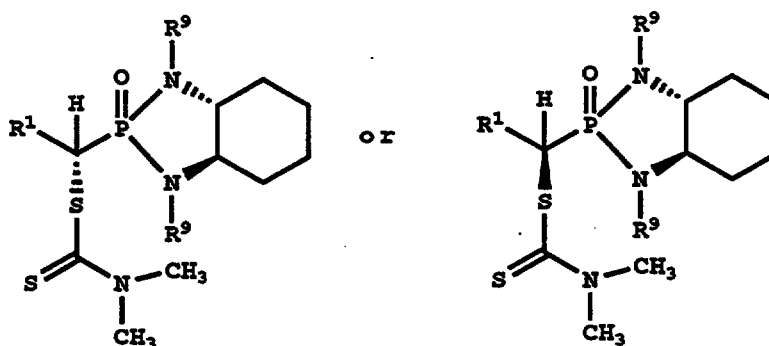
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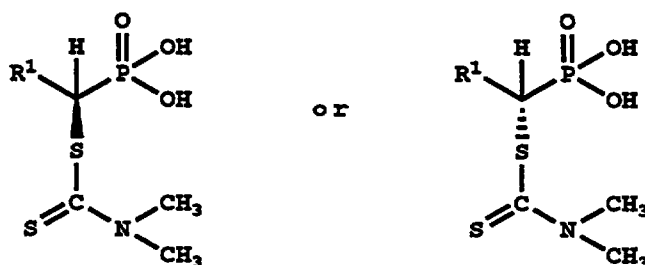
* C L M S *



treating either deprotected isomer with dimethyl-dithiocarbamic acid, zinc salt and triphenylphosphine and diisopropylazodicarboxylate (DIAD) to form the isomer



treating the desired isomer with an acid to form the desired diacid

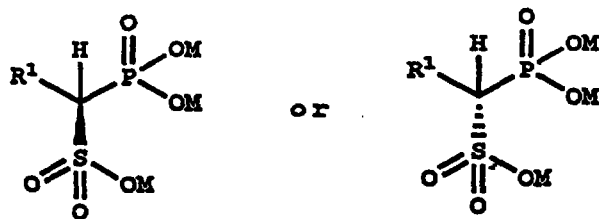


treating the desired diacid with an oxidizing agent and then with base to form the desired enantiomer

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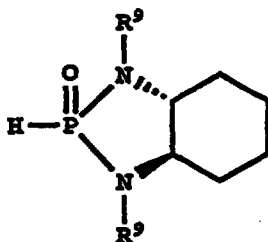


* C L M S *

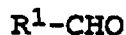


where M is an alkali metal;

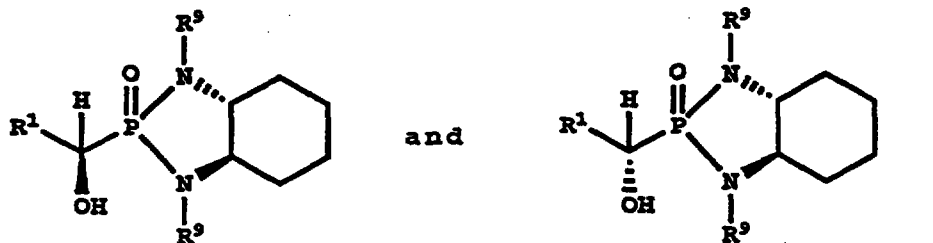
or D) ~~forming an enantiomer of a compound as defined in Claim 1, which comprises~~ providing a phosphorous diamide of the structure



wherein R⁹ is alkyl or arylalkyl, treating the diamide with an aldehyde of the structure



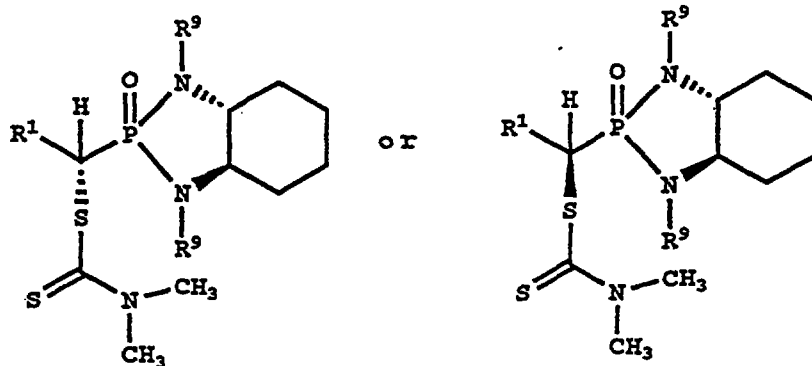
and a base including a fluoride source to form a mixture of isomers of deprotected compound of the structures



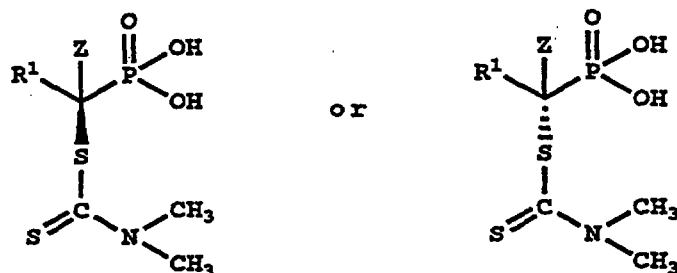
separating the isomers,

treating either deprotected isomer with dimethyldithiocarbamic acid, zinc salt, triphenylphosphine and DIAD to form the isomer

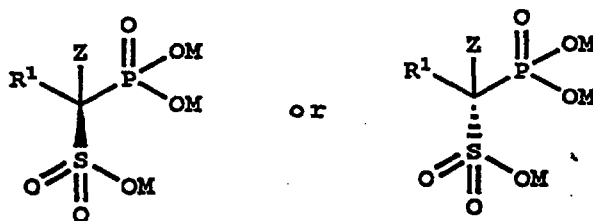




treating the desired isomer with an acid to form the desired diacid



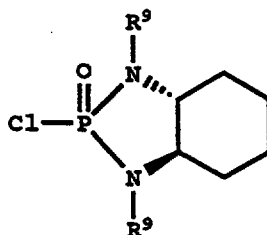
treating the desired diacid with an oxidizing agent and then with base to form the desired enantiomer



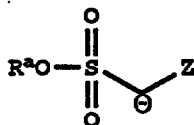
where M is an alkali metal;

or E) ~~forming an enantiomer of a compound as defined in Claim 1, which comprises~~ providing an acid chloride of the structure

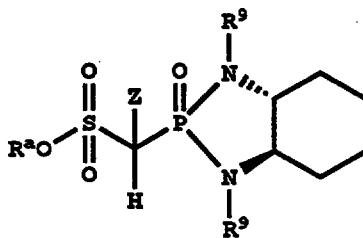




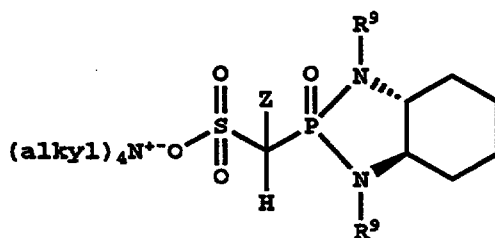
reacting the acid chloride with the metalated anion



(where R^a is alkyl or cycloalkyl) to form



treating the product with (alkyl)₄N[⊕]I[⊖] to form the corresponding ammonium compound



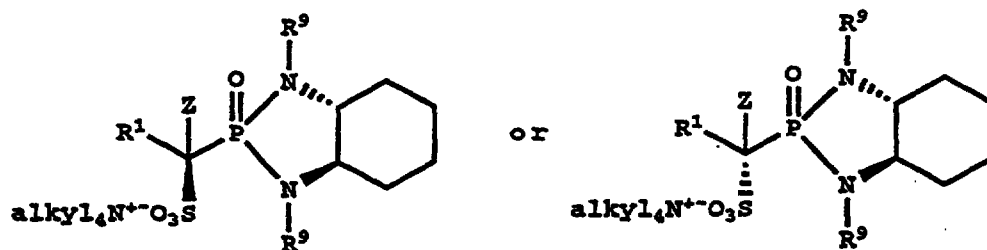
treating the above dealkylated compound with a metalating agent and then with an alkylating agent



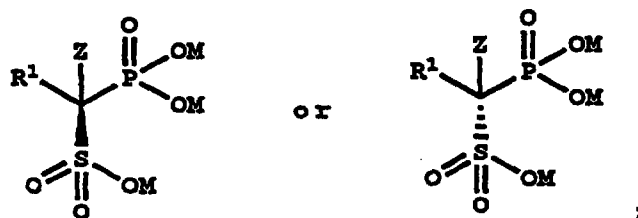
to form the alkylated compound

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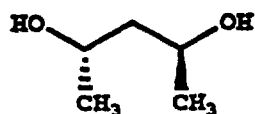
treating the desired isomer with an acid and then with an ion exchange resin to form the desired enantiomer



or F) ~~forming an enantiomer of a compound as defined in Claim 1, which comprises~~ treating an aldehyde of the structure

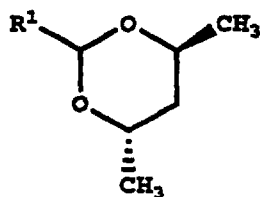


where R^1 is as defined in Claim 1 with an (S,S)-diol

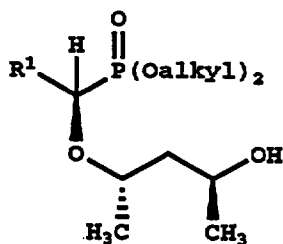


(S,S)

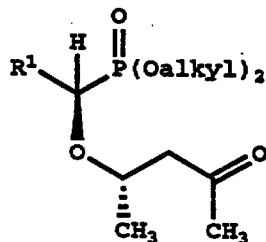
in the presence of an acid catalyst to form the acetal of the structure



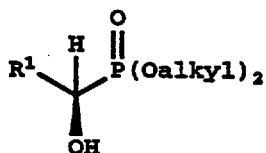
treating the acetal with a trialkylphosphite in the presence of titanium tetrachloride to form the alcohol



treating the above alcohol with an oxidizing agent to form a compound of the structure



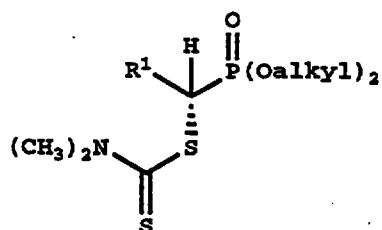
treating the above with p-toluenesulfonic acid in the presence of dioxane to form the diester



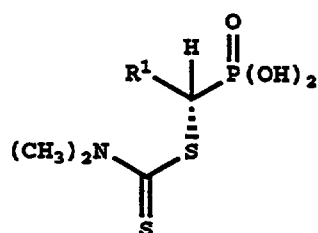
treating the above diester with triphenyl phosphine, dimethyldithiocarbamic acid, zinc salt and diisopropyl azodicarboxylate to form

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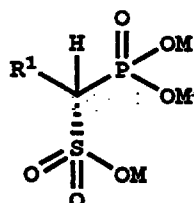




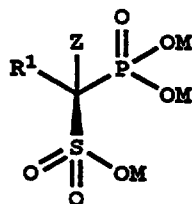
treating the above diester with a
bromotrimethylsilane to form the diacid



treating the diacid with an oxidizing agent
and then with a strong base to form the desired
enantiomer



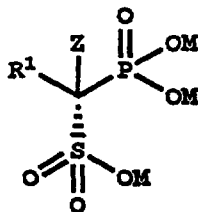
20. The method as defined in Claim 19 part
A) or part E) wherein the final product is the (S)-
enantiomer when Z is H



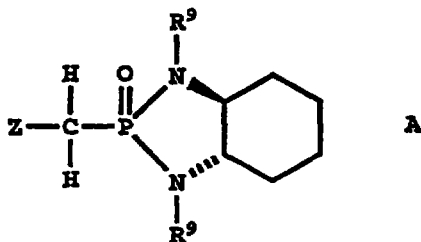
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and as defined in Claim 19 part B) or part F)
wherein the final product is the (R)-enantiomer
when Z is H



21. A method for forming an enantiomer of a compound as defined in Claim 1 by any of the following processes: A) ~~which comprises~~ providing a methylphosphondiamide compound of the structure



wherein R⁹ is alkyl or arylalkyl,

treating the above diamide with a metalating agent to form an anion of the diamide,

alkylating the anion of the diamide by treating with a halide of the structure

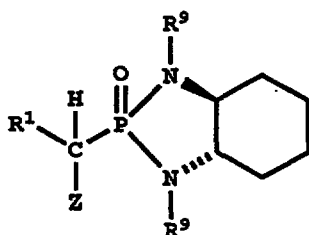


where R¹ is as defined in Claim 1 and X is I, Cl, Br, tosylate, or CF₃SO₃-, to form the alkylated compound

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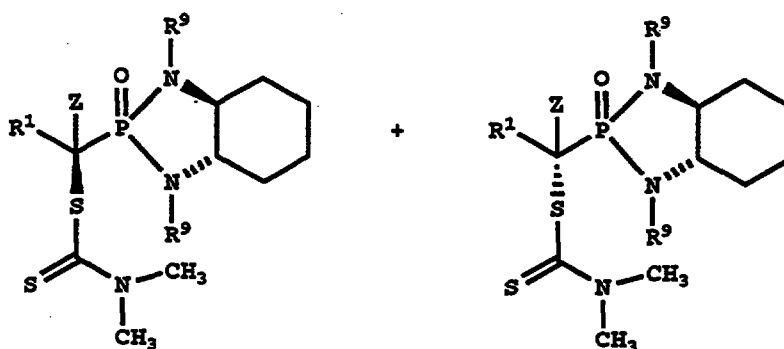


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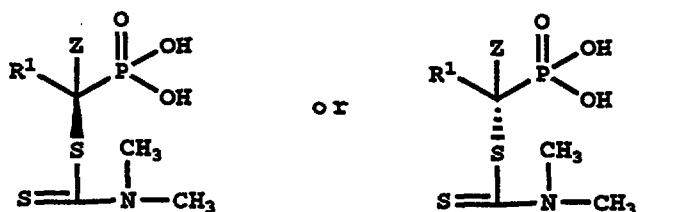
treating the above alkylated diamide with a metalating agent to form the metalated alkylated compound,

subjecting the metalated alkylated compound to sulfuration with tetramethylthiuram disulfide, to form a mixture of isomers of the structures



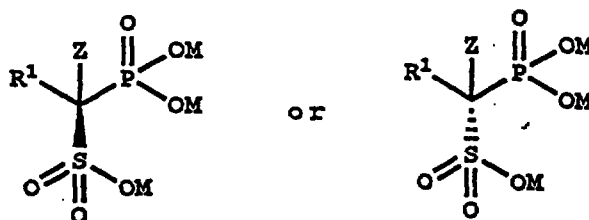
separating the isomers into the α -(S) isomer and α -(R) isomer,

treating the desired isomer with an acid to form the desired diacid



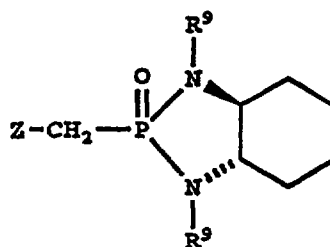
treating the diacid with an oxidizing agent and then with base to form the desired enantiomer





where M is an alkali metal;

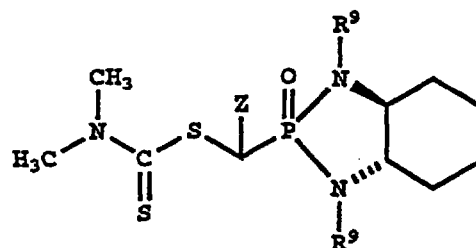
or B) ~~forming an enantiomer of a compound as defined in Claim 1, which comprises~~ providing a methylphosphondiamide of the structure



wherein R⁹ is alkyl or arylalkyl,

treating the above diamide with a metalating agent to form the corresponding anion salt,

treating the anion salt with sulfur and a dialkylthiocarbamoyl halide to form a dithiocarbamoylate of the structure



treating the dithiocarbamoylate with a metalating agent to form the corresponding metalated compound,

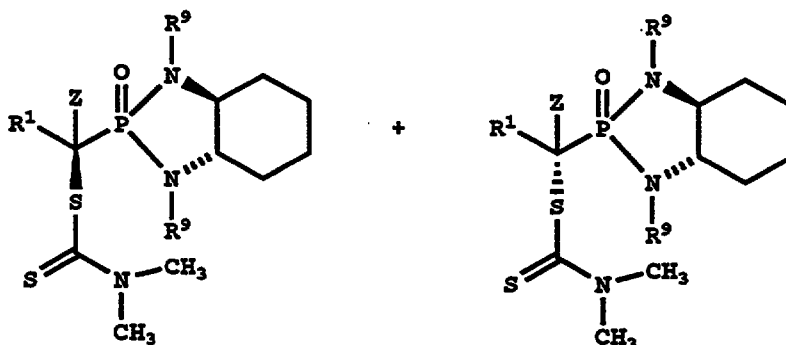




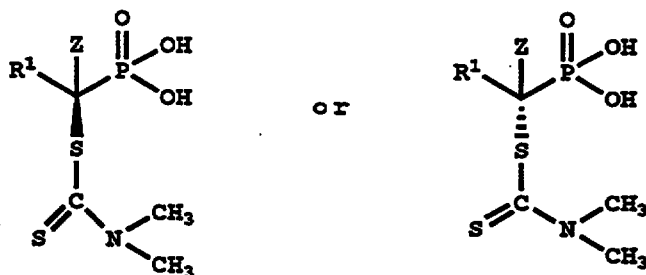
treating the so-formed metalated compound
with an alkylating agent



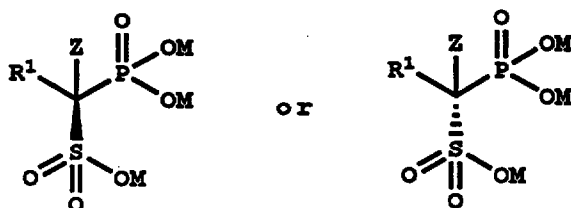
to form a mixture of isomers of the structure



separating the isomers,
treating the desired isomer with an acid to
form the desired diacid



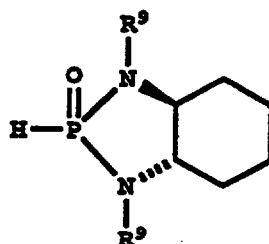
treating the desired diacid with an
oxidizing agent and then with base to form the
desired enantiomer





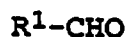
where M is an alkali metal;

or C) ~~forming an enantiomer of a compound as defined in Claim 1, which comprises~~ providing a phosphorous diamide of the structure

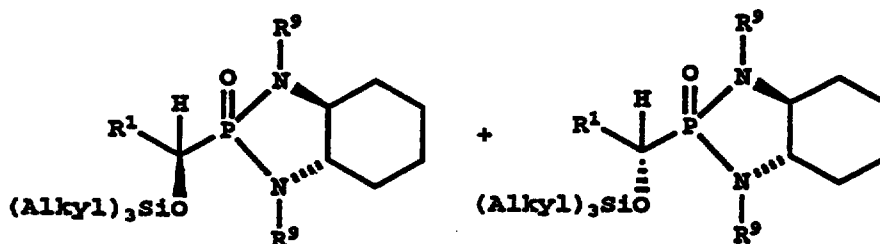


wherein R⁹ is alkyl, aryl or arylalkyl,

treating the diamide with an aldehyde of the structure

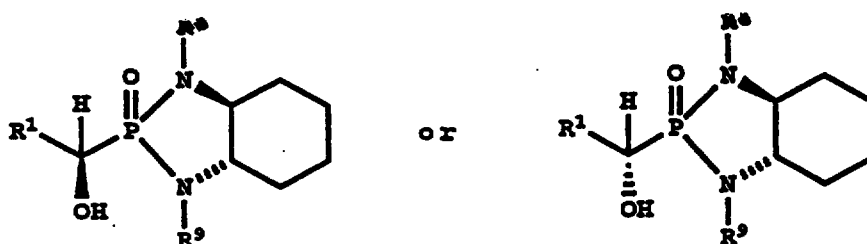


and a silylating compound to form a mixture of protected isomers of the structures

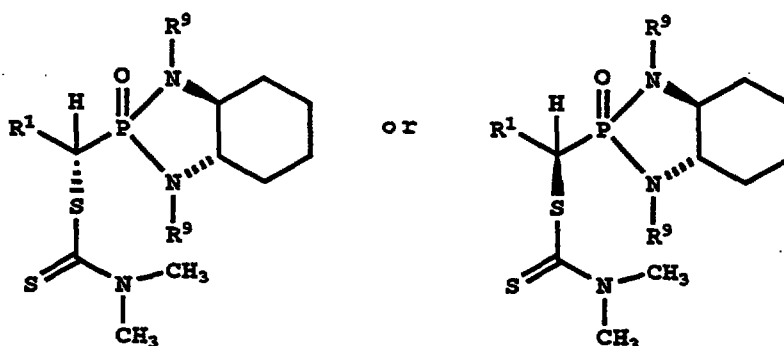


separating the isomers,

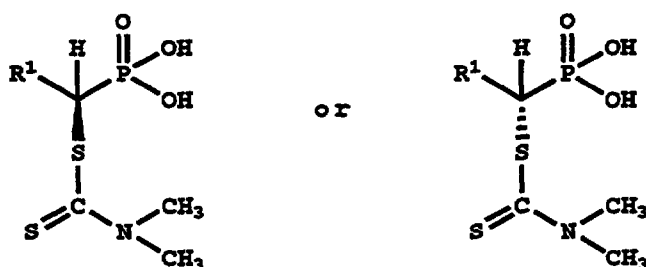
reacting the desired isomer with a fluoride source to form a deprotected compound of the structure



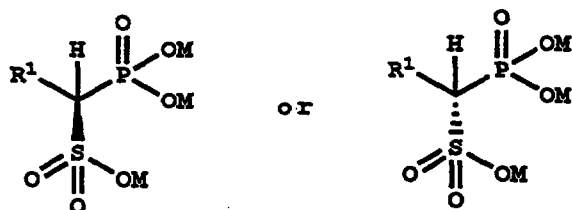
treating either deprotected isomer with dimethyldithiocarbamic acid, zinc salt and triphenylphosphine and diisopropylazodicarboxylate (DIAD) to form the isomer



treating the desired isomer with an acid to form the desired diacid



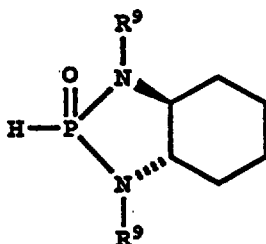
treating the desired diacid with an oxidizing agent and then with base to form the desired enantiomer



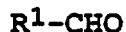
where M is an alkali metal;



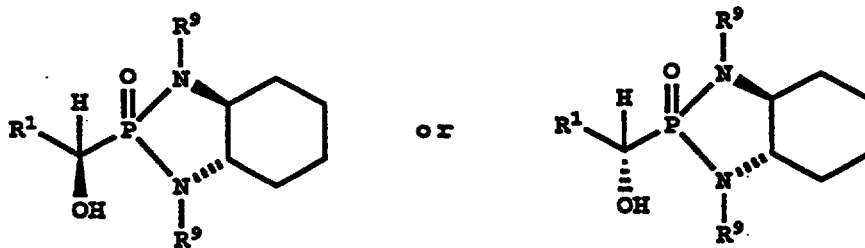
or D) ~~forming an enantiomer of a compound as defined in Claim 1, which comprises~~ providing a phosphorous diamide of the structure



wherein R^9 is alkyl or arylalkyl, treating the diamide with an aldehyde of the structure



and a base including a fluoride source to form a mixture of isomers of deprotected compound of the structures



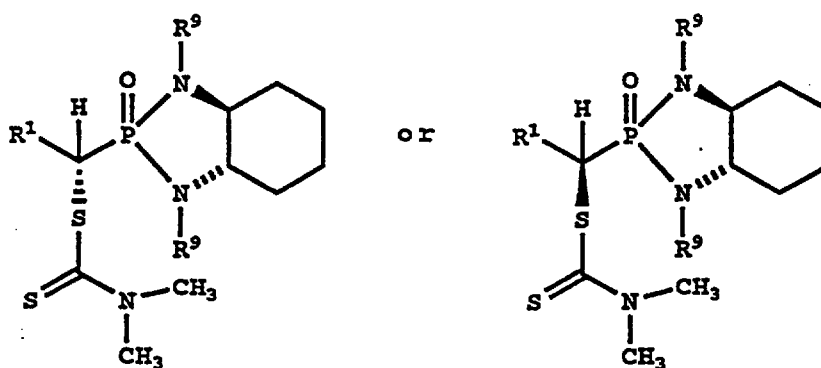
separating the isomers,

treating either deprotected isomer with dimethyldithiocarbamic acid, zinc salt, triphenylphosphine and DIAD to form the isomer

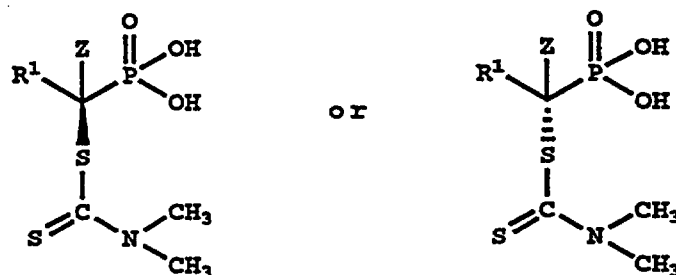
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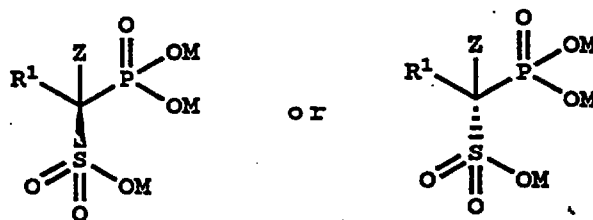
* C L M S *



treating the desired isomer with an acid to form the desired diacid



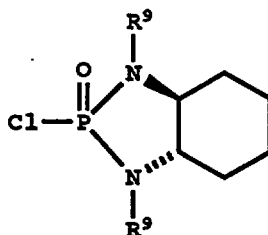
treating the desired diacid with an oxidizing agent and then with base to form the desired enantiomer



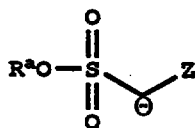
where M is an alkali metal;

or E) ~~forming an enantiomer of a compound as defined in Claim 1, which comprises~~ providing an acid chloride of the structure

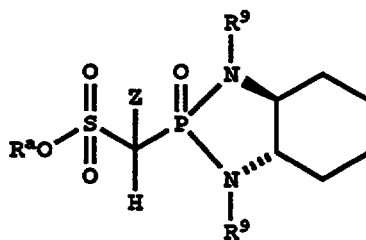




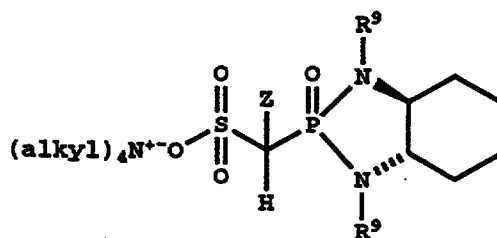
reacting the acid chloride with the metalated anion



(where R^a is alkyl or cycloalkyl) to form



treating the above reaction product with
(alkyl)₄N⁺I⁻ agent to form the corresponding
ammonium compound



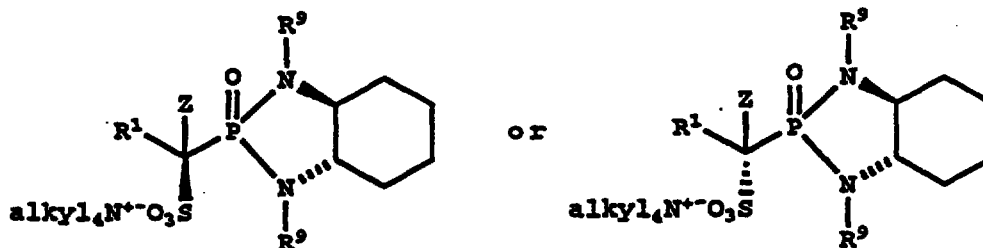
treating the above dealkylated compound
with a metalating agent and then with an alkylating
agent



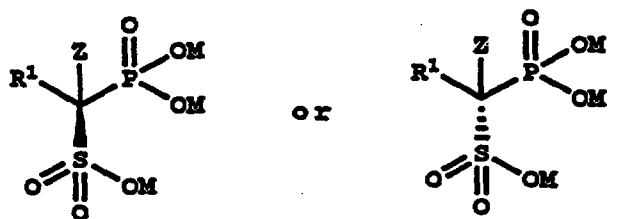
to form the alkylated compound

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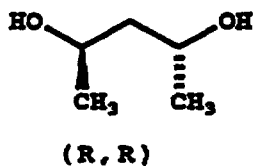
treating the desired isomer with an acid
and then with an ion exchange resin to form the
desired enantiomer



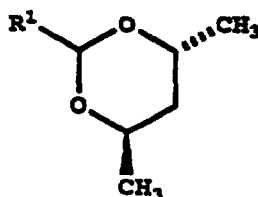
or F) ~~forming an enantiomer of a compound~~
~~as defined in Claim 1, which comprises~~ treating an
aldehyde of the structure



where R^1 is as defined in Claim 1, with an (R,R)-
diol



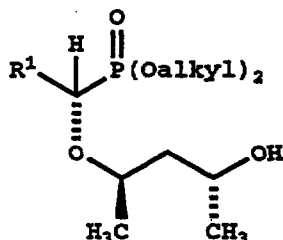
in the presence of an acid catalyst to form the
acetal of the structure



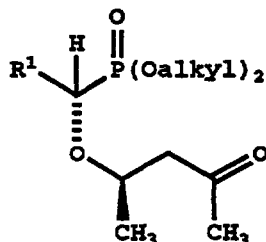
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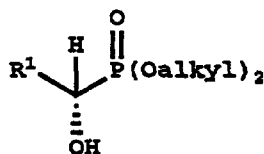
treating the acetal with a trialkylphosphite in the presence of titanium tetrachloride to form the alcohol



treating the above alcohol with an oxidizing agent to form a compound of the structure



treating the above with p-toluenesulfonic acid in the presence of dioxane to form the diester

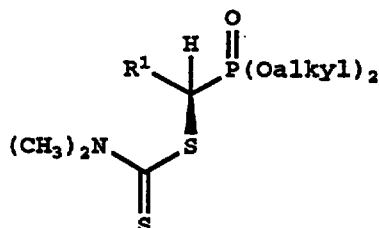


treating the above diester with triphenyl phosphine, dimethyldithiocarbamic acid, zinc salt and diisopropyl azodicarboxylate to form

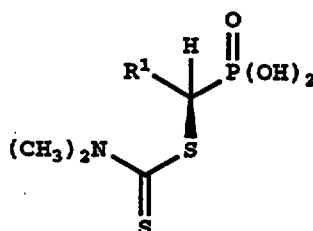
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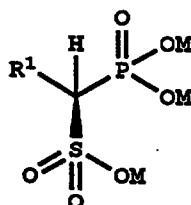
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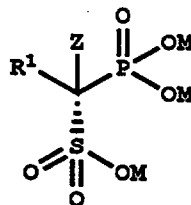
treating the above diester with a
bromotrimethylsilane to form the diacid



treating the diacid with an oxidizing agent
and then with a strong base to form the desired
enantiomer



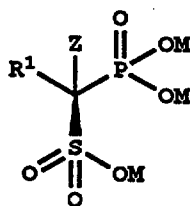
22. The method as defined in Claim 21 part
A) or part E) wherein the final product is the (R)-
enantiomer when Z is H



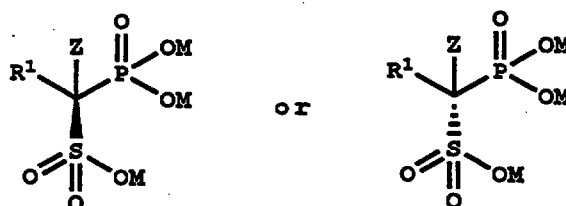
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or the method as defined in Claim 21 part B) or part F) wherein the final product is the (S)-enantiomer when Z is H



23. A method for purifying an enantiomer of the compound of Claim 1, which enantiomer has the structure



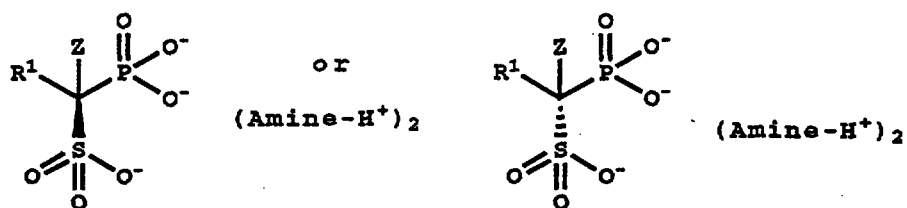
which comprises resolving the racemic mixtures of the above compounds or treating either of the above isomers with an ion exchange resin (H⁺ form) to form the triacid



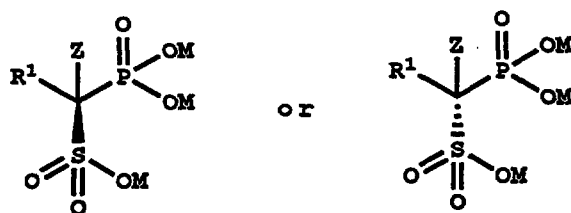
treating the triacid with an achiral or chiral amine to form an amine salt, optionally recrystallizing the amine salt to purify or resolve the salt

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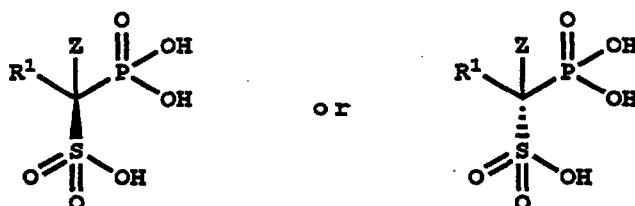




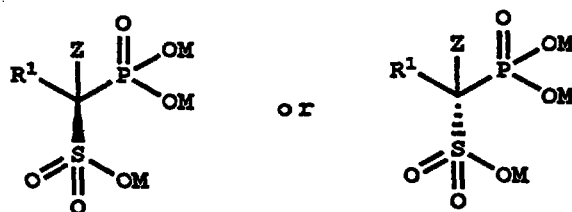
(a) treating the amine salt with an ion exchange resin (M^+ form) or with a base MOH to form



or (b) treating the amine salt with an ion exchange resin (H^+ form) to form the triacid

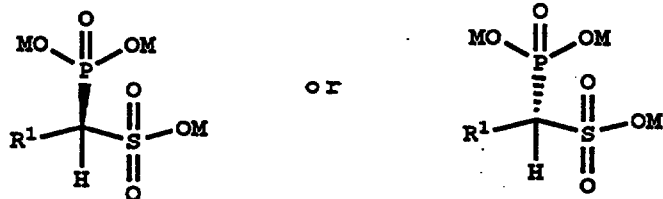


and treating the triacid with ion exchange resin (M^+ form) or a base MOH to form the enantiomer

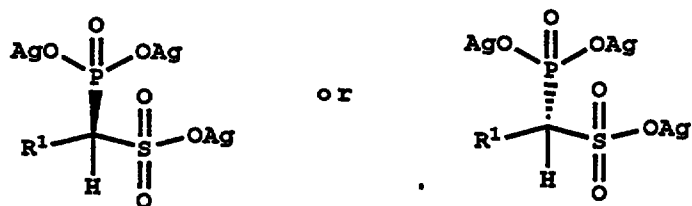


24. A method for preparing a prodrug of an enantiomer of a compound of Claim 1, which comprises treating an enantiomer of the structure

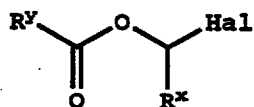




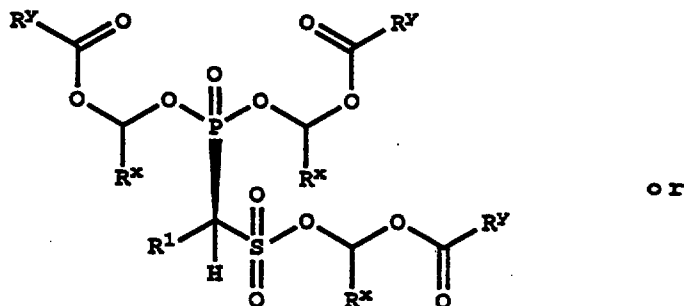
with a silver salt to form the silver salt of the structure



treating the silver salt with a halide of the structure



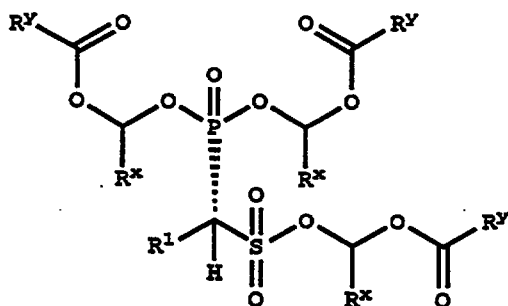
wherein R^x is H, alkyl, aryl or arylalkyl, R^y is alkyl, alkoxy, aryl, or arylalkyl, to form a triester of the structure



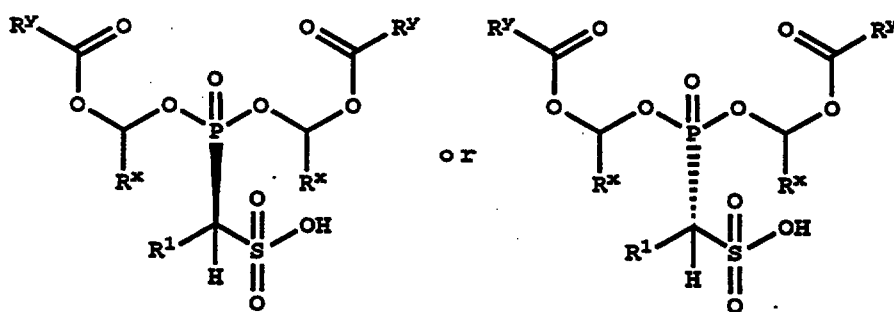
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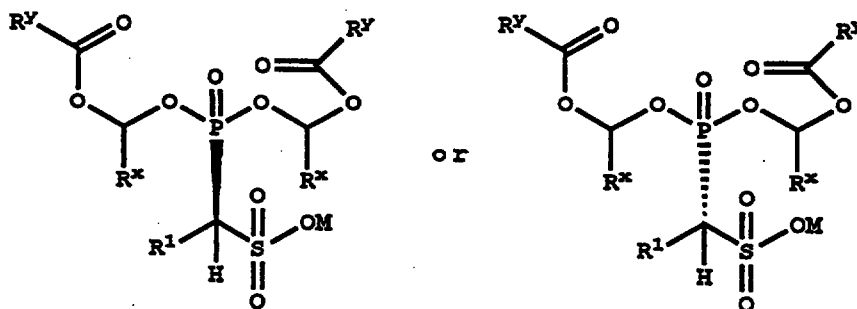
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treating the triester with water in the optional presence of a water miscible organic solvent to form



and treating the above compound with an alkali metal phosphate buffer or ion exchange resin to form the salt



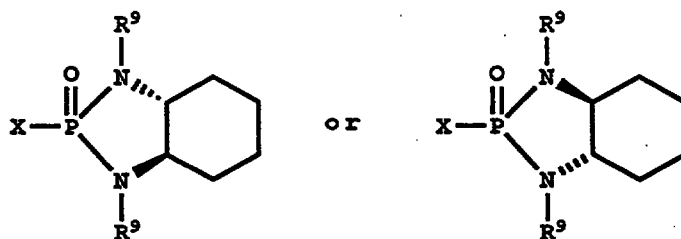
25. An intermediate having the structure

a)

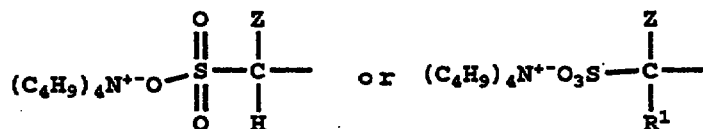
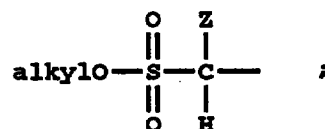
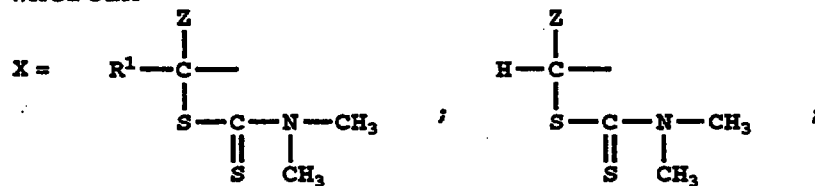
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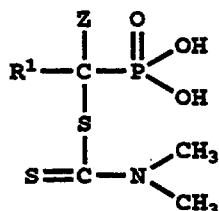
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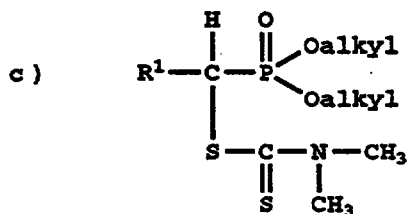
wherein



or having the structure



or

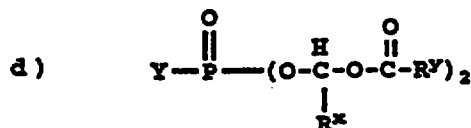


or

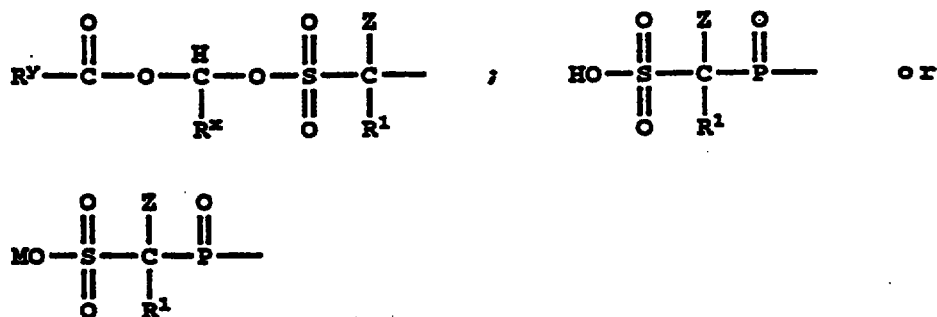
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wherein Y is



wherein R¹ is a lipophilic group containing at least 7 carbons;

Z is H, halogen, lower alkyl or lower alkenyl; and

R⁹ is lower alkyl or arylalkyl;

R^x is H, alkyl, aryl or arylalkyl; and

R^y is alkyl, alkoxy, aryl or arylalkyl.

26. The compound as defined in any one of Claims 1-9 for use as an active pharmaceutical substance.

27. A product containing (i) a compound as defined in any one of Claims 1-9 and (ii) an antihyperlipoproteinemic agent, antihypercholesterolemic agent, antihypertriglyceridemic agent and/or an antiatherosclerotic agent, as a combined preparation for simultaneous, separate or sequential use in medical treatment.

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