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(54) **STABILIZED VANCOMYCIN FORMULATIONS**

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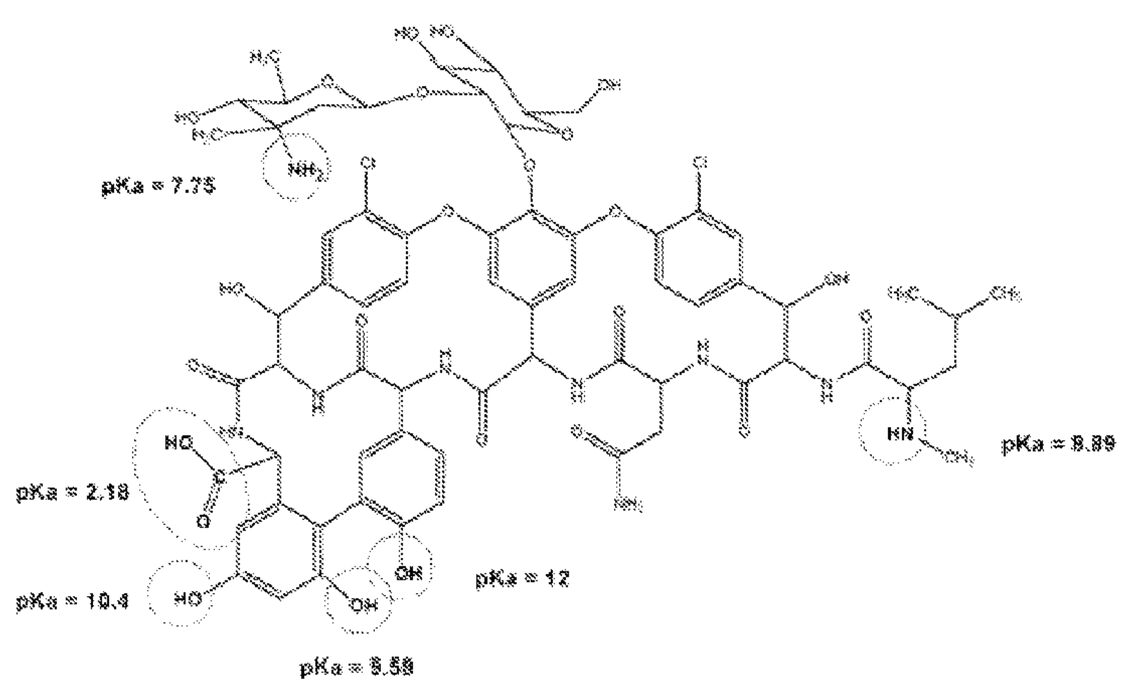
(57) **ABSTRACT**

In one aspect, the invention provides a stabilized lipid-based glycopeptide antibiotic composition and a process for producing the same. In another aspect, the invention provides methods for treating a bacterial pulmonary infection by administering to a subject in need thereof a therapeutically effective amount of the stabilized lipid-based glycopeptide antibiotic composition.

20 Claims, 18 Drawing Sheets



Vancomycin

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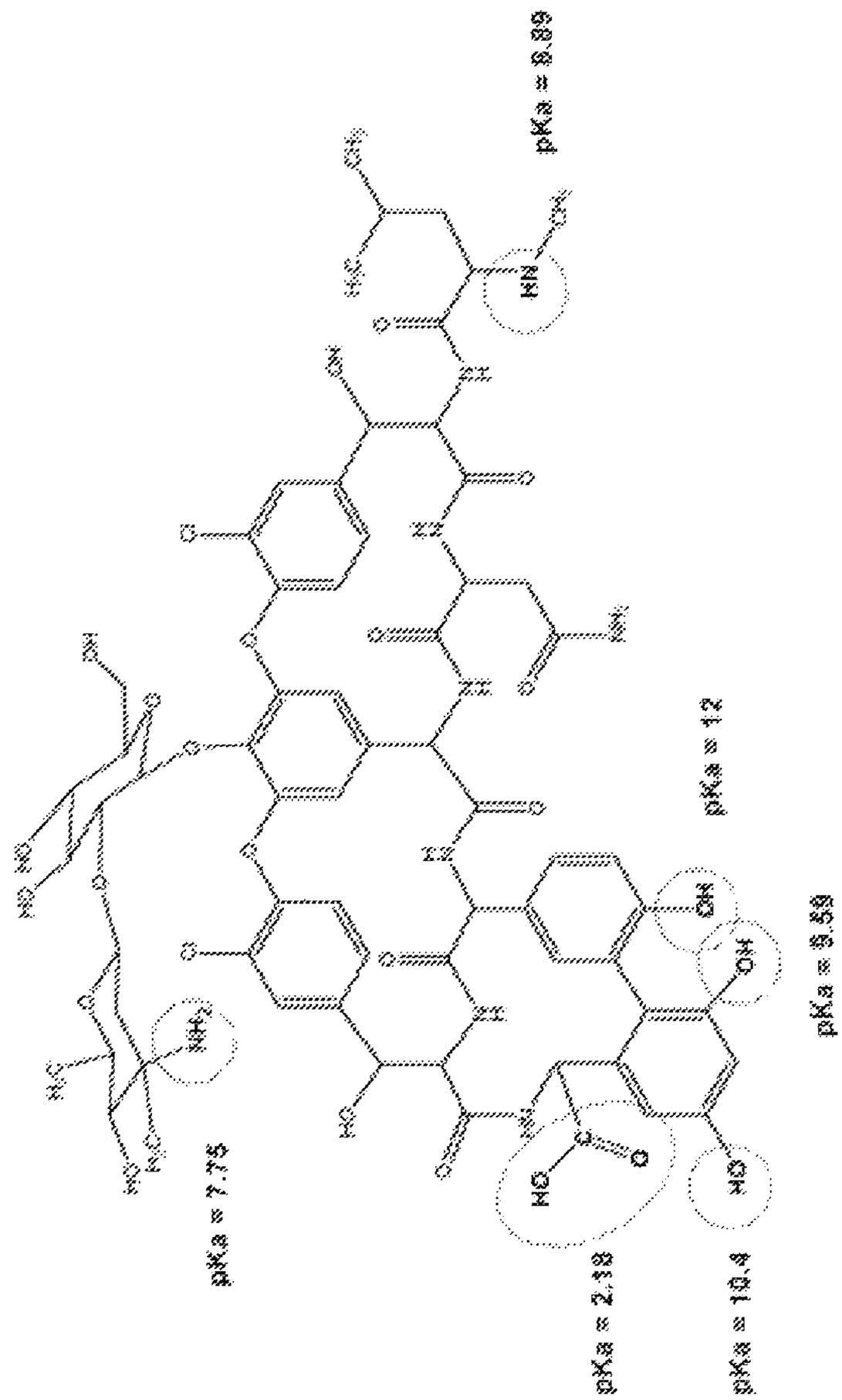


Vancomycin

Figure 1

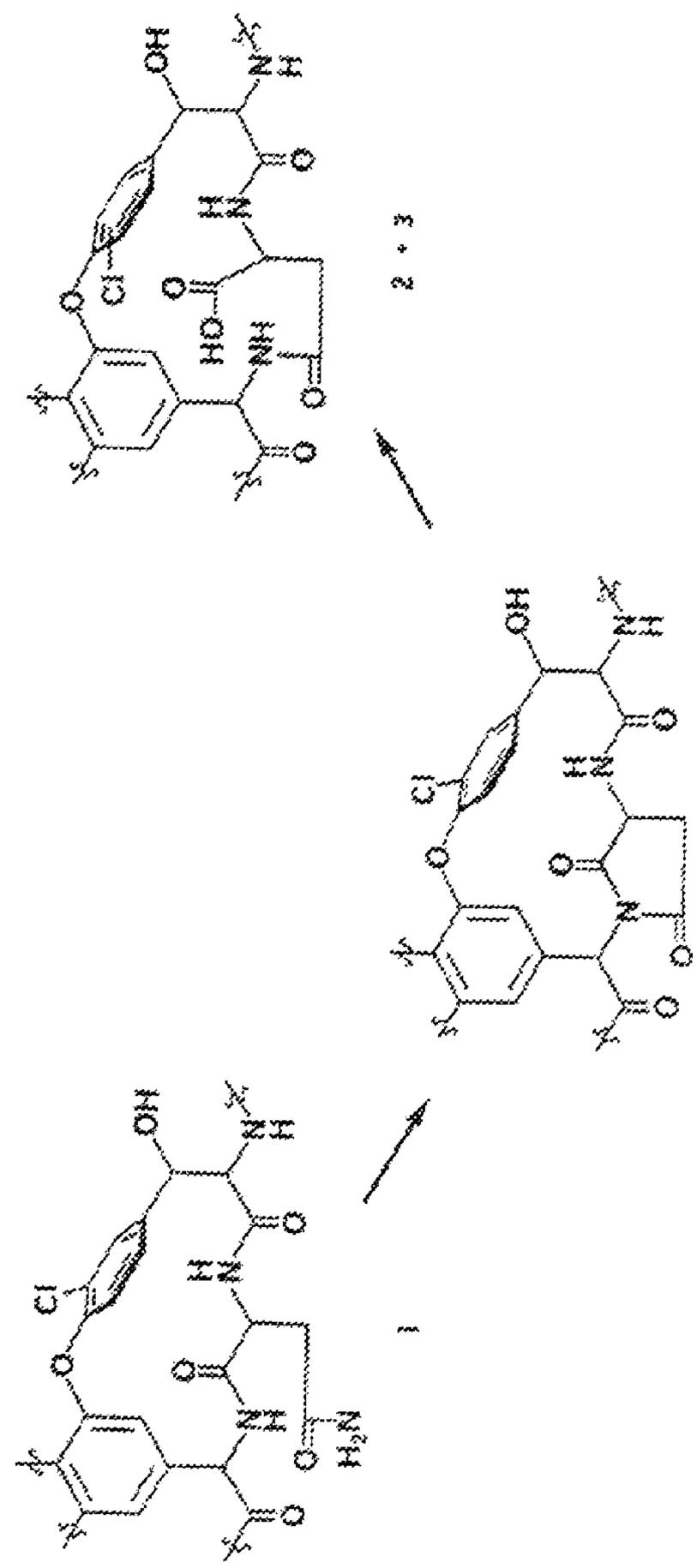
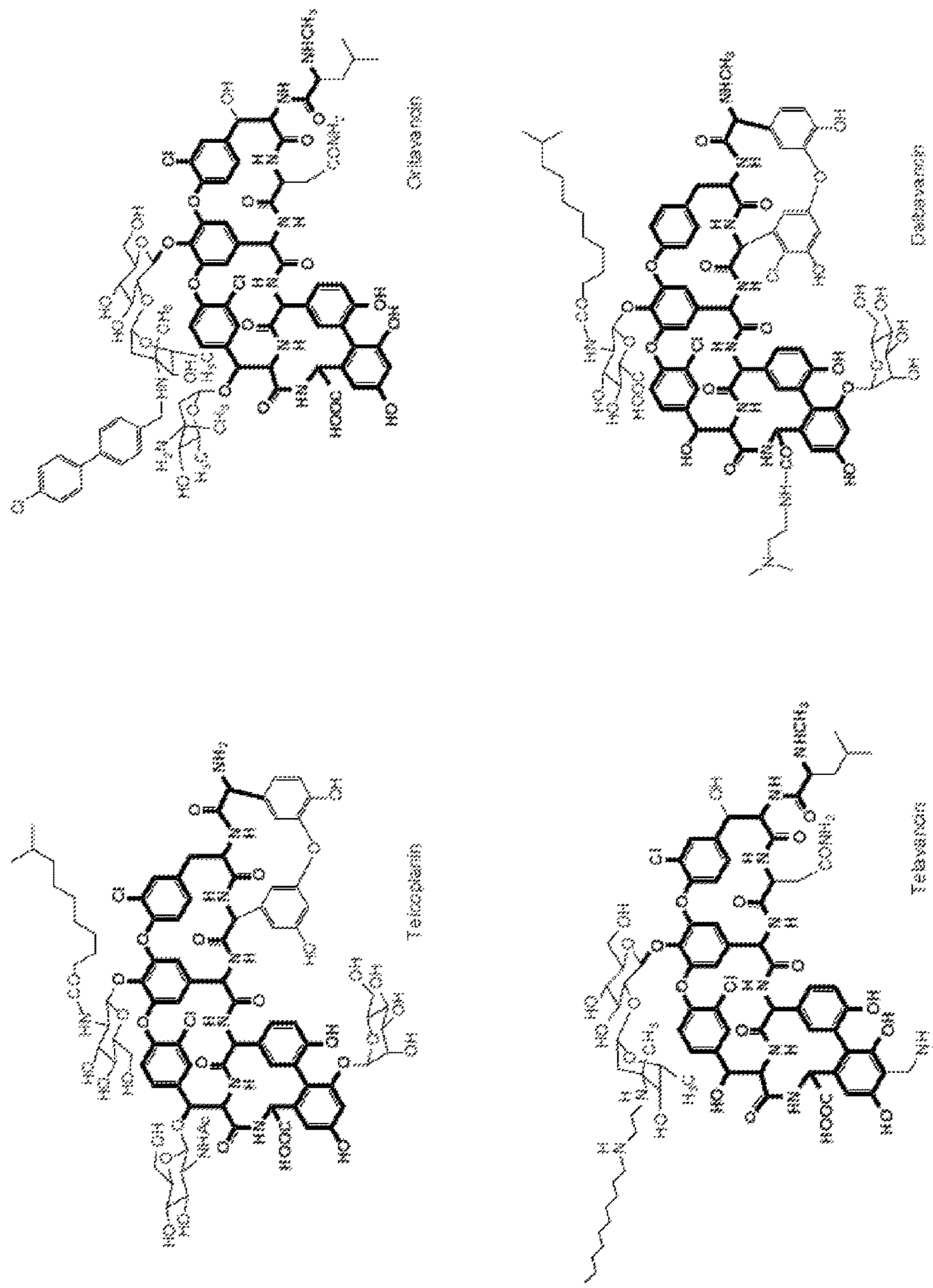


Figure 2

Figure 3



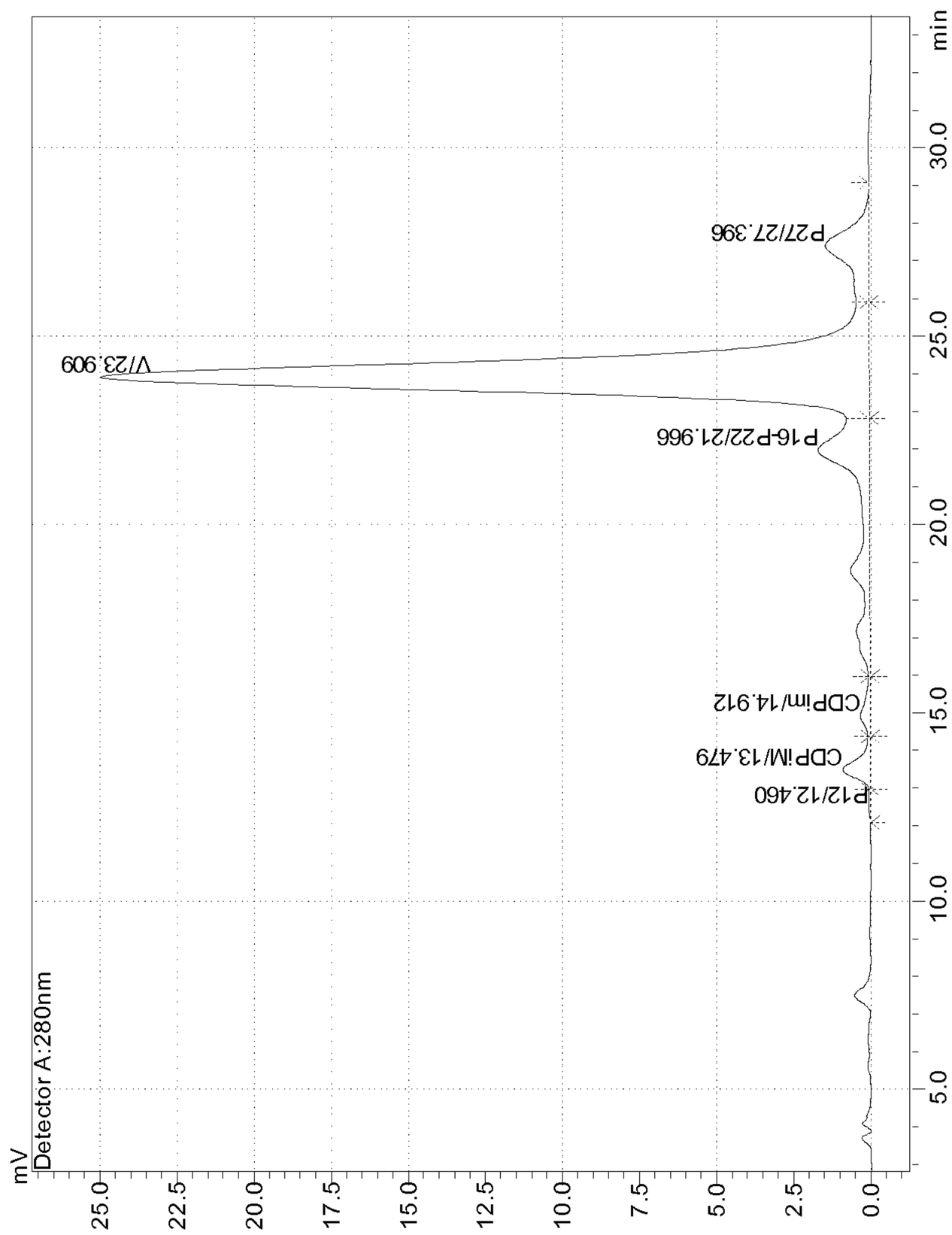

mV
Detector A:280nm
25.0
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
5.0
10.0
15.0
20.0
25.0
30.0
min
P12/12.460
CDPiM/13.479
CDPim/14.912
P16-P22/21.966
V/23.909
P27/27.396

Figure 4

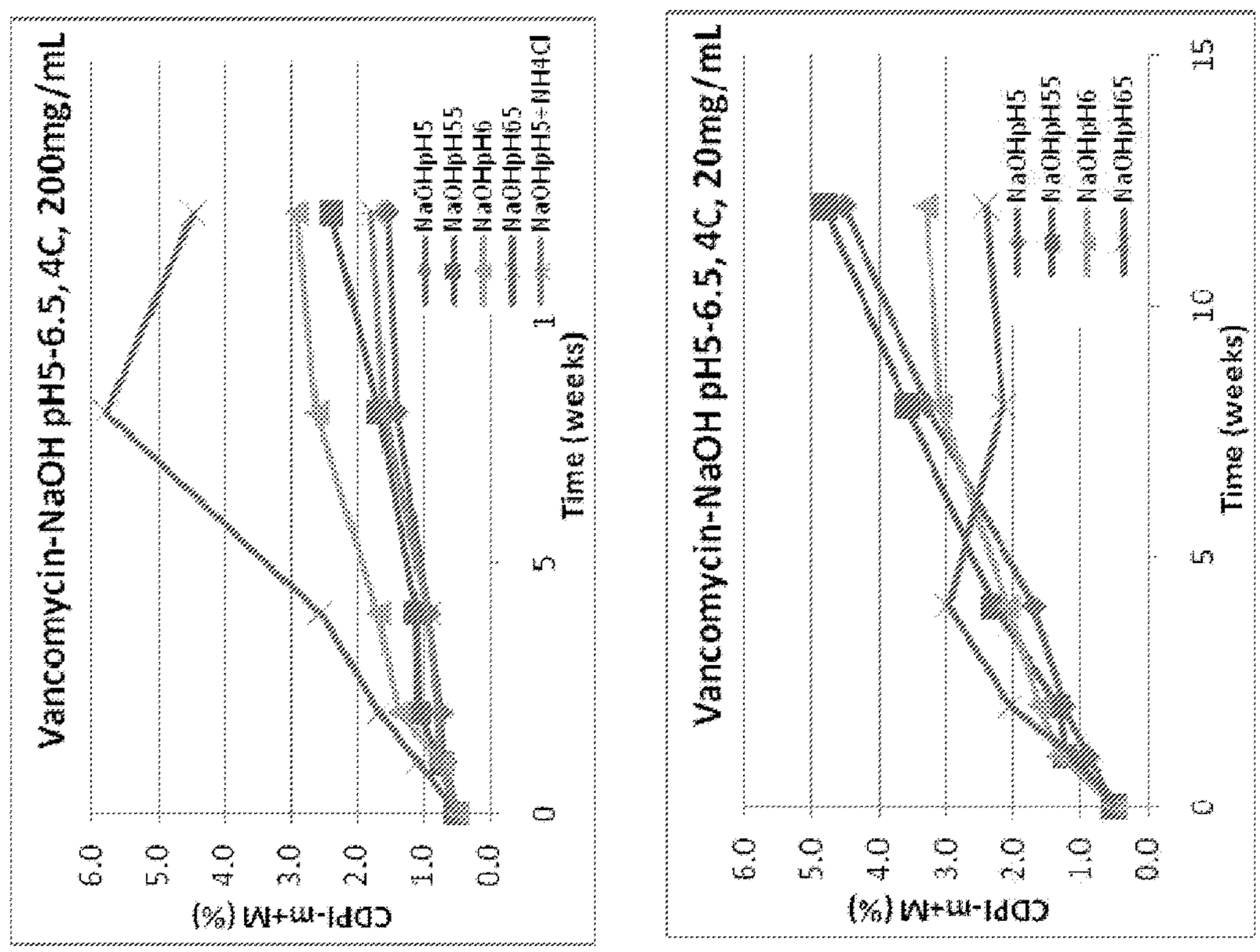
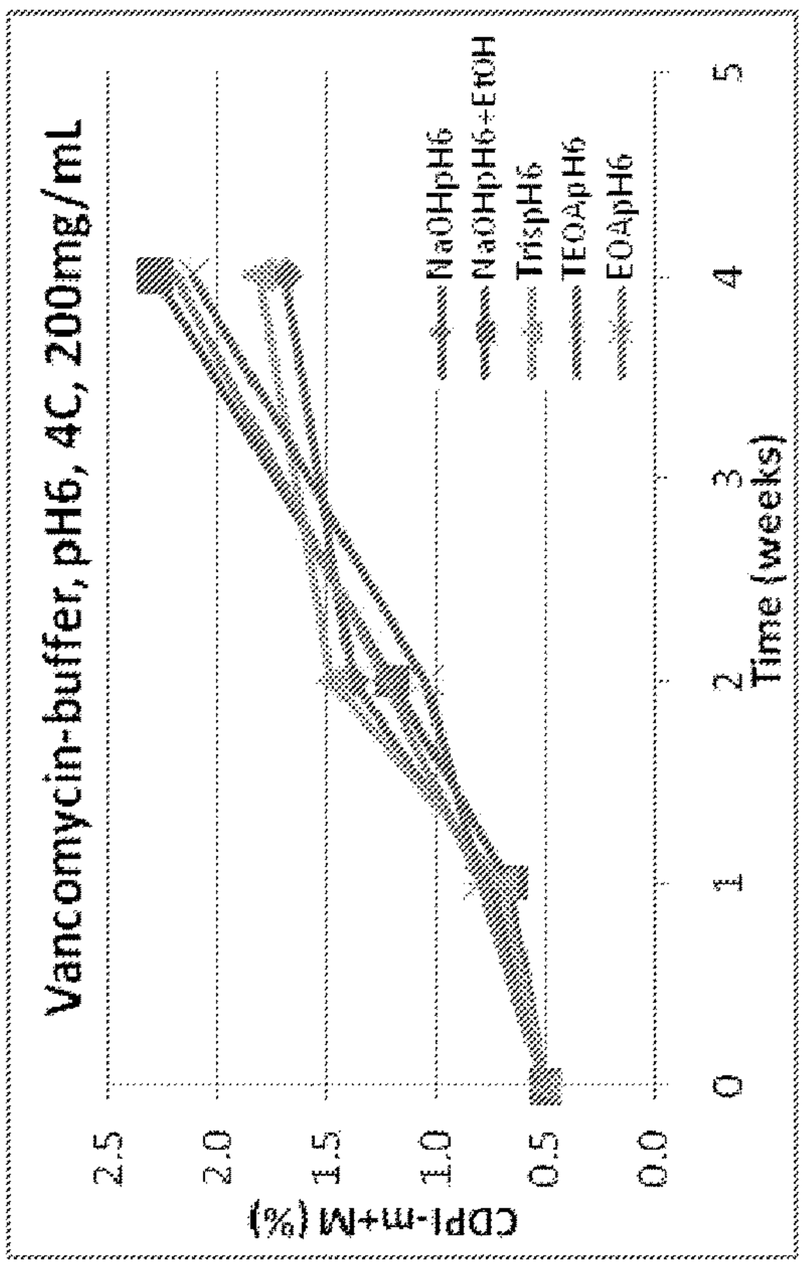

Vancomycin-NaOH pH5-6.5, 4C, 200mg/mL
CDPI-m+M (%)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
Time (weeks)
NaOHpH5
NaOHpH55
NaOHpH6
NaOHpH65
NaOHpH5+NH4Cl
Vancomycin-NaOH pH5-6.5, 4C, 20mg/mL
CDPI-m+M (%)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
Time (weeks)
NaOHpH5
NaOHpH55
NaOHpH6
NaOHpH65

Figure 5


Vancomycin-buffer, pH6, 4C, 200mg/mL
CDPI-m+M (%)
2.5
2.0
1.5
1.0
0.5
0.0
0
1
2
3
4
5
Time (weeks)
NaOHpH6
NaOHpH6+EtOH
TrispH6
TEOApH6
EOApH6

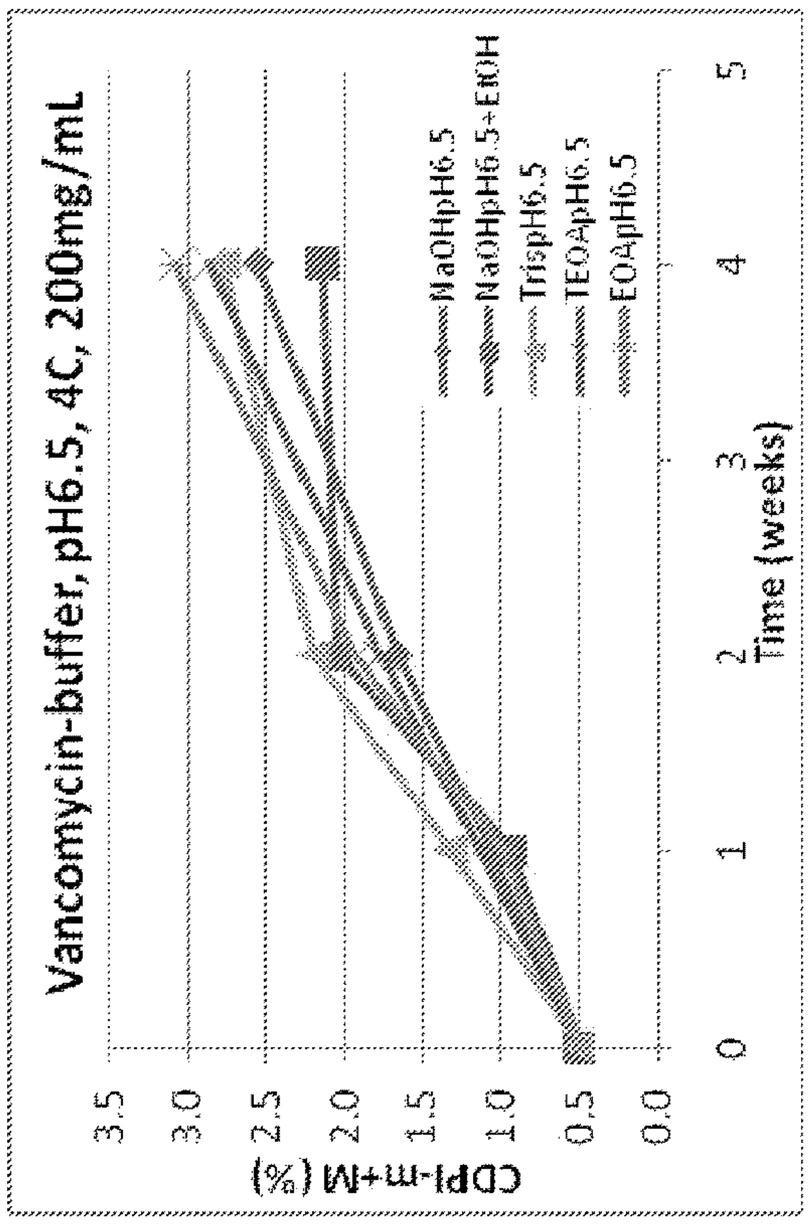
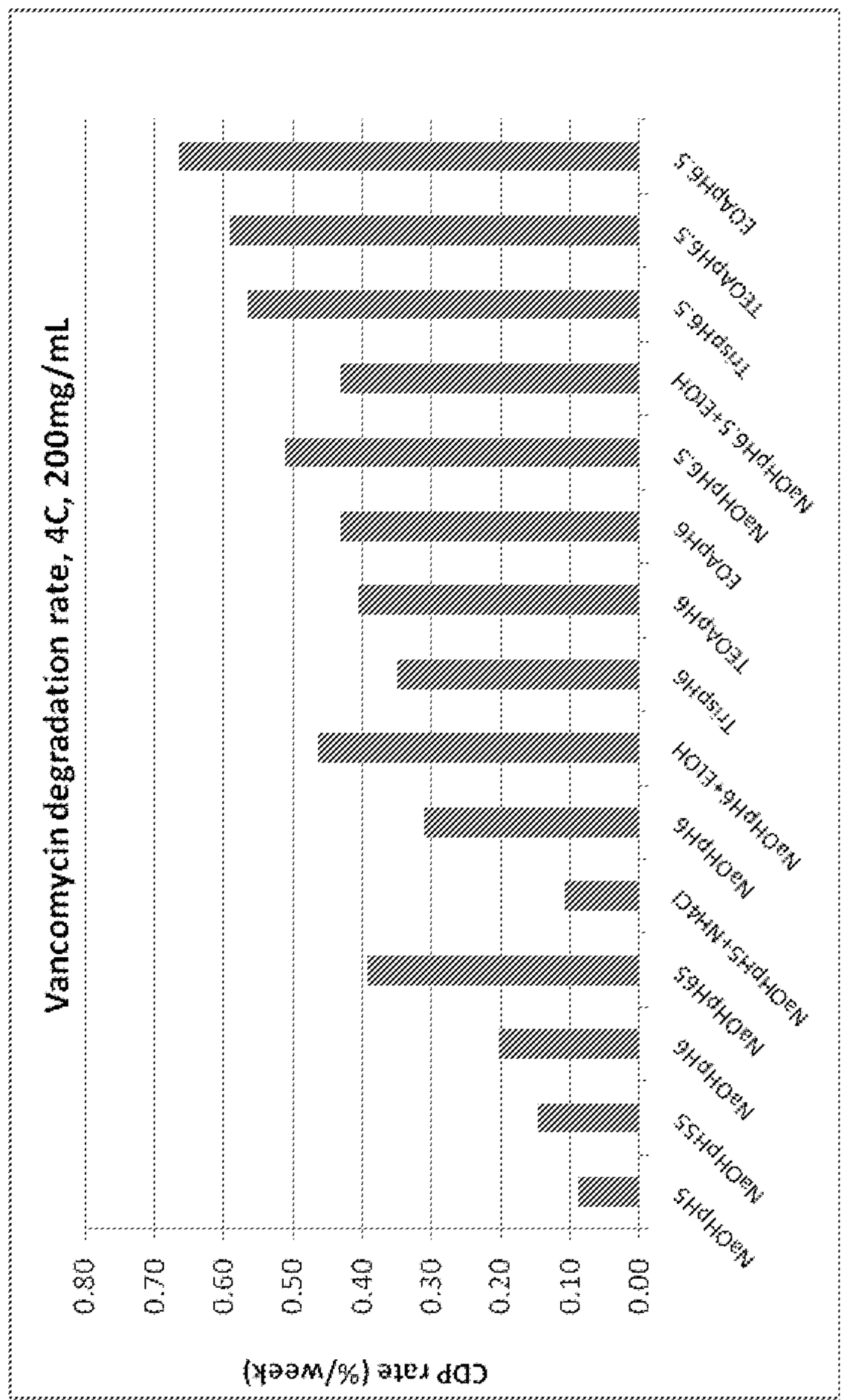

Vancomycin-buffer, pH6.5, 4C, 200mg/mL
CDPI-m+M (%)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
1
2
3
4
5
Time (weeks)
NaOHpH6.5
NaOHpH6.5+EtOH
TrispH6.5
TEOApH6.5
EOApH6.5

Figure 6

Figure 7


Vancomycin degradation rate, 4C, 200mg/mL
CDP rate (%/week)
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
NaOHpH5
NaOHpH55
NaOHpH6
NaOHpH65
NaOHpH5+NH4Cl
NaOHpH6
NaOHpH6+EtOH
TrispH6
TEOApH6
EOApH6
NaOHpH6.5
NaOHpH6.5+EtOH
TrispH6.5
TEOApH6.5
EOApH6.5

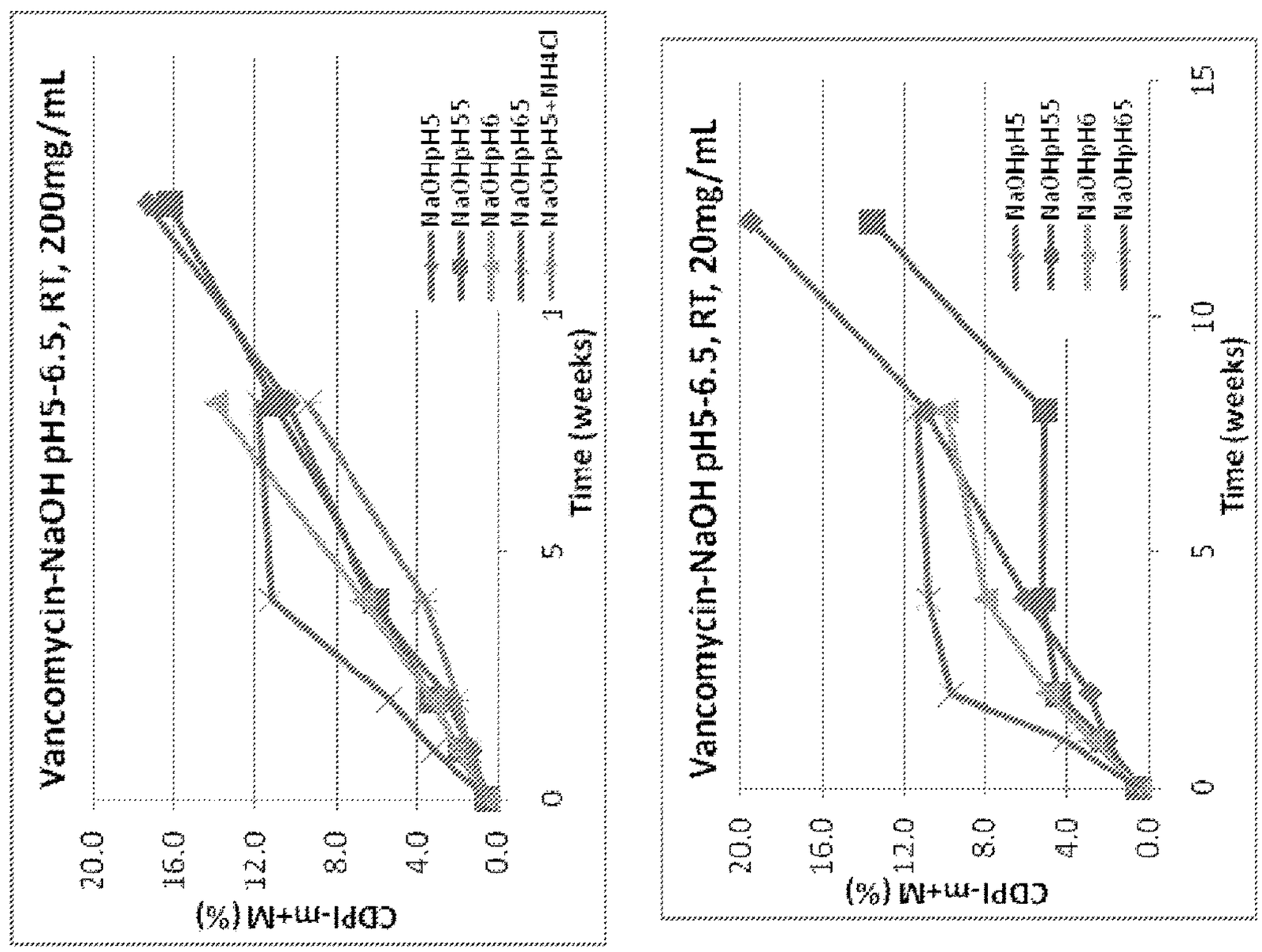

Vancomycin-NaOH pH5-6.5, RT, 200mg/mL
CDPI-m+M (%)
20.0
16.0
12.0
8.0
4.0
0.0
0
5
10
15
Time (weeks)
NaOHpH5
NaOHpH55
NaOHpH6
NaOHpH65
NaOHpH5+NH4Cl
Vancomycin-NaOH pH5-6.5, RT, 20mg/mL
CDPI-m+M (%)
20.0
16.0
12.0
8.0
4.0
0.0
0
5
10
15
Time (weeks)
NaOHpH5
NaOHpH55
NaOHpH6
NaOHpH65

Figure 8

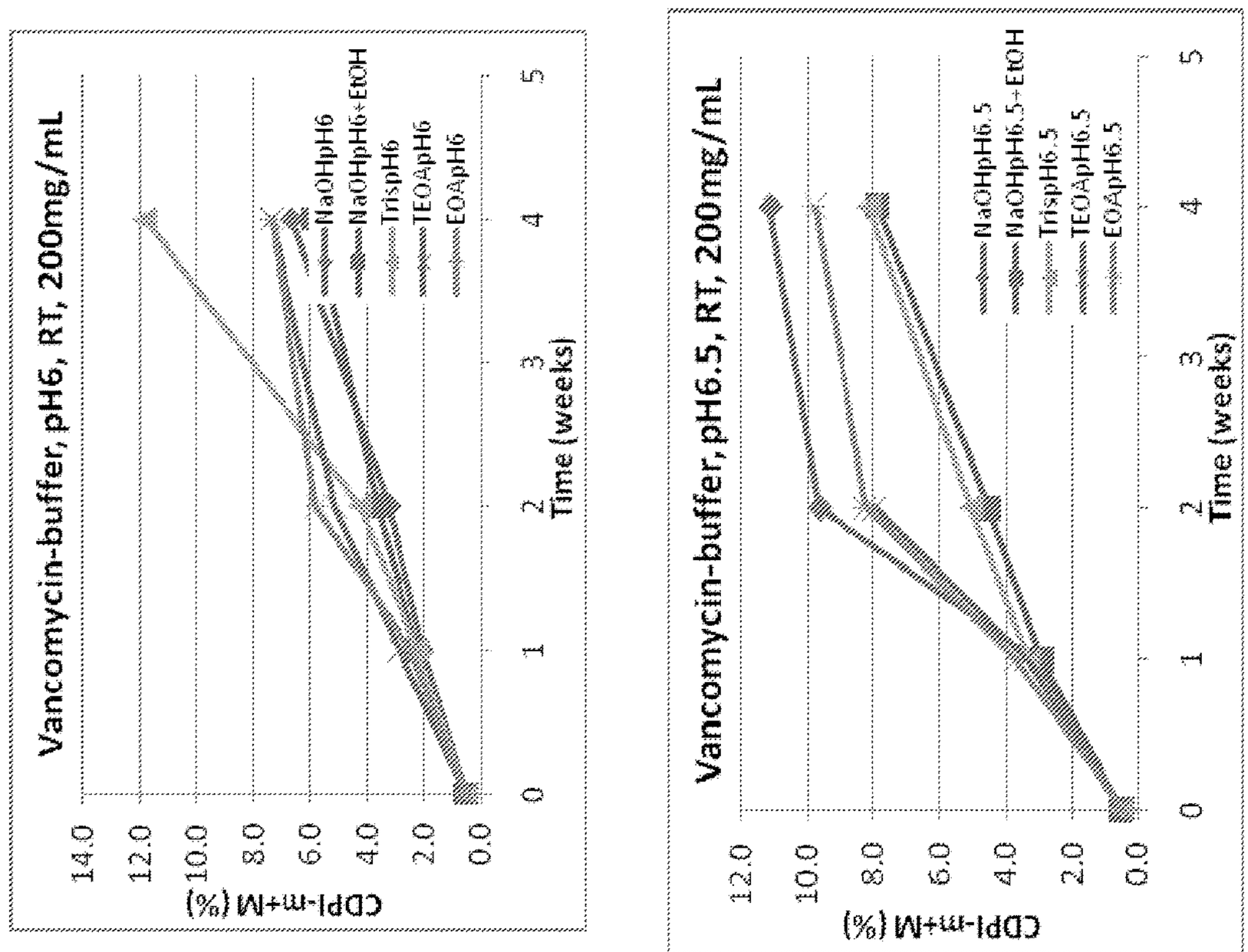

Vancomycin-buffer, pH6, RT, 200mg/mL
CDPI-m+M (%)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
1
2
3
4
5
Time (weeks)
NaOHpH6
NaOHpH6+EtOH
TrispH6
TEOApH6
EOApH6
Vancomycin-buffer, pH6.5, RT, 200mg/mL
CDPI-m+M (%)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
1
2
3
4
5
Time (weeks)
NaOHpH6.5
NaOHpH6.5+EtOH
TrispH6.5
TEOApH6.5
EOApH6.5

Figure 9

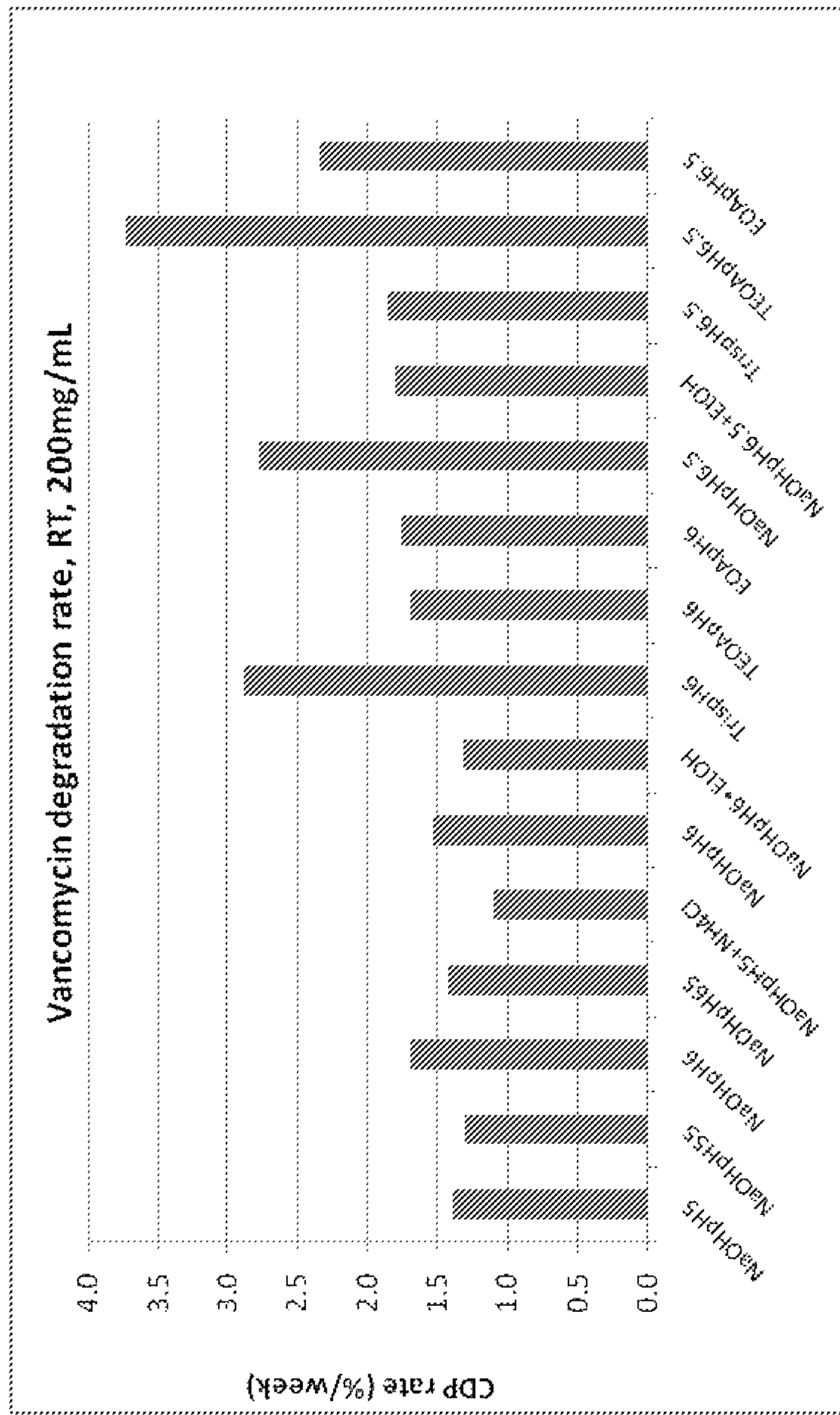

Vancomycin degradation rate, RT, 200mg/mL
CDP rate (%/week)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
NaOHpH5
NaOHpH5.5
NaOHpH6
NaOHpH6.5
NaOHpH5+NH4Cl
NaOHpH6
NaOHpH6+EtOH
Tris pH6
TEOA pH6
EOA pH6
NaOHpH6.5
NaOHpH6.5+EtOH
Tris pH6.5
TEOA pH6.5
EOA pH6.5

Figure 10

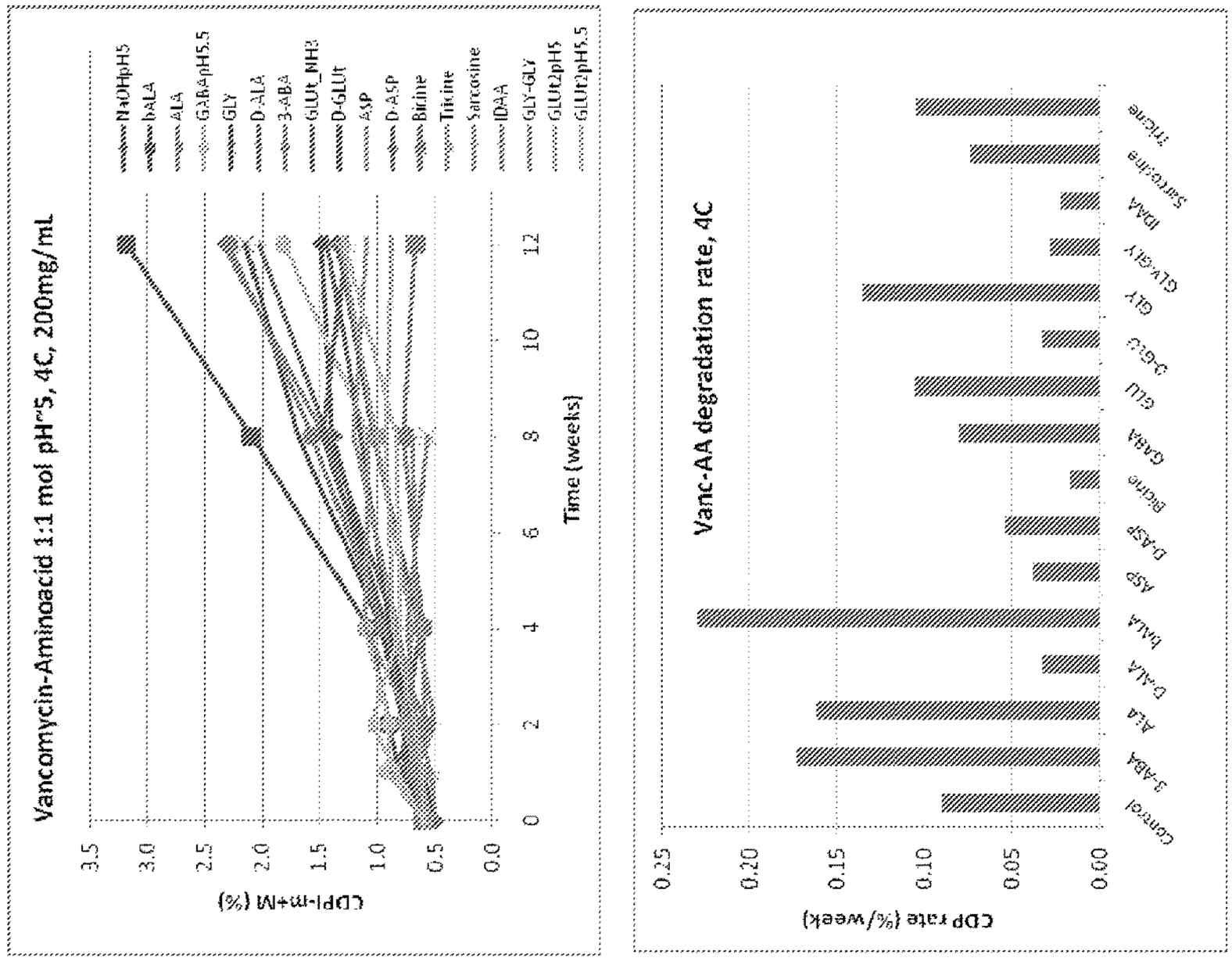

Vancomycin-Aminoacid 1:1 mol pH~5, 4C, 200mg/mL
CDPI-m+M (%)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
2
4
6
8
10
12
Time (weeks)
NaOHpH5
baLA
ALA
GABApH5.5
GLY
D-ALA
3-ABA
GLUt_NH3
D-GLUt
ASP
D-ASP
Betine
Tiricine
Sarcosine
IDAA
GLY-GLY
GLUt2pH5
GLUt2pH5.5
Vanc-AA degradation rate, 4C
CDP rate (%/week)
0.25
0.20
0.15
0.10
0.05
0.00
Control
3-ABA
ALA
D-ALA
baLA
ASP
D-ASP
Betine
GABA
GLU
D-GLU
GLY
GLY-GLY
IDAA
Sarcosine
Tricine

Figure 11

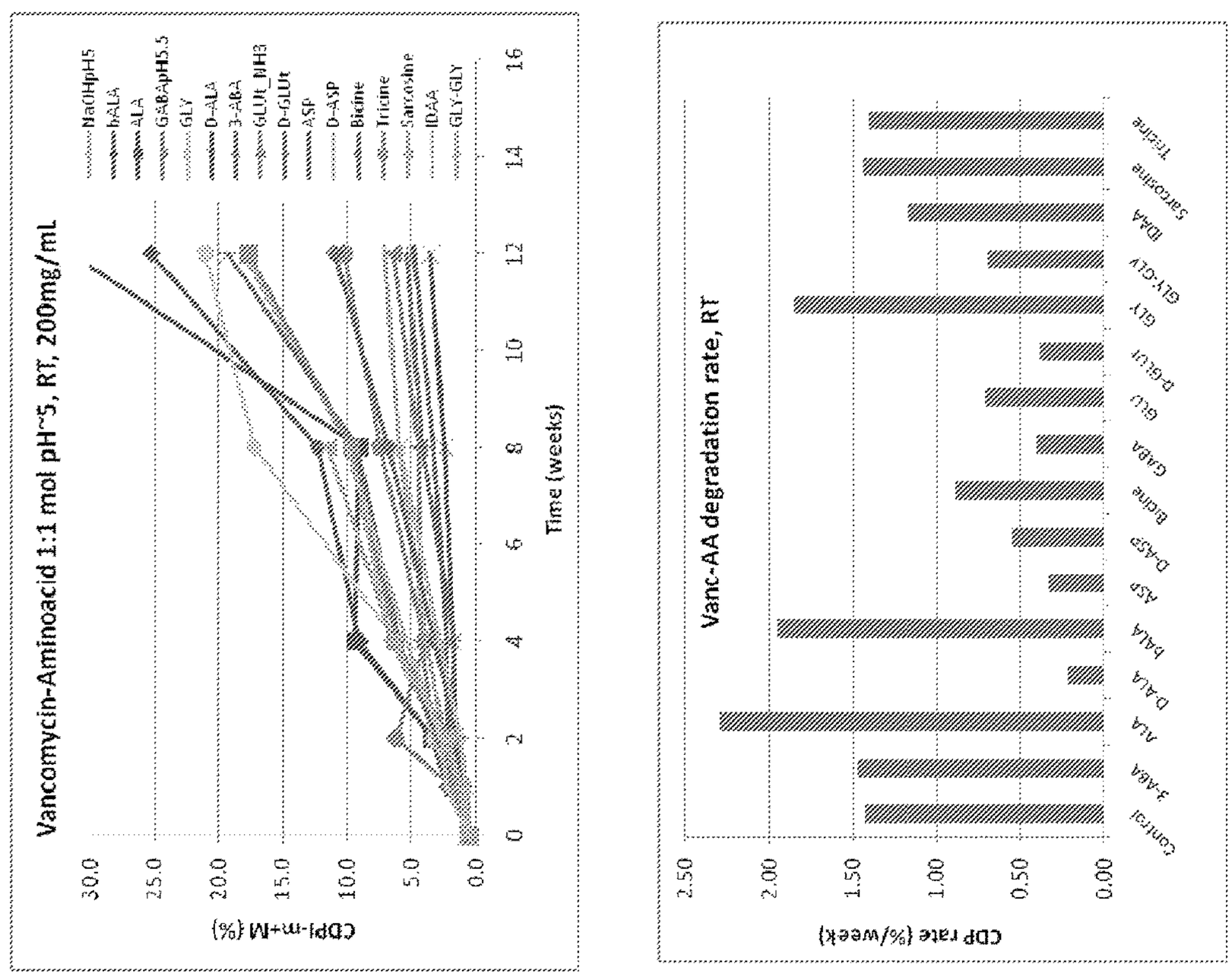

Vancomycin-Aminoacid 1:1 mol pH~5, RT, 200mg/mL
CDPI-m+M (%)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0
2
4
6
8
10
12
14
16
Time (weeks)
NaOHpH5
bALA
ALA
GABApH5.5
GLY
D-ALA
3-ABA
GLUt_NH3
D-GLUt
ASP
D-ASP
Betine
Tricine
Sarcosine
IDAA
GLY-GLY
Vanc-AA degradation rate, RT
CDP rate (%/week)
2.50
2.00
1.50
1.00
0.50
0.00
control
3-ABA
ALA
D-ALA
bALA
ASP
D-ASP
Betine
GABA
GLU
D-GLUt
GLY
GLY-GLY
IDAA
Sarcosine
Tricine

Figure 12

Figure 13

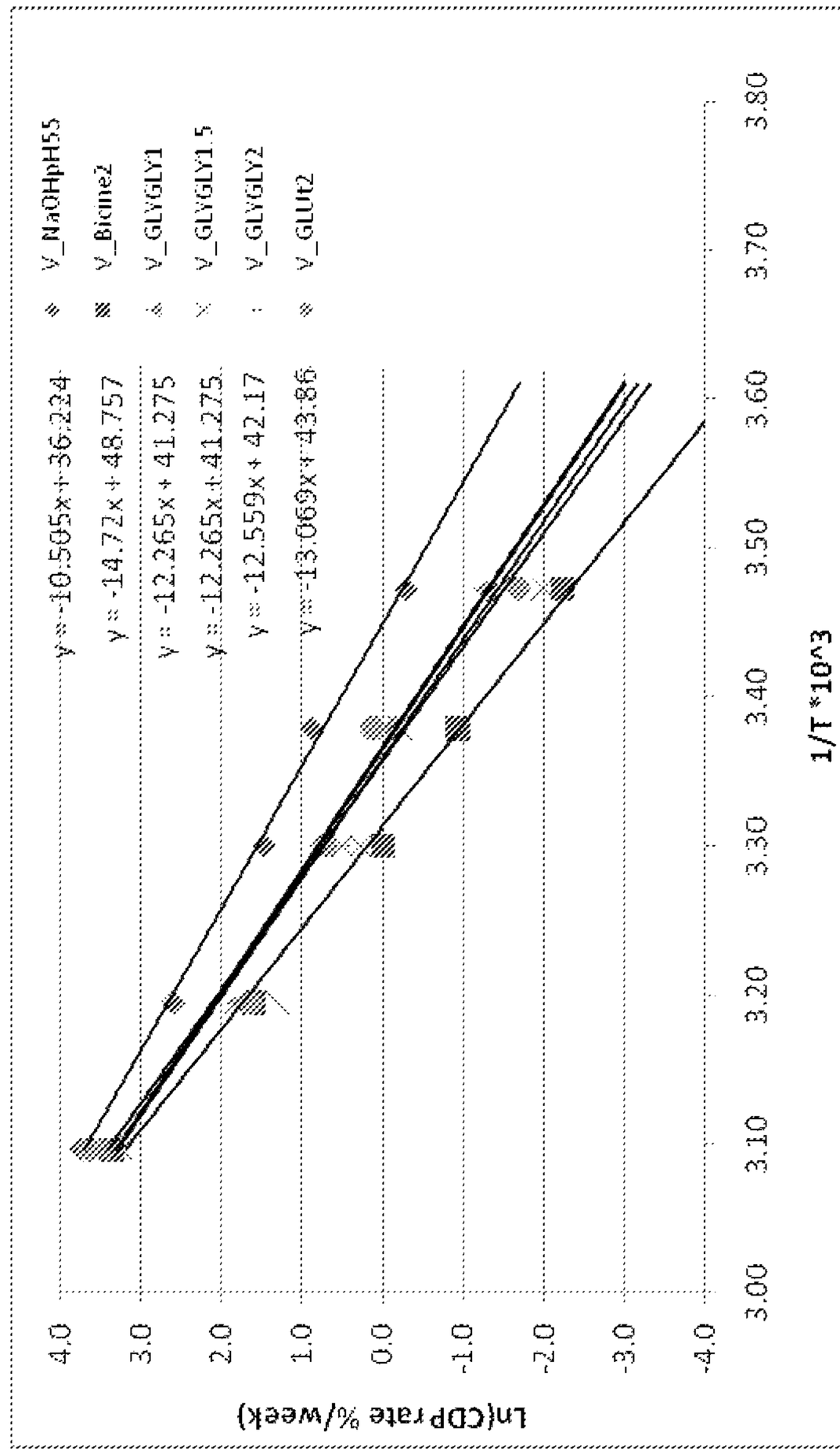
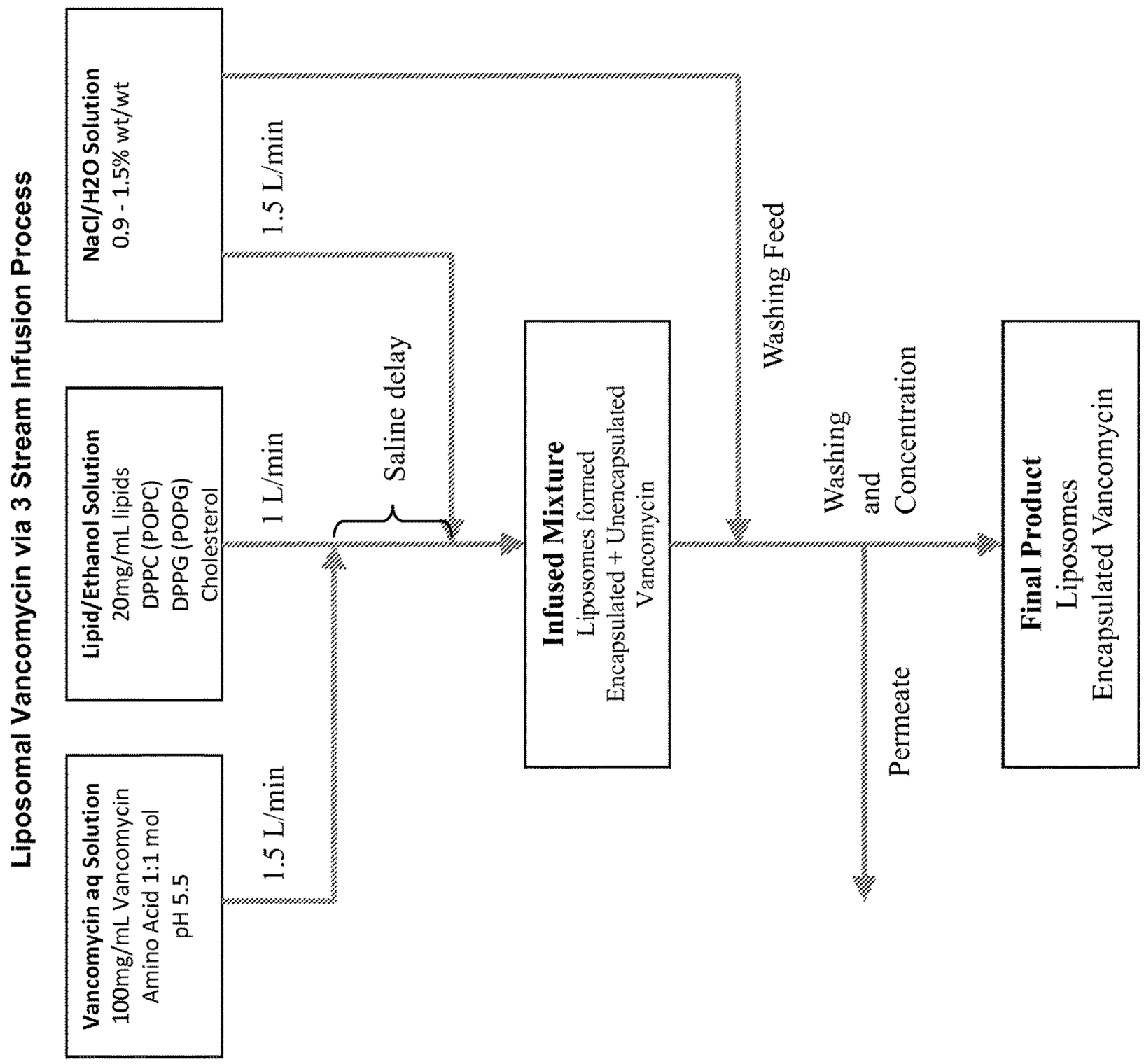

y = -10.505x + 36.224
y = -14.72x + 48.757
y = -12.265x + 41.275
y = -12.265x + 41.275
y = -12.559x + 42.17
y = -13.069x + 43.86
V_NaOHpH55
V_Biome2
V_GLYGLY1
V_GLYGLY1.5
V_GLYGLY2
V_GLUt2
ln(CDP rate %/week)
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
3.00
3.10
3.20
3.30
3.40
3.50
3.60
3.70
3.80
1/T *10^3

Figure 14


Liposomal Vancomycin via 3 Stream Infusion Process
Vancomycin aq Solution
100mg/mL Vancomycin
Amino Acid 1:1 mol
pH 5.5
Lipid/Ethanol Solution
20mg/mL lipids
DPPC (POPC)
DPPG (POPG)
Cholesterol
NaCl/H2O Solution
0.9 - 1.5% wt/wt
1.5 L/min
1 L/min
1.5 L/min
Saline delay
Infused Mixture
Liposomes formed
Encapsulated + Unencapsulated
Vancomycin
Washing Feed
Washing
and
Concentration
Permeate
Final Product
Liposomes
Encapsulated Vancomycin

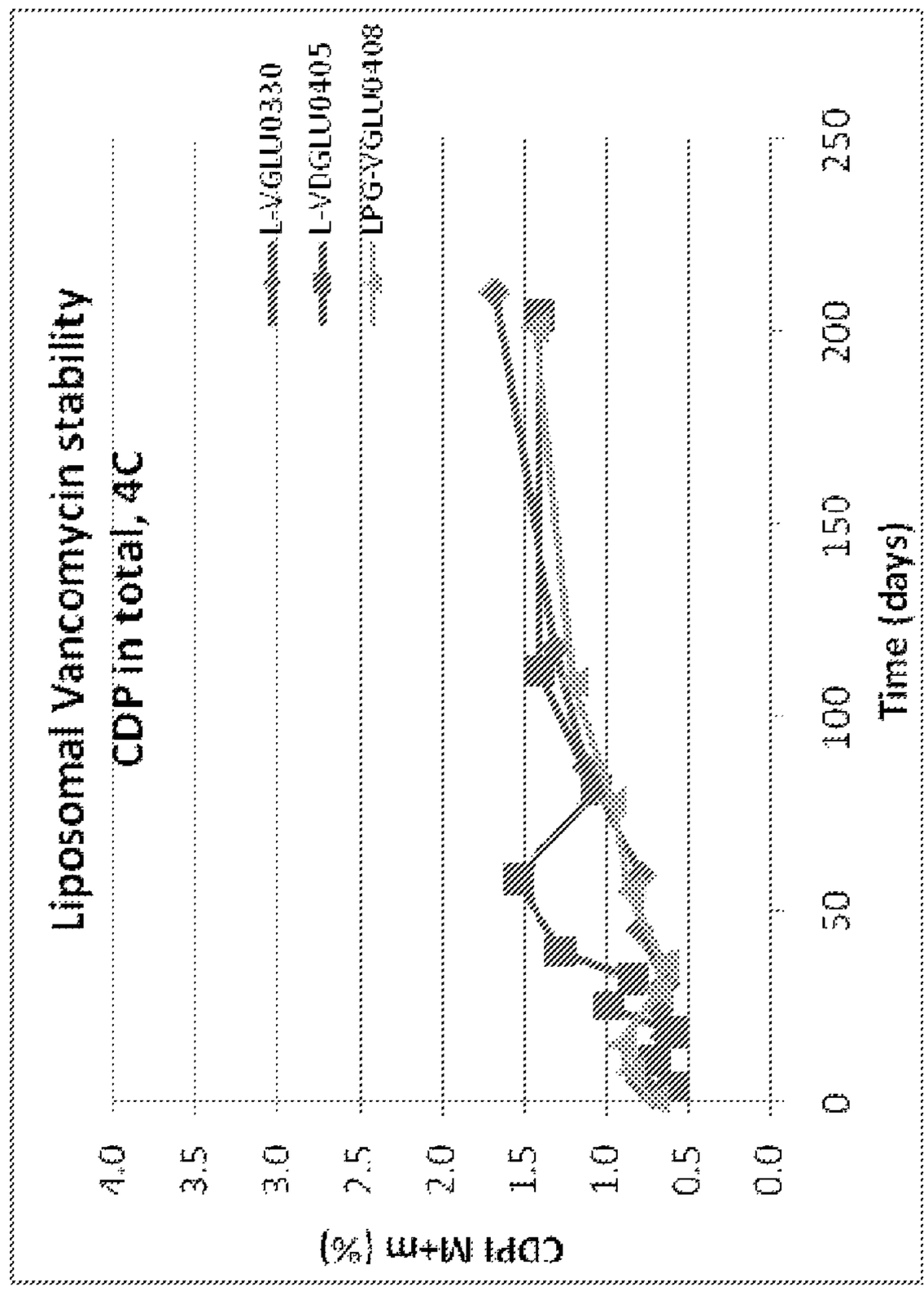

Liposomal Vancomycin stability
CDP in total, 4C
L-VGLU0330
L-VDGLU0405
LPG-VGLU0408
CDP1 M1+m1 (%)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
50
100
150
200
250
Time (days)

Figure 15

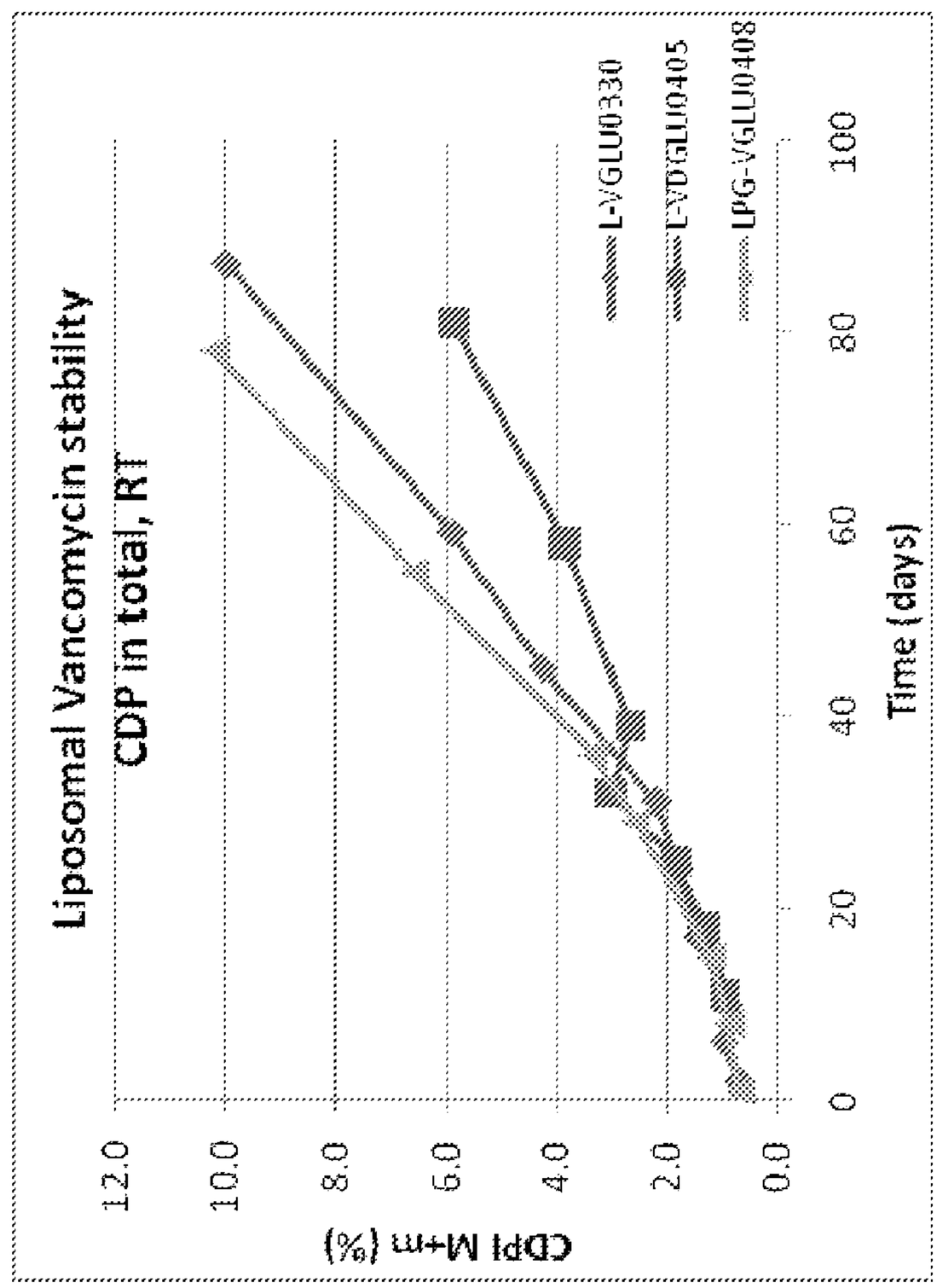

Liposomal Vancomycin stability
CDP in total, RT
CDPI M+m (%)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
20
40
60
80
100
Time (days)
L-VGLU0330
L-VDGLU0405
LPG-VGLU0408

Figure 16

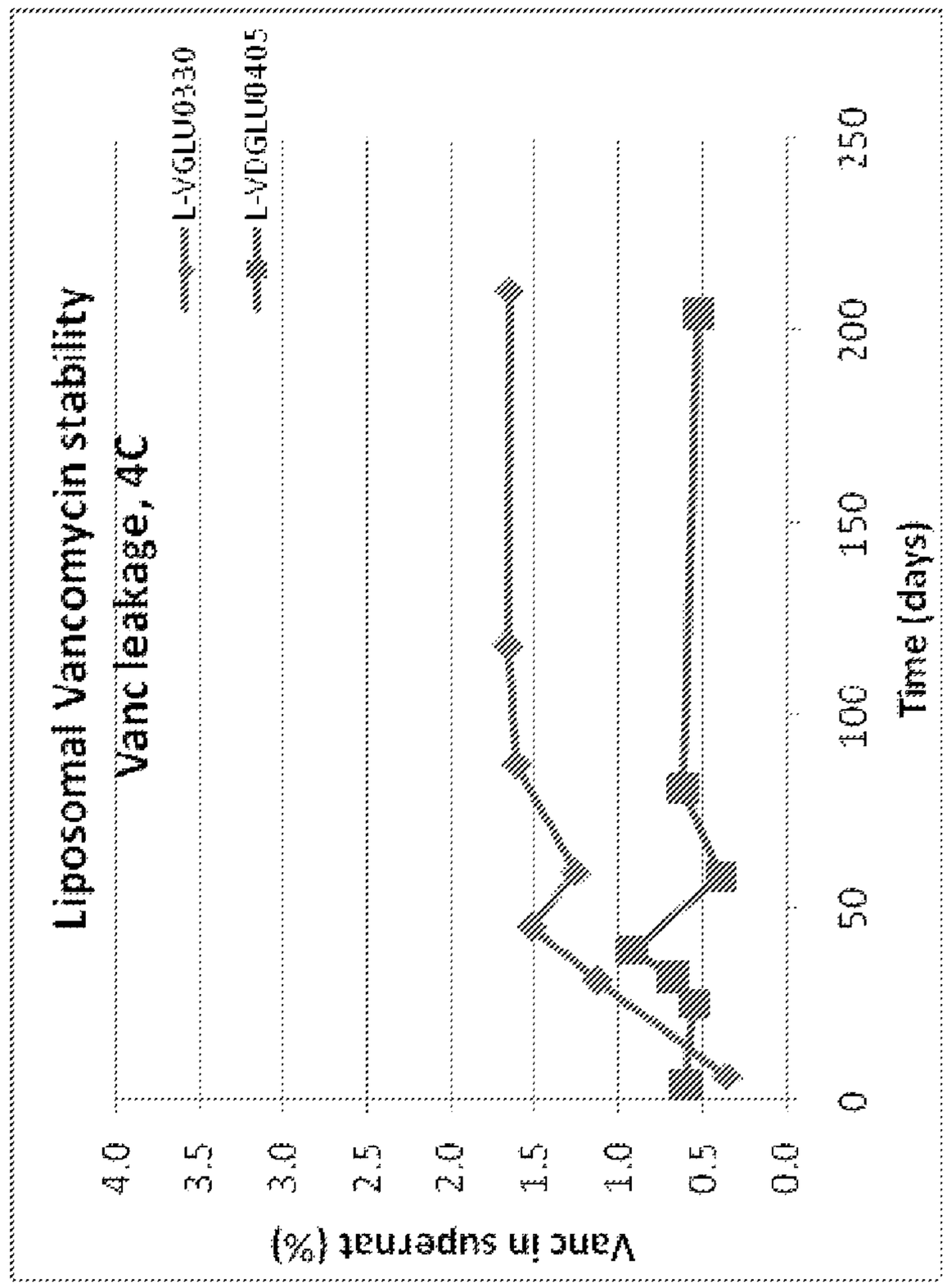

Liposomal Vancomycin stability
Vanc leakage, 4C
L-VGLU0330
L-VDGLU0405
Vanc in supernat (%)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
50
100
150
200
250
Time (days)

Figure 17

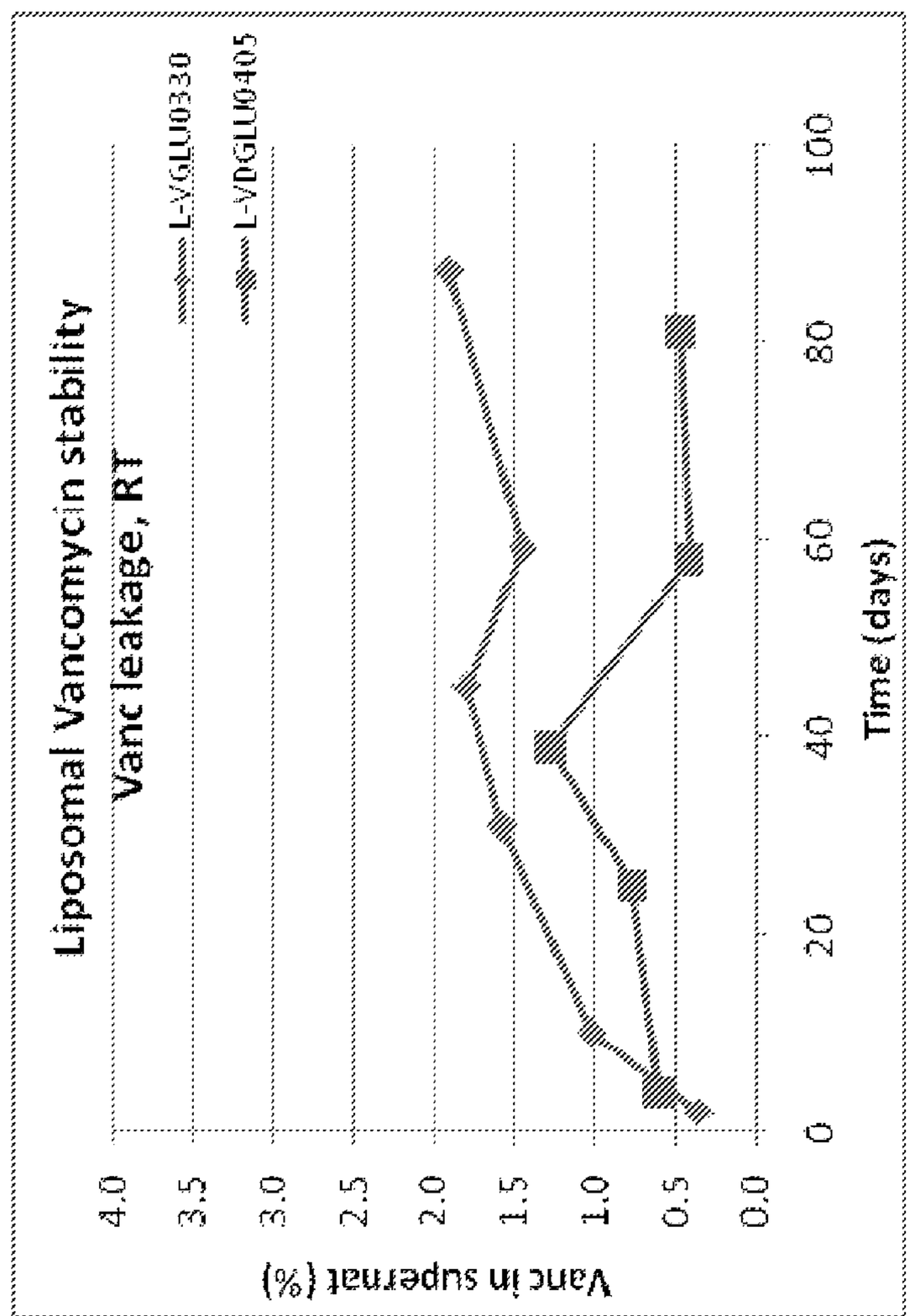

Liposomal Vancomycin stability
Vanc leakage, RT
L-VGLU0330
L-VDGLU0405
Vanc in supernat (%)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
20
40
60
80
100
Time (days)

Figure 18

STABILIZED VANCOMYCIN FORMULATIONS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a 371 national phase entry of PCT Application No. PCT/US2013/072136, filed Nov. 27, 2013, which claims priority from U.S. Provisional Application Ser. No. 61/731,363, filed Nov. 29, 2012, both of which are incorporated herein by reference in their entirety for all purposes.

BACKGROUND OF THE INVENTION

Vancomycin is a branched tricyclic glycosylated non ribosomal peptide antibiotic produced by the fermentation of the *Actinobacteria* species *Amycolaopsis orientalis*, and is believed to act by inhibiting proper cell wall synthesis in Gram-positive bacteria. Additionally, it is believed that vancomycin alters cell membrane permeability and RNA synthesis. Accordingly, vancomycin is generally used in the prophylaxis and treatment of infections caused by Gram-positive bacteria that are unresponsive to other types of antibiotics.

Vancomycin has been reported as a treatment of last resort for infections that are resistant to other first line antibiotics. This is because vancomycin is given intravenously for most indications. Additionally, vancomycin presents toxicity concerns, and semi-synthetic penicillins have been developed and used preferentially over vancomycin. Nevertheless, the use of vancomycin has increased particularly with the spread of multiple-resistant *Staphylococcus aureus* (MRSA).

Methods for treating pulmonary disorders using liposomal vancomycin formulations are described in U.S. Publication Nos. US 2009-0105126 and US 2009-0104257, and U.S. Provisional Application Nos. 61/103,725 and 60/981,990, all of which are hereby incorporated by reference in their entireties. There is a need in the art for cost-effective vancomycin formulations that degrade at a slower rate and therefore exhibit improved stability. The present invention addresses these and other needs.

SUMMARY OF THE INVENTION

In one aspect, a stabilized lipid-based glycopeptide antibiotic composition is provided. In one embodiment, the composition comprises a lipid component, a glycopeptide antibiotic, and an amino acid or a derivative thereof. In a further embodiment, the amino acid or derivative thereof binds to the glycopeptide antibiotic and forms a stabilized glycopeptide antibiotic-amino acid complex. In even a further embodiment, the stabilized glycopeptide antibiotic-amino acid complex is entrapped by, or complexed with, the lipid component. In one embodiment, the antibiotic is vancomycin. In another embodiment, the antibiotic is teicoplanin, telavancin, oritavancin, decaplanin or dalbavancin. In one embodiment, the lipid component is a mixture of two or three lipids.

In one embodiment, a pharmaceutical composition comprising a lipid-based glycopeptide antibiotic is provided. In a further embodiment, the composition comprises a lipid component, a glycopeptide antibiotic, and an amino acid or derivative thereof. In a further embodiment, the amino acid or the derivative thereof stabilizes the glycopeptide antibiotic. In a yet further embodiment, the antibiotic and amino acid are entrapped by, or complexed with, the lipid. In one

embodiment, the antibiotic is vancomycin, teicoplanin, telavancin, oritavancin, decaplanin or dalbavancin. In a further embodiment, the antibiotic is vancomycin.

In one embodiment, a stabilized lipid-based vancomycin formulation is provided that produces product degradants at a rate less than about 0.05% by weight per week at 4° C. In another embodiment, a stabilized lipid-based vancomycin composition is provided, and the composition produces product degradants at a rate less than about 0.03% by weight per week at 4° C. In a further embodiment, a stabilized lipid-based vancomycin composition is provided that produces product degradants at a rate less than about 0.02% by weight per week at 4° C. In yet a further embodiment, a stabilized lipid-based vancomycin composition is provided that produces product degradants at a rate less than about 0.01% by weight per week at 4° C. In one embodiment, the product degradants are crystalline degradation products.

In one embodiment, a stabilized lipid-based vancomycin formulation is provided that produces product degradants at a rate less than about 0.5% by weight per week at room temperature (RT). In another embodiment, a stabilized lipid-based vancomycin composition is provided that produces product degradants at a rate less than about 0.4% by weight per week at RT. In a further embodiment, a stabilized lipid-based vancomycin composition is provided where the composition produces product degradants at a rate less than about 0.2% by weight per week at RT. In one embodiment, the product degradants are crystalline degradation products.

In one embodiment, the stabilized lipid-based glycopeptide antibiotic composition comprising a lipid component, a glycopeptide antibiotic, and an amino acid or derivative thereof is at least about 44% more stable, or at least about 55% more stable, or at least about 66% more stable, or at least about 77% more stable, or at least about 88% more stable than a lipid-based glycopeptide antibiotic composition that does not comprise an amino acid or derivative thereof.

In another embodiment, the present invention relates to a stabilized lipid-based glycopeptide antibiotic comprising a lipid component, a glycopeptide antibiotic, and an amino acid or a derivative thereof, wherein the lipid component comprises a phospholipid. In a further embodiment, the phospholipid is phosphatidylcholine (PC), phosphatidylglycerol (PG), phosphatidylinositol (PI), phosphatidylserine (PS), phosphatidylethanolamine (PE), phosphatidic acid (PA), egg phosphatidylcholine (EPC), egg phosphatidylglycerol (EPG), egg phosphatidylinositol (EPI), egg phosphatidylserine (EPS), phosphatidylethanolamine (EPE), phosphatidic acid (EPA), soy phosphatidylcholine (SPC), soy phosphatidylglycerol (SPG), soy phosphatidylserine (SPS), soy phosphatidylinositol (SPI), soy phosphatidylethanolamine (SPE), soy phosphatidic acid (SPA), hydrogenated egg phosphatidylcholine (HEPC), hydrogenated egg phosphatidylglycerol (HEPG), hydrogenated egg phosphatidylinositol (HEPI), hydrogenated egg phosphatidylserine (HEPS), hydrogenated phosphatidylethanolamine (HEPE), hydrogenated phosphatidic acid (HEPA), hydrogenated soy phosphatidylcholine (HSPC), hydrogenated soy phosphatidylglycerol (HSPG), hydrogenated soy phosphatidylserine (HSPS), hydrogenated soy phosphatidylinositol (HSPI), hydrogenated soy phosphatidylethanolamine (HSPE), hydrogenated soy phosphatidic acid (HSPA), dipalmitoylphosphatidylcholine (DPPC), dimyristoylphosphatidylcholine (DMPC), dimyristoylphosphatidylglycerol (DMPG), dipalmitoylphosphatidylglycerol (DPPG), distcaroylphosphatidylcholine (DSPC), distcaroylphosphatidylglycerol (DSPG), dioleoylphosphatidylcholine (DOPC), dioleyl-

phosphatidylcthanolamine (DOPE), palmitoylstearoylphosphatidyl-choline (PSPC), palmitoylstearolphosphatidylglycerol (PSPG), mono-oleoyl-phosphatidylethanolamine (MOPE), tocopherol, tocopherol hemisuccinate, cholesterol sulfate, cholesteryl hemisuccinate, cholesterol derivatives, ammonium salts of fatty acids, ammonium salts of phospholipids, ammonium salts of glycerides, myristylamine, palmitylamine, laurylamine, stearylamine, dilauroyl ethylphosphocholine (DLEP), dimyristoyl ethylphosphocholine (DMEP), dipalmitoyl ethylphosphocholine (DPEP) and distearoyl ethylphosphocholine (DSEP). N-(2,3-di-(9-(Z)-octadecenyloxy)-prop-1-yl-N,N,N-trimethylammonium chloride (DOTMA), 1,2-bis(oleoyloxy)-3-(trimethylammonio) propane (DOTAP), distearoylphosphatidylglycerol (DSPG), dimyristoylphosphatidylacid (DMPA), dipalmitoylphosphatidylacid (DPPA), distearoylphosphatidylacid (DSPA), dimyristoylphosphatidylinositol (DMPI), dipalmitoylphosphatidylinositol (DPPI), distearoylphospatidylinositol (DSPI), dimyristoylphosphatidylserine (DMPS), dipalmitoylphosphatidylserine (DPPS), distearoylphosphatidylserine (DSPS), or mixtures thereof. In one embodiment, the lipid component comprises DPPC. In another embodiment, the lipid component comprises DPPG. In another embodiment, the lipid component comprises DPPC and DPPG. In one embodiment, the lipid component comprises one lipid, two lipids or three lipids. In yet another embodiment, the lipid component consists of one lipid, two lipids or three lipids.

In another embodiment, a stabilized lipid-based glycopeptide antibiotic comprising a sterol, a glycopeptide antibiotic, and an amino acid or a derivative thereof is provided. In one embodiment, the sterol is cholesterol. In another embodiment, the composition further comprises DPPC.

In another embodiment, the present invention comprises a stabilized lipid-based glycopeptide antibiotic comprising a lipid component comprising a phospholipid and a sterol, a glycopeptide antibiotic, and an amino acid or a derivative thereof. In one embodiment, the phospholipid and sterol are dipalmitoylphosphatidylcholine (DPPC) and cholesterol, respectively. In another embodiment, the phospholipid and sterol are dipalmitoylphosphatidylglycerol (DPPG) and cholesterol. In another embodiment, the phospholipid and sterol comprise DPPC, DPPG and cholesterol.

In one embodiment, the present invention comprises a stabilized lipid-based glycopeptide antibiotic comprising a lipid component, a glycopeptide antibiotic, and an amino acid or a derivative thereof, wherein the amino acid or derivative thereof is conjugated to the glycopeptide antibiotic to form a stabilized glycopeptide antibiotic-amino acid complex. In a further embodiment, the stabilized glycopeptide antibiotic-amino acid complex is entrapped by the lipid component. In a further embodiment, the lipid component is in a lipid clathrate, proliposome, micelle or liposome. In a further embodiment, the liposome has a mean particle size of about 0.05 to about 10 microns, 0.05 to about 1 microns, 0.05 to about 0.5 microns, about 0.1 to about 5.0 microns, about 0.1 to about 3.0 microns, about 0.1 to about 2.0 microns, about 0.1 to about 1.0 microns, about 0.1 to about 0.5 microns, about 0.1 to about 0.4 microns, about 0.1 to about 0.3 microns, or about 0.1 to about 0.2 microns. In another embodiment, the mean particular size of the liposome is about 1.0 microns or less, about 0.9 microns or less, about 0.8 microns or less, about 0.7 microns or less, about 0.6 microns or less, about 0.5 microns or less, about 0.4 microns or less, about 0.3 microns or less, or about 0.2 microns or less.

In one embodiment, the present invention provides a stabilized lipid-based glycopeptide antibiotic composition comprising a lipid component, vancomycin, and an amino acid or a derivative thereof. In one embodiment, the amino acid is D-alanine. In another embodiment, the amino acid is aspartic acid. In another embodiment, the amino acid derivative is bicine. In another embodiment, the amino acid is D-glutamic acid. In another embodiment, the amino acid derivative is glycylglycine (GLY-GLY). In yet another embodiment, the amino acid derivative is iminodiacetic acid (IDAA). In one embodiment, the vancomycin is conjugated to the amino acid or derivative thereof.

In one embodiment, a stabilized lipid-glycopeptide antibiotic comprising a lipid component, a glycopeptide antibiotic, and an amino acid or derivative thereof is provided, wherein the molar ratio of the glycopeptide antibiotic to the amino acid derivative thereof is from about 1:1 to about 1:4. In a further embodiment, the molar ratio of the glycopeptide antibiotic to the amino acid or derivative thereof is from about 1:1 to about 1:2. In a further embodiment, the molar ratio of the glycopeptide antibiotic to the amino acid or derivative thereof is about 1:1. In another embodiment, the molar ratio of the glycopeptide antibiotic to the amino acid or derivative thereof is about 1:2.

In another embodiment, the present invention relates to a stabilized lipid-glycopeptide antibiotic composition comprising a lipid component, a glycopeptide antibiotic, and an amino acid or derivative thereof, wherein the weight ratio of the total lipid component to the glycopeptide antibiotic is from about 0.1:1 to about 5:1. In a further embodiment, the weight ratio of the lipid component to the glycopeptide antibiotic is about 3:1 or less. In a further embodiment, the weight ratio of the lipid component to the glycopeptide antibiotic is about 1:1 or less. In another embodiment, the weight ratio of the lipid component to the glycopeptide antibiotic is less than 1:1.

In another aspect of the invention, a method for preparing a stabilized lipid-based glycopeptide antibiotic composition is provided. In some embodiments, the glycopeptide antibiotic is vancomycin. In a further embodiment, the method comprises mixing a first stream of a lipid solution containing a lipid in a solvent with a second stream of an aqueous solution comprising a glycopeptide antibiotic (e.g., vancomycin) and an amino acid or a derivative thereof. In one embodiment, the mixing of the two streams comprises infusing, in an in-line fashion, the first stream of the lipid solution with the second stream of the aqueous solution containing the glycopeptide antibiotic and amino acid or derivative thereof. In a further embodiment, the glycopeptide antibiotic and amino acid or derivative thereof is present as a conjugated complex. In a further embodiment, the glycopeptide antibiotic-amino acid complex is entrapped by the lipid when mixed in an in-line fashion. In a further embodiment, the solvent is ethanol. In another embodiment, the first stream of lipid solution is provided at a first flow rate and the second stream of aqueous solution is provided at a second flow rate. In a further embodiment, the first flow rate is about 1 L/min and the second flow rate is about 1.5 L/min.

In one embodiment, the second stream of the aqueous solution comprises the amino acid D-alanine. In another embodiment, the amino acid in the aqueous solution is aspartic acid. In another embodiment, the amino acid derivative in the aqueous solution is bicine. In another embodiment, the amino acid in the aqueous solution is D-glutamic acid. In another embodiment, the amino acid derivative in the aqueous solution is gycylglycine (GLY-GLY). In another

embodiment, the amino acid derivative in the aqueous solution is iminodiacetic acid (IDAA).

In yet another aspect of the invention, a method for treating a bacterial pulmonary infection with a stabilized glycopeptide antibiotic composition is provided. In one embodiment, the method comprises administering to a subject in need thereof a therapeutically effective amount of an amino acid stabilized lipid-based glycopeptide antibiotic composition. In a further embodiment, the glycopeptide antibiotic is vancomycin. In another embodiment, the bacterial pulmonary infection is caused by a Gram-positive bacteria selected from the group consisting of *Staphylococcus, Streptococcus, Enterococcus, Bacillus, Corynebacterium, Nocardia, Clostridium*, and *Listeria*. In a further embodiment, the Gram-positive bacteria are selected from the group consisting of Methicillin-resistant *Staphylococcus aureus* (MRSA), *Escherichia coli, Klebsiella, Enterobacter, Serratia, Haemophilus, Yersinia pesos, Burkholderia pseudomallei, Burkholderia cepacia, Burkholderia gladioli, Burkholderia multivorans, Burkholderia vietnamiensis, Mycobacterium tuberculosis, Mycobacterium avium* complex (MAC)(*Mycobacterium avium* and *Mycobacterium intracellulare*), *Mycobacterium kansasii, Mycobacterium xenopi, Mycobacterium marinum, Mycobacterium mucogenicum, Mycobacgerium gordonae, Mycobacterium ulcerans*, and *Mycobacterium fortuitum* complex (including, but not limited to, *Mycrobacterium fortuitum, Mycrobacterium peregrinum, Mycrobacterium chelonae, Mycrobacterium abscessus*, and *Mycrobacterium mucogenicum.*

In one embodiment, a method for treating a pulmonary disease with a stabilized glycopeptide antibiotic composition is provided. In one embodiment, the pulmonary disease is cystic fibrosis, bronchiectasis, pneumonia, or chronic obstructive pulmonary disease (COPD). In another embodiment, a method for treating osteomyelitis; endocarditis; bronchitis; hepatitis; myocarditis; nephritis; bacteremia; a skin or connective tissue infection including, but not limited to, folliculitis, cellulitis, furuncules, or pymyositis; or a wound or surgical site infection with a stabilized glycopeptide antibiotic composition is provided.

In one embodiment, a composition comprising a stabilized lipid-based glycopeptide antibiotic for use in the therapy of cystic fibrosis, bronchiectasis, pneumonia, or chronic obstructive pulmonary disease (COPD) is provided. In another embodiment, a composition comprising a stabilized lipid-based glycopeptide antibiotic for use in the therapy of osteomyelitis; endocarditis; bronchitis; hepatitis; myocarditis; nephritis; bacteremia; a skin or connective tissue infection including, but not limited to, folliculitis, cellulitis, furuncules, or pymyositis; or a wound or surgical site infection is provided. In one embodiment, the composition for use in the therapy comprises a lipid component, a glycopeptide antibiotic, and an amino acid or a derivative thereof. In a further embodiment, the amino acid or derivative thereof binds to the glycopeptide antibiotic and forms a stabilized glycopeptide antibiotic-amino acid complex. In even a further embodiment, the stabilized glycopeptide antibiotic-amino acid complex is entrapped by, or complexed with, the lipid component. In one embodiment, the antibiotic is vancomycin. In another embodiment, the antibiotic is teicoplanin, telavancin, oritavancin, decaplanin or dalbavancin.

In one embodiment, a composition comprising a stabilized lipid-based glycopeptide antibiotic for use as a medicament in the treatment of cystic fibrosis, bronchiectasis, pneumonia, or chronic obstructive pulmonary disease (COPD) is provided. In another embodiment, a composition comprising a stabilized lipid-based glycopeptide antibiotic for use as a medicament in the treatment of osteomyelitis; endocarditis; bronchitis; hepatitis; myocarditis; nephritis; bacteremia; a skin or connective tissue infection including, but not limited to, folliculitis, cellulitis, furuncules, or pymyositis; or a wound or surgical site infection is provided. In one embodiment, the composition for use as a medicament comprises a lipid component, a glycopeptide antibiotic, and an amino acid or a derivative thereof. In a further embodiment, the amino acid or derivative thereof binds to the glycopeptide antibiotic and forms a stabilized glycopeptide antibiotic-amino acid complex. In even a further embodiment, the stabilized glycopeptide antibiotic-amino acid complex is entrapped by, or complexed with, the lipid component. In one embodiment, the antibiotic is vancomycin. In another embodiment, the antibiotic is teicoplanin, telavancin, oritavancin, decaplanin or dalbavancin.

In one embodiment, a composition comprising a stabilized lipid-based glycopeptide antibiotic for use in the manufacture of a medicament for cystic fibrosis, bronchiectasis, pneumonia, or chronic obstructive pulmonary disease (COPD) is provided. In another embodiment, a composition comprising a stabilized lipid-based glycopeptide antibiotic for use in the manufacture of a medicament for osteomyelitis; endocarditis; bronchitis; hepatitis; myocarditis; nephritis; bacteremia; a skin or connective tissue infection including, but not limited to, folliculitis, cellulitis, furuncules, or pymyositis; or a wound or surgical site infection is provided. In one embodiment, the composition for use in the manufacture of a medicament comprises a lipid component, a glycopeptide antibiotic, and an amino acid or a derivative thereof. In a further embodiment, the amino acid or derivative thereof binds to the glycopeptide antibiotic and forms a stabilized glycopeptide antibiotic-amino acid complex. In even a further embodiment, the stabilized glycopeptide antibiotic-amino acid complex is entrapped by, or complexed with, the lipid component. In one embodiment, the antibiotic is vancomycin. In another embodiment, the antibiotic is teicoplanin, telavancin, oritavancin, decaplanin or dalbavancin.

In another embodiment, the therapeutically effective amount of a stabilized lipid-based glycopeptide antibiotic composition is an amount greater than a minimum inhibitory concentration (MIC) for the bacterial pulmonary infection. In another embodiment, the therapeutically effective amount of a stabilized lipid-based glycopeptide antibiotic composition is a dose of about 50 to 1000 mg/day, about 100 to 500 mg/day, or about 250 to 500 mg/day. In a further embodiment, the dose is about 100 mg/day. In other embodiments, the dose is about 200 mg, about 300 mg, about 400 mg, or about 500 mg per day. In another embodiment, the composition is administered 1 time to 4 times a day. In a further embodiment, the composition is administered once a day, twice a day, three times a day or four times a day. In another embodiment, the composition is administered in a daily treatment cycle for a period of time, or is administered in a cycle of every other day, every third day, every fourth day, every firth day, every 6th day or once a week for a period of time, the period of time being from one week to several months, for example, 1, 2, 3, or 4 weeks, or 1, 2, 3, 4, 5, or 6 months.

In another embodiment, the lipid based glycopeptide antibiotic composition is administered by inhalation as a nebulized spray, powder, or aerosol. In a further embodiment, the stabilized lipid based glycopeptide composition is administered via a nebulizer.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows the structure of vancomycin.

FIG. **2** shows the structural changes during vancomycin degradation to Crystalline Degradation Product-I (CDP-I).

FIG. **3** shows the general structure of four types of natural glycopeptide antibiotics.

FIG. **4** is a typical chromatogram of vancomycin using a ZIC-HILIC column. CDP-I-M, CDP-I-m, and Vancomycin peaks are shown at retention times of 13, 5, 4.9, and 23.9, respectively.

FIG. **5** is a graph of vancomycin degradation over time at pH of 5, 5.5, 6, or 6.5, at 4° C., and at a concentration of 200 mg/mL (top panel) or 20 mg/mL (bottom panel).

FIG. **6** is a graph of vancomycin degradation over time in NaOH (diamonds); NaOH with EtOH (squares); Tris-base (triangle symbols); Tri-Ethanol Amine (TEOA; Xs); or Ethanol Amine (EOA; asterisks) at 4° C. and at pH 6 (top panel) or pH 6.5 (bottom panel).

FIG. **7** is a bar graph of the rate of degradation of vancomycin at 4° C. in the presence of the indicated organic buffers at the indicated pH.

FIG. **8** is a graph of the degradation of vancomycin over time at pH of 5, 5.5, 6, or 6.5, at room temperature (RT), and at a concentration of 200 mg/mL (top panel) or 20 mg/mL (bottom panel).

FIG. **9** is a graph of the degradation of vancomycin over time in the presence of NaOH (diamonds); NaOH with EtOH (squares); Tris-base (triangles); Tri-Ethanol Amine (TEOA; Xs); or Ethanol Amine (EOA; asterisks), at room temperature (RT), and at pH 6 (top panel) or pH 6.5 (bottom panel).

FIG. **10** is a graph of vancomycin degradation rates at room temperature (RT) in the presence of the indicated organic buffers and at the indicated pH.

FIG. **11** is a graph of vancomycin degradation over time (top panel) and vancomycin degradation rates (bottom panel) in vancomycin compositions with the indicated amino acid or derivative thereof at 4° C. Amino acids were added on a mole per mole basis unless otherwise stated. In the top panel, the vancomycin compositions comprise: control (NaOH alone, pH 5, dark diamonds); bALA (dark squares); ALA (dark triangles); GABA, pH5.5 (light circles); GLY (dark line with X symbols); D-ALA (dark line with asterisk symbols); 3-ABA (dark circles); GLU (dark line with plus symbols); G-GLU (dark line with no symbols); ASP (medium line with no symbols); D-ASP (light diamonds); bicine (light squares); tricine (light triangles); sarcosine (light line with Xs); IDAA (light line with asterisks); GLY-GLY (light line with plus symbols); GLU, pH5 (2:1 ratio of GLU-vancomycin, pH5; lighter line with no symbols); and GLU, pH5.5 (2:1 ratio of GLU-vancomycin, pH5.5; lightest line with no symbols).

FIG. **12** is a graph of vancomycin degradation over time (top panel) and vancomycin degradation rates (bottom panel) in vancomycin compositions with the indicated amino acid or derivative thereof at RT. Amino acids were added on a mole per mole base unless otherwise stated. In the top panel, the vancomycin compositions comprise: control (NaOH alone, pH 5, light line with plus symbol); bALA (dark diamonds); ALA (dark squares); GABA, pH5.5 (dark triangles); GLY (light circles); D-ALA (dark line with X symbols); 3-ABA (dark line with asterisk symbols); GLUt (dark circles); G-GLUt (dark line with plus symbols); ASP (dark line with no symbols); D-ASP (medium line with no symbols); bicine (light diamonds); tricine (light squares); sarcosine (light triangles); IDAA (light line with asterisk symbols); GLY-GLY (light line with plus symbols); GLU pH5 (2:1 ratio of GLU-vancomycin, pH5; light line with X symbols); and GLU pH5.5 (2:1 ratio of GLU-vancomycin, pH5.5; light line with asterisk symbols).

FIG. **13** shows an Arrhenius plot for vancomycin degradation rates based on Table 14. Vancomycin in NaOH at pH 5.5 (diamonds); Bicine-vancomycin in a 2:1 ratio (squares); GLY-GLY-vancomycin in a 1:1 ratio (triangles); GLY-GLY-vancomycin in a 1.5:1 ratio (Xs); GLY-GLY-vancomycin in a 2:1 ratio (asterisks); and GLU-vancomycin in a 2:1 ratio (circles).

FIG. **14** shows a liposomal vancomycin infusion diagram (three stream infusion process).

FIG. **15** is a graph of the stability over time of liposomal vancomycin-GLU compositions at 4° C. The batches of liposomal vancomycin compositions tested are those shown in Table 15 (i.e., diamonds correspond to L-VGLU0330, comprising GLU and DPPC/cholesterol; squares correspond to L-VDGLU0405, comprising D-GLU and DPPC/DPPG/cholesterol; and triangles correspond to LPG-VGLU0408, comprising GLU and DPPC/cholesterol).

FIG. **16** is a graph of the stability over time of liposomal vancomycin-GLU compositions at RT. The batches of liposomal vancomycin compositions tested are those shown in Table 15 (i.e., diamonds correspond to L-VGLU0330, comprising GLU and DPPC/cholesterol; squares correspond to L-VDGLU0405, comprising D-GLU and DPPC/DPPG/cholesterol; and triangles correspond to LPG-VGLU0408, comprising GLU and DPPC/cholesterol).

FIG. **17** is a graph of stability over time of liposomal vancomycin-GLU compositions at 4° C. The batches of liposomal vancomycin compositions tested are those shown in Table 15 (i.e., diamonds correspond to L-VGLU0330, comprising GLU and DPPC/cholesterol; and squares correspond to L-VDGLU0405, comprising D-GLU and DPPC/DPPG/cholesterol).

FIG. **18** is a graph of stability over time of liposomal vancomycin-GLU compositions at RT. The batches of liposomal vancomycin compositions tested are those shown in Table 15 (i.e., diamonds correspond to L-VGLU0330, comprising GLU and DPPC/cholesterol; and squares correspond to L-VDGLU0405, comprising D-GLU and DPPC/DPPG/cholesterol).

DETAILED DESCRIPTION OF THE INVENTION

The abbreviations used herein for amino acids are those abbreviations which are conventionally used: A=Ala=Alanine; R=Arg=Arginine; N=Asn=Asparagine; D=Asp=Aspartic acid; C=Cys=Cysteine; Q=Gln=Glutamine; E=Glu=Gutamic acid; G=Gly=Glycine; H=His=Histidine; =Ile=Isoleucine; L=Leu=Leucine; K=Lys=Lysine; M=Met=Methionine; F=Phe=Phenylalanine; P=Pro=Proline; S=Ser=Serine; T=Thr=Threonine; W=Trp=Tryptophan; Y=Tyr=Tyrosine; V=Val=Valine. The amino acids in the compositions provided herein are L- or D-amino acids. In one embodiment, a synthetic amino acid is used in the compositions provided herein. In one embodiment, the amino acid increases the half-life, efficacy and/or bioavailability of the glycopeptide antibiotic in the composition. In a further embodiment, the glycopeptide antibiotic is vancomycin.

The term "amino acid derivative" as used herein refers to a moiety having both an amine functional group, either as NH_2, NHR, or NR_2, and a carboxylic acid functional group, either as NH_2, NHR, or NR_2, and a carboxylic acid func-

tional group. The term "amino acids" encompasses both natural and unnatural amino acids, and can refer to alpha-amino acids, beta-amino acids, or gamma amino acids. Unless specified otherwise, an amino acid structure referred to herein can be any possible stereoisomer, e.g., the D or L enantiomer. In some embodiments, the amino acid derivatives are short peptides, including dipeptides and tripeptides. Exemplary amino acids and amino acid derivatives suitable for the invention include alanine (ALA), D-alanine (D-ALA), alanine-alanine (ALA-ALA), beta-alanine (bALA), alanine-beta-alanine (ALA-bALA), 3-aminobutanoic acid (3-ABA), gamma-aminobutyric acid (GABA), glutamic acid (GLU or GLUt), D-glutamic acid (D-GLU), glycine (GLY), glycylglycine (GLY-GLY), glycine-alanine (GLY-ALA), alanine-glycine (ALA-GLY), aspartic acid (ASP), D-aspartic acid (D-ASP), lysine-alanine-alanine (LYS-ALA-ALA), L-Lysine-D-alanine-D-alanine (L-LYS-D-ALA-D-ALA), bicine, tricine, sarcosine, and iminodiacetic acid (IDAA). Amino acids and derivatives thereof can be synthesized according to known techniques, or can be purchased from suppliers, e.g., Sigma-Aldrich (Milwaukee, Wis.).

The term "administering" includes in vive administration, as well as administration directly to tissue ex vivo. Generally, compositions may be administered systemically either orally, buccally, parenterally, topically, by inhalation or insufflation (i.e., through the mouth or through the nose), or rectally in dosage unit formulations containing conventional nontoxic pharmaceutically acceptable carriers, adjuvants, and vehicles as desired, or may be locally administered by means such as, but not limited to, injection, implantation, grafting, topical application, or parenterally.

In one embodiment, the composition of the invention is administered via inhalation. In a further embodiment, the composition of the invention is administered via nebulization, vaporization, aerosolization, or dry powder inhalation. A "nebulizer" or an "aerosol generator" in one embodiment, is used to administer the compositions of the present invention to a patient in need thereof. A "nebulizer" or an "aerosol generator" is a device that converts a liquid into an aerosol of a size that can be inhaled into the respiratory tract. Pneumonic, ultrasonic, electronic nebulizers, e.g., passive electronic mesh nebulizers, active electronic mesh nebulizers and vibrating mesh nebulizers are amenable for use with the invention if the particular nebulizer emits an aerosol with the required properties, and at the required output rate.

The process of pneumatically converting a bulk liquid into small droplets is called atomization. The operation of a pneumatic nebulizer requires a pressurized gas supply as the driving force for liquid atomization. Ultrasonic nebulizers use electricity introduced by a piezoelectric element in the liquid reservoir to convert a liquid into respirable droplets. Various types of nebulizers are described in Respiratory Care, Vol. 45, No. 6, pp. 609-622 (2000), the disclosure of which is incorporated herein by reference in its entirety. The terms "nebulizer" and "aerosol generator" are used interchangeably throughout the specification. "Inhalation device", "inhalation system" and "atomizer" are also used in the literature interchangeably with the terms "nebulizer" and "aerosol generator."

"Mass median aerodynamic diameter" or "MMAD" is normalized regarding the aerodynamic separation of aqua aerosol droplets and is determined by impactor measurements, e.g., the Anderson Cascade Impactor (ACI) or the Next Generation Impactor (NGI). The gas flow rate, in one embodiment, is 28 Liter per minute by the Anderson Cascade Impactor (ACI) and 15 liter per minute by the Next Generation Impactor (NGI). "Geometric standard deviation" or "GSD" is a measure of the spread of an aerodynamic particle size distribution.

In one embodiment, the MMAD of the aerosol of the pharmaceutical composition is less than about 4.9 m, less than about 4.5 μm, less than about 4.3 μm, less than about 4.2 μm, less than about 4.1 μm, less than about 4.0 μm or less than about 3.5 m, as measured by the ACI at a gas flow rate of about 28 L/minute, or by the Next Generation Impactor (NGI) at a gas flow rate of about 15 L/minute.

In one embodiment, the MMAD of the aerosol of the pharmaceutical composition is about 1.0 μm to about 4.2 μm, about 3.2 μm to about 4.2 μm, about 3.4 μm to about 4.0 μm, about 3.5 μm to about 4.0 μm or about 3.5 m to about 4.2 μm, as measured by the ACI. In one embodiment, the MMAD of the aerosol of the pharmaceutical composition is about 2.0 μm to about 4.9 μm, about 4.4 μm to about 4.9 μm, about 4.5 μm to about 4.9 μm, or about 4.6 m to about 4.9 μm, as measured by the NGI.

"Fine particle fraction" or "FPF", as used herein, refers to the fraction of the aerosol having a particle size less than 5 μm in diameter, as measured by cascade impaction. FPF is usually expressed as a percentage.

In one embodiment, the fine particle fraction (FPF) of the composition post nebulization, i.e., the aerosolized pharmaceutical composition, is about 50%, or about 55%, or about 60%, or about 65%, or about 70%, or about 75%, as measured by NGI or ACI. In a further embodiment, the FPF of the aerosol is greater than or equal to about 64%, as measured by the ACI, greater than or equal to about 70%, as measured by the ACI, greater than or equal to about 51%, as measured by the NGI, or greater than or equal to about 60%, as measured by the NGI.

In one embodiment, the FPF of the aerosolized composition is greater than or equal to 50%, greater than or equal to 60%, greater than or equal to 70%, greater than or equal to 80%, greater than or equal to 90%, greater than or equal to 95%, greater than or equal to 97.5%, or greater than or equal to 99%, as measured by cascade impaction. In a further embodiment, the composition comprises vancomycin and a liposome.

The terms "carrier," "excipient," and "vehicle" are used interchangeably herein and refer to materials suitable for formulation and administration of the pharmaceutically acceptable compositions described herein. Carriers useful herein include any materials known in the art which are nontoxic, do not interact with other components, do not cause significant irritation to an organism, and do not abrogate the biological activity and properties of the compound of the composition of the described invention. Carriers must be of sufficiently high purity and of sufficiently low toxicity to render them suitable for administration to the mammal being treated. The term "pharmaceutically acceptable salt" means those salts which are, within the scope of sound medical judgment, suitable for use in contact with the tissues of humans and lower animals without undue toxicity, irritation, allergic response and the like and are commensurate with a reasonable benefit/risk ratio. The term "coacervation" refers to a separation into two liquid phases in colloidal systems. The phase more concentrated in the colloid component (active agent) is referred herein as the "coacervate." and the other phase is the equilibrium solution. Coacervate formation leads to higher internal active agent concentrations relative to external active agent concentrations and lower lipid to drug ratios.

The term "colloidal" refers to being of or relating to or having the properties of a colloid, meaning aggregates of

atoms or molecules in a finely divided state (submicroscopic), dispersed in a gaseous, liquid or solid medium, and resisting sedimentation, diffusion, and filtration. A solution of macromolecules is a simple and the most common colloid system. Small molecules also can form association colloids as reversible aggregates. An association colloid is a reversible chemical combination due to weak chemical bonding forces wherein up to hundreds of molecules or ions aggregate to form colloidal structures with sizes of from about 1 to about 2000 nanometers or larger.

The term "effective amount" refers to the amount necessary or sufficient to realize a desired biologic effect.

The term "hydrophilic" refers to a material or substance having an affinity for polar substances, such as water. The term "lipophilic" refers to preferring or possessing an affinity for a non-polar environment compared to a polar or aqueous environment.

The term "solvent" as used herein refers to a substance capable of dissolving another substance ("a solute") to form a solution.

"Solvent infusion" is a process that includes dissolving one or more lipids in a small, minimal, amount of a process compatible solvent to form a lipid suspension or solution and then adding the solution to an aqueous medium containing bioactive agents. Typically a process compatible solvent is one that can be washed away in an aqueous process such as dialysis. The composition that is cool/warm cycled in one embodiment, is formed by solvent infusion. In one embodiment, the solvent is an alcohol. In a further embodiment, the alcohol is ethanol. "Ethanol infusion" is a type of solvent infusion, and is a process that includes dissolving one or more lipids in a small, minimal, amount of ethanol to form a lipid solution and then adding the solution to an aqueous medium containing bioactive agents. A "small" amount of solvent is an amount compatible with forming liposomes or lipid complexes in the infusion process. The term "solvent infusion" also includes an in-line infusion process where two streams of formulation components are mixed in-line.

The term "symptom" as used herein refers to a phenomenon that arises from and accompanies a particular disease or disorder and serves as an indication of it.

The term "therapeutic effect" refers to a consequence of treatment, the results of which are judged to be desirable and beneficial. A therapeutic effect may include, directly or indirectly, the arrest, reduction, or elimination of a disease manifestation. A therapeutic effect may also include, directly or indirectly, the arrest reduction or elimination of the progression of a disease or condition, or delay in the recurrence of a disease or condition.

The term "treat" or "treating" includes abrogating, substantially inhibiting, slowing or reversing the progression of a disease, condition or disorder, substantially ameliorating clinical or esthetical symptoms of a condition, substantially preventing the appearance of clinical or esthetical symptoms of a disease, condition, or disorder, and protecting from harmful or annoying symptoms. The term "treat" or "treating" as used herein further refers to accomplishing one or more of the following: (a) reducing the severity of the disorder; (b) limiting development of symptoms characteristic of the disorder(s) being treated; (c) limiting worsening of symptoms characteristic of the disorder(s) being treated; (d) limiting recurrence of the disorder(s) in patients that have previously had the disorder(s); and (e) limiting recurrence of symptoms in patients that were previously symptomatic for the disorder(s).

The term "minimum inhibitory concentration" or "MIC" as used herein refers to the lowest concentration of an antimicrobial agent that will inhibit visible growth of a microorganism after overnight incubation (this period is extended for organisms such as anaerobes, which require prolonged incubation for growth). "MIC_{10}," "MIC_{50}," or "MIC_{90}," as used herein, refer to the concentration of an antimicrobial agent that will inhibit growth of the microorganism by 10%, 50%, or 90%, respectively. When no subscript is used, MIC, it is assumed that it is the MIC_{50} that is being discussed. The range of antibiotic concentrations used for determining MICs is accepted universally to be in doubling dilution steps up and down from 1 mg/mL as required (Andrews, J., J. Antimicrob. Chemother., 2001, 48, (Suppl. 1), 5-16, incorporated herein in its entirety).

In one aspect of the invention, a stabilized lipid-based glycopeptide antibiotic composition is provided, comprising a lipid component, a glycopeptide antibiotic and an amino acid or a derivative thereof, wherein the amino acid or derivative thereof is conjugated to the glycopeptide antibiotic. The conjugation of the amino acid or derivative thereof to the glycopeptide antibiotic forms a stabilized glycopeptide antibiotic-amino acid complex. In one embodiment, the glycopeptide antibiotic-amino acid complex is associated with the lipid. For example, in one embodiment, the lipid is conjugated (e.g., bound) to the glycopeptide antibiotic-amino acid complex. In one embodiment, the glycopeptide antibiotic-amino acid complex is entrapped by the lipid component, for example, where the lipid is in the form of a liposome.

The composition described herein, in one embodiment, comprises a liposome, proliposome, lipid colloidal dispersion, micelle, inverted micelle, discoid structure, or a combination thereof. In a further embodiment, the composition comprises a liposome. The glycopeptide antibiotic and amino acid or derivative thereof, in one embodiment, is complexed to the liposome, or encapsulated by the liposome.

"Encapsulated" and "encapsulating" are used to refer to adsorption of active agents on the surface of a lipid based formulation, an association of active agents in the interstitial region of bilayers or between two monolayers, capture of active agents in the space between two bilayers, or capture of active agents in the space surrounded by the inner most bilayer or monolayer.

The lipids used in the compositions of the present invention can be synthetic, semi-synthetic or naturally-occurring lipids, including phospholipids such as phosphatidylglycerols (PGs), phosphatidic acids (PAs), phosphotidylcholines (PCs), phosphatidylinositols (PIs), and phosphatidylserines (PSs); fatty acids; ammonium salts of fatty acids; tocopherols; tocopherol derivatives; sterols; sterol derivatives; and glycerides. The fatty acids have carbon chain lengths of from 12 to 26 carbon atoms, which are either saturated or unsaturated. The lipids can be anionic, cationic, or neutral, where neutral includes both uncharged lipids and zwitterionic lipids. According to one embodiment, the lipid component is substantially free of anionic lipids. According to another embodiment, the lipid component comprises only neutral lipids. According to another embodiment, the lipid component is free of anionic lipids.

According to another embodiment, the lipid in the composition comprises a phospholipid. Phospholipids are comprised of ester linkages of fatty acids in the 2 and 3 of glycerol positions containing chains of 12 to 26 carbon atoms, and different head groups in the 1 position of glycerol that include choline, glycerol, inositol, serine, ethanolamine,

as well as the corresponding phosphatidic acids. The chains on these fatty acids can be saturated or unsaturated, and the phospholipid can be made up of fatty acids of different chain lengths and different degrees of unsaturation.

Almost all biologically occurring phospholipids are constructed from combinations of apolar and "backbone" moieties: a glycerol (or other polyol) moiety substituted with one or two acyl or alkyl chains or an N-acylated sphingoid base (i.e., a ceramide). Typically, the hydroxyl group at position 3 of the glycerol is esterified to phosphoric acid, whereas the hydroxyl groups at positions 1 and 2 of the glycerol are esterified with long chain fatty acids, which provide the lipid characteristic of the phospholipid. One of the remaining oxygen groups of phosphoric acid can be esterified further to a variety of organic molecules including glycerol, choline, ethanolamine, serine, and inositol. The phosphate moiety along with the attached alcohol represent the head group of phospholipid. The fatty acid part of a phospholipid is important in that differences in the fatty acid part can change the characteristics of the phospholipid. Fatty acids can differ in the length of their carbon chain (e.g., short, medium, or long chain) and in the level of saturation.

In one embodiment, one or more phospholipids are present in the composition of the present invention. The most abundant phospholipid in plants and animals is phosphatidylcholine (also known as lecithin) and phosphatidylethanolamine, which constitute the major structural part of most biological membranes. In phosphatidylserine, the phosphoric acid moiety is esterified to the hydroxyl group of the amino acid L-serine, whereas, in phosphatidylinositol, the phosphoric acid moiety is esterified to the cyclic sugar alcohol inositol. The other type of phospholipid found in human is phosphatidylglyccrol, which is a natural component of the lung surfactant. In the case of phosphatidylglycerol, the alcohol that is esterified to the phosphate moiety is glycerol instead of phosphoric acid (Vemuri, S. and Rhodes, C., 1995, Pharmaceutica Acta Helvetiae 70: 95-111).

Examples of phospholipids that can be used in the composition of the present invention include, but are not limited to, phosphatidylcholine (PC), phosphatidylglycerol (PG), phosphatidylinositol (PI), phosphatidylserine (PS), phosphatidylethanolamine (PE), phosphatidic acid (PA), egg phosphatidylcholine (EPC), egg phosphatidylglycerol (EPG), egg phosphatidylinositol (EPI), egg phosphatidylserine (EPS), phosphatidylethanolamine (EPE), phosphatidic acid (EPA), soy phosphatidylcholine (SPC), soy phosphatidylglycerol (SPG), soy phosphatidylserine (SPS), soy phosphatidylinositol (SPI), soy phosphatidylethanolamine (SPE), soy phosphatidic acid (SPA), hydrogenated egg phosphatidylcholine (HEPC), hydrogenated egg phosphatidylglycerol (HEPG), hydrogenated egg phosphatidylinositol (HEPI), hydrogenated egg phosphatidylserine (HEPS), hydrogenated phosphatidylethanolamine (HEPE), hydrogenated phosphatidic acid (HEPA), hydrogenated soy phosphatidylcholine (HSPC), hydrogenated soy phosphatidylglycerol (HSPG), hydrogenated soy phosphatidylserine (HSPS), hydrogenated soy phosphatidylinositol (HSPI), hydrogenated soy phosphatidylethanolamine (HSPE), hydrogenated soy phosphatidic acid (HSPA), dipalmitoylphosphatidylcholine (DPPC), dimyristoylphosphatidylcholine (DMPC), dimyristoylphosphatidylglycerol (DMPG), dipalmitoylphosphatidylglycerol (DPPG), distearoylphosphatidylcholine (DSPC), distearoylphosphatidylglycerol (DSPG), dioleoylphosphatidylcholine (DOPC), dioleylphosphatidylethanolamine (DOPE), palmitoylstearoylphosphatidyl-choline (PSPC), palmitoylstearolphosphatidylglycerol (PSPG), mono-oleoyl-phosphatidylethanolamine (MOPE), tocopherol, tocopherol hemisuccinate, cholesterol sulfate, cholesteryl hemisuccinate, cholesterol derivatives, ammonium salts of fatty acids, ammonium salts of phospholipids, ammonium salts of glycerides, myristylamine, palmitylamine, laurylamine, stearylamine, dilauroyl ethylphosphocholine (DLEP), dimyristoyl ethylphosphocholine (DMEP), dipalmitoyl ethylphosphocholine (DPEP) and distearoyl ethylphosphocholine (DSEP), N-(2,3-di-(9-(Z)-octadecenyloxy)-prop-1-yl-N,N,N-trimethylammonium chloride (DOTMA), 1,2-bis(oleoyloxy)-3-(trimethylammonio) propane (DOTAP), distearoylphosphatidylglycerol (DSPG), dimyristoylphosphatidylacid (DMPA), dipalmitoylphosphatidylacid (DPPA), distearoylphosphatidylacid (DSPA), dimyristoylphosphatidylinositol (DMPI), dipalmitoylphosphatidylinositol (DPPI), distearoylphospatidylinositol (DSPI), dimyristoylphosphatidylserine (DMPS), dipalmitoylphosphatidylserine (DPPS), distearoylphosphatidylserine (DSPS), or a mixture thereof.

In one embodiment, the composition comprises DPPC and/or DPPG.

According to another embodiment, the phospholipid used in the composition of the present invention is a mixed phospholipid, including, but not limited to, palmitoylstearoylphosphatidylcholine (PSPC) and palmitoylstearoylphosphatidylglycerol (PSPG)), triacylglycerol, diacylglycerol, ceramide, sphingosine, sphingomyelin, and single acylated phospholipids, such as mono-oleoyl-phosphatidylethanol amine (MOPE).

In one embodiment, the lipid component of the present invention comprises one or more sterols. In a further embodiment, the sterol is cholesterol. The sterols, of which cholesterol and its derivatives are the most widely studied in mammalian systems, constitute a component of membrane lipids, along with the glycerophospholipids and sphingomyelins (Bach et al., 2003, Biochem. Biophys. Acta., 1610: 187-197). Sterol lipids are subdivided primarily on the basis of biological function. There are many examples of unique sterols from plant, fungal, and marine sources that are designated as distinct subclasses of sterols. These are subdivided on the basis of the number of carbons in the core skeleton. The C_{18} sterols include the estrogen family, whereas the C_{19} sterols comprise the androgens, such as testosterone and androsterone. The C_{21} subclass, containing a two carbon side chain at the C_{17} position, includes the progestogens as well as the glucocorticoids and mineralocorticoids. The secosterols, comprising various forms of vitamin D, are characterized by cleavage of the B ring of the core structure, hence the "seco" prefix. Additional classes within the sterols category are the bile acids, which in mammals are primarily derivatives of cholan-24-oic acid synthesized from cholesterol in the liver and their conjugates (sulfuric acid, taurine, glycine, glucuronic acid, and others) (Fahy, E. et al., 2005, J. Lipid Res., 46:839-861). Each of the publications referenced in this paragraph are incorporated by reference herein in their entireties.

As provided herein, in one embodiment, the lipid component of the present invention comprises cholesterol. Cholesterol is found in animal membranes and has been used in the preparation of liposomes to improve bilayer characteristics of the liposomes. The cholesterol molecule orients itself among the phospholipid molecules with its hydroxyl group facing towards the water phase, the tricyclic ring sandwiched between the first few carbons of the fatty acyl chains, into the hydrocarbon core of the bilayer (Vermuri, S. and Rhode, C., Pharmacecutica Acta Helvetiae, 1995, 70: 95-111). Cholesterol improves the fluidity of the bilayer membrane, reduces the permeability of water soluble mol-

ecules through the membrane, and improves the stability of the bilayer membrane in the presence of biological fluids such as blood/plasma. Liposomes without cholesterol tend to react with blood proteins, such as albumin, m-transferrin, and macroglobulin, which tend to destabilize the liposomes and reduce the utility of liposomes as drug delivery systems.

According to another embodiment, the lipid component consists essentially of a phosphatidylcholine. According to another embodiment, the lipid component consists essentially of dipalmitoylphosphatidylcholine (DPPC). According to another embodiment, the lipid component consists essentially of palmitoyloleoylphosphatidylcholine (POPC).

According to another embodiment, the lipid component consists essentially of phosphatidylglycerol. According to another embodiment, the lipid component consists essentially of 1-palmitoyl-2-oleoyl-sn-glycero-3-phosphoglycerol (POPG).

According to one embodiment, the stabilized glycopeptide antibiotic is entrapped by or complexed with the lipid component. In one embodiment, the lipid component is in the form of a liposome. Liposomes are completely closed lipid bilayer membranes containing an entrapped aqueous volume. It has been reported that liposomes spontaneously form when phospholipids are dispersed in aqueous medium (Bangham et al., 1974, In Korn, E. D. ed., Methods in Membrane Biology, Vol. 1. Plenum Press, New York, pp. 1-68, incorporated by reference herein in its entirety). The hydrophilic interaction of the lipid head groups with water results in the formation of vesicles composed of simple lipid bilayers that resemble biological membranes, in the form of a spherical shell. Liposomes can be unilamellar vesicles (possessing a single membrane bilayer) or multilamellar vesicles (onion-like structures characterized by multiple membrane bilayers, each separated from the next by an aqueous layer), or a combination thereof. The bilayer is composed of two lipid monolayers having a hydrophobic "tail" region and a hydrophilic "head" region. The structure of the membrane bilayer is such that the hydrophobic (nonpolar) "tails" of the lipid monolayers orient toward the center of the bilayer while the hydrophilic "heads" orient towards the aqueous phase.

Depending on the method of preparation, liposomes of the invention vary widely in size (e.g., 0.02-10 μm) and in the number of lamellae (i.e., number of bilayers present within a liposome). Typically, liposomes are classified into three categories on the basis of their size and lamellarity: small unilamellar vesicles (SUVs), small oligolamellar vesicles (OLVs), large unilamellar vesicles (LUVs), and multilamellar vesicles (MLVs). More detailed classification based on structure is shown in Table 1. (Smad, A. et al., Current Drug Delivery, 2007, 4: 297-305, incorporated by reference herein in its entirety).

According to one embodiment, the pharmaceutical composition comprises a liposome or a plurality of liposomes. The glycopeptides antibiotic and amino acid (or derivative thereof) is entrapped by the liposome (or plurality of liposomes), complexed to the liposome (or plurality of liposomes), for example, complexed to the bilayer of the liposome, or a combination of entrapped and complexed.

In one embodiment, the liposome is a unilamellar vesicle (UV). According to further embodiment, the liposome is a small unilamellar vesicle (SUV), a medium unilamellar vesicle (MUV), a large unilamellar vesicle (LUV) or a giant unilamellar vesicle (GUV). According to another embodiment, the liposome is an oligolamellar vesicle (OV). According to another embodiment, the plurality of liposomes comprise liposome is a multilamellar vesicle (MV) and unilamellar vesicles. According to another embodiment, the liposome comprises a multilamellar vesicle (MV).

TABLE 1

Vesicle Types with their Size and Number of Lipid layers

Vesicle Type	Abbre-viation	Diameter	Number of Lipid Bilaver
Unilamellar vesicle	UV	All size ranges	One
Small Unilamellar vesicle	SUV	20-100 nm	One
Medium Unilamellar vesicle	MUV	>100 nm	One
Large Unilamellar vesicle	LUV	>100 nm	One
Giant Unilamenar vesicle	GUV	>1 μm	One
Oligolamellar vesicle	OLV	0.1-1 μm	Approximately 5
Multilamellar vesicle	MLV	>1 μm	5-25
Multi vesicular vesicle	MV	>1 μm	Multi compartmental structure

According to one embodiment, the liposome has a mean particle size of about 0.05 to about 10 microns, 0.05 to about 1 microns, 0.05 to about 0.5 microns, about 0.1 to about 5.0 microns, about 0.1 to about 3.0 microns, about 0.1 to about 2.0 microns, about 0.1 to about 1.0 microns, about 0.1 to about 0.5 microns, about 0.1 to about 0.4 microns, about 0.1 to about 0.3 microns, or about 0.1 to about 0.2 microns. In another embodiment, the mean particular size of the liposome is about 1.0 microns or less, about 0.9 microns or less, about 0.8 microns or less, about 0.7 microns or less, about 0.6 microns or less, about 0.5 microns or less, about 0.4 microns or less, about 0.3 microns or less, or about 0.2 microns or less.

According to one embodiment, the lipid component of the present invention is in the form of a micelle or plurality of micelles. Many surfactants can assemble in a bulk solution into aggregates or micelles. The concentration at which surfactants begin to form micelles is known as the "critical micelle concentration" ("CMC"). The lipid in the compositions provided herein, in one embodiment, is a surfactant with an extremely low CMC.

According to another embodiment, the stabilized glycopeptide antibiotic is entrapped by a lipid clathrate. A lipid clathrate is a three-dimensional, cage-like structure employing one or more lipids wherein the structure entraps a bioactive agent. Such clathrates are included in the scope of the present invention.

According to anther embodiment, the stabilized glycopeptide antibiotic is entrapped by a proliposome or plurality of proliposomes. Proliposomes are formulations that can become liposomes or lipid complexes upon coming in contact with an aqueous liquid, and include for example dry powders. Agitation or other mixing may be necessary. Such proliposomes are included in the scope of the present invention.

The tissue distribution and clearance kinetics of drug-containing liposomes are known to be affected by lipid composition and surface charge (Juliano and Stamp, Biochem. Biophys. Res. Commun., 1975, 63: 651, incorporated by reference herein in its entirety). There are a number of synthetic phospholipids available and utilized in the preparation of liposomes. Gangliosides, a class of sphingolipids, sometimes are included in liposome formulations to provide a layer of surface charged groups, which provide longer circulating liposomes in the blood stream. Such liposome formulations comprising sphingolipids are included in the scope of the present invention.

The composition of the present invention includes one or more glycopeptides antibiotics. Glycopeptide antibiotics, including vancomycin and teicoplanin, are large, rigid molecules that inhibit a late stage in bacterial cell wall peptidoglycan synthesis. Glycopeptides are characterized by a multi-ring peptide core containing six peptide linkages, an unusual triphenyl ether moiety, and sugars attached at various sites. Over 30 antibiotics designated as belonging to the glycopeptide class have been reported. Among the glycopeptides, vancomycin and teicoplanin are used widely and are recommended for treatment of severe infections, especially those caused by multiple-drug-resistant Gram-positive pathogens. The glycopeptide avoparcin has been introduced as a growth promoter in animal husbandry in the past, and represents the main reservoir for the VanA type of vancomycin resistance in *enterococci*. Semisynthetic derivatives of vancomycin and teicoplanin, lipoglycopeptides, showed an extended spectrum of activity against multi-resistant and partly vancomycin-resistant bacteria (Reynolds P., Eur. J. Clin Microbiol Infect Dis, 1989, 8: 943-950; Renolds, 1989; Nordmann et al., Curr. Opin. Microbiol., 2007, 10: 436-440). Each of the publications referenced in this paragraph are incorporated by reference herein in their entireties.

Glycopeptide antibiotics are active against Gram-positive organisms and a few anaerobes. The main indications for glycopeptide antibiotics are infections caused by beta-lactamase-producing *Staphylococcus aureus* (for which beta-lactamase-resistant penicillins, cephalosporins, and combinations of penicillins with inhibitors of beta-lactamases proved safer alternatives), and colitis caused by *Clostridium difficile*. The emergence and rapid spread of methicillin-resistant *S. aureus* (MRSA) strains, which were resistant not only to all beta-lactams but also to the main antibiotic classes, renewed the interest in vancomycin and pushed teicophalnin, another natural glycopeptide, onto the market. Teicoplanin is comparable to vancomycin in terms of activity, but presents pharmacokinetic advantages, such as prolonged half-life, allowing for a once-daily administration (van Bambeke F., Curr. Opin. Pharm., 4(5):471-478).

Prior to 1984, the glycopeptide class included few members beyond vancomycin, teicoplanin, ristocetin, and avoparcin. With the acknowledgement of the threat posed by antibiotic resistance, the class expanded to include thousands of natural and semi-synthetic compounds. Structural studies on these compounds have clarified the biological mode of action and have served as a basis for reasonable predictions regarding structure-activity relationships.

The structures of hundreds of natural and semisynthetic glycopeptides have been determined. These structures are highly related and fall within five structural subtypes, I-V. Of the varying structural subtypes, type I structures contain aliphatic chains, whereas types II, III, and IV include aromatic side chains within these amino acids. Unlike types I and II, types III and IV contain an extra F-O-G ring system. Type IV compounds have, in addition, a long fatty-acid chain attached to the sugar moiety. Structures of type V, such as complestatin, chloropeptin I, and kistamincin A and B, contain the characteristic tryptophan moiety linked to the central amino acid. The structures of the subtypes are known in the art and described in Nicolaou et al. (Angew. Chem. Int. Ed., 1999, 38: 2096-2152, incorporated by reference herein in its entirety), the entire contents of which are incorporated herein by reference. Compounds of each of the structural subtypes mentioned above can be used in the compositions described herein.

Biochemical studies of the mode of action of glycopeptide antibiotics indicate that these substances inhibit cell wall peptidoglycan synthesis. Treatment of intact bacteria with vancomycin at concentrations close to the minimum inhibitory concentration (MIC) resulted in the accumulation of cytoplasmically located wall precursors (Reynolds et al., Biochimica et Biophysica Acta. 1961, 52: 403-405; Jordan. Biochemical and Biophysical Research Communications, 1961, 6: 167-170), suggesting that glycopeptides interfered with a late stage in the assembly of the peptidoglycan. Vancomycin, and other glycopeptides, cannot penetrate the cytoplasmic membrane (Perkins et al., Biochemical Journal, 1970, 116: 83-92), and thus the critical transglycosylation reaction is the first to be inhibited (Jordan and Reynolds: Vancomycin. In: Corcoran, J. W., Hahn, F. E. (ed.): Antibiotics, volume III. Mechanism of action of antimicrobial and antitumor agents. Springer-Verlag, Berlin, 1974, 704-718). Inhibition of this reaction results in the accumulation of lipid intermediates in the biosynthetic pathway and of UDP-MurNAc-pentapeptide in the cytoplasm. Each of the publications referenced in this paragraph are incorporated by reference herein in their entireties.

Glycopeptide antibiotics tend to be unstable in solution, resulting in a loss of activity. Stability of glycopeptides can be enhanced using one of the two peptides Ac-D-Ala-D-Ala and Di-Ac-L-Lys-D-Ala-D-Ala (Harris et al., 1985, J. Antibiot, 38(1):51-7, incorporated by reference herein in its entirety). However, a need exists for more improvement in stability of glycopeptide antibiotics, preferably in a cost-effective manner. Unexpectedly, the compositions of the present invention, comprising a glycopeptide antibiotic, an amino acid or derivative thereof, and a lipid component, exhibited superior stability compared glycopeptide antibiotic compositions that are not lipid-based and/or do not comprise an amino acid or derivative thereof.

A representative number of glycopeptides that can be used in the compositions of the present invention are provided in Table 2. The antibiotic complexes are listed in alphabetical order along with the structure type producing organism. These metabolites are elaborated by a diverse group of actinomycetes ranging from the more prevalent *Streptomyces* species to the relatively rare genera of *Streptosporangium* and *Saccharomonospora*. The less common *Actionplanes* and *Amycolatopsis* account for almost half of the producing organisms (Nagarajan, R., Glycopeotide Antibiotics, CRC Press, 1994, incorporated by reference herein in its entirety).

TABLE 2

Glycopeptide Antibiotics and Producing Organisms

Antibiotic	Type	Producing Organism
A477	ND	*Actinoplanes* sp. NRRL 3884
A35512	III	*Streptomyces candidus* NRRL 8156
A40926	IV	*Actinomadura* sp. ATTC39727
A41030	III	*Streptomyces virginiae* NRRL 15156
A42867	I	*Nocardia* sp. ATTC 53492
A47934	III	*Streptomyces toyocaensis* NRRL 15009
A80407	III	*Kibdelosporangium philippinensis* NRRL 18198 or NRRL 18199
A82846	I	*Amycolatopsis orientalis* NRRL 18100
A83850	I	*Amycolatopsis albus* NRRL 18522
A84575	I	*Streptosporangium carneum* NRRL 18437, 18505
AB-65	ND	*Saccharomonospora viride* T-80 FERM-P 2389
Actaplanin	III	*Actinoplanes missouriensis* ATCC 23342
Actinoidin	II	*Proactinomyces actinoides*
Ardacin	IV	*Kibdelosporangium aridum* ATCC 39323
Avoparcin	II	*Streptomyces candidus* NRRL 3218

TABLE 2-continued

Glycopeptide Antibiotics and Producing Organisms		
Antibiotic	Type	Producing Organism
Azureomycin	ND	*Pseudonocardia azurea* NRRL11412
Chloroorienticin	I	*Amyclolatopsis orientalis* PA-45052
Chloropolysporin	II	*Micropolyspora* sp. FERM BP-538
Decaplanin	I	*Kibdelosporangium deccaensis* DSM 4763
N-demethylvancomycin	I	*Amycolatops orientalis* NRRL 15252
Eremomycin	I	*Actinomycetes* sp. INA 238
Galacardin	II	*Actinomycetes* strain SANK 64289 FERM P-10940
Helvecardin	II	*Pseudonocardia compacta* subsp. *helvetica*
Izupeptin	ND	Norcardia AM-5289 FERM P-8656
Kibdelin	IV	*Kibdelosporangium aridum* ATCC 39922
LL-AM374	ND	*Streptomyces eburosporeus* NRRL 3582
Mannopeptin	ND	*Streptomyces platenis* FS-351
MM45289	I	*Amycolatopsis orientalis* NCIB12531
MM47761	I	*Amycolatopsis orientalis* NCIB 12608
MNI47766	II	*Amycolatopsis orientalis* NCBI 40011
MM55266	IV	*Amycolatopsis* sp. NCIB 40089
MM55270	ND	*Amycolatopsis* sp. NCIB 40086
OA-7653	I	*Streptomyces hygromscopicus* ATCC 31613
Orienticin	I	*Nocardia orientalis* FERM BP-1230
Parvodicin	IV	*Actinomadura parvosata* ATCC 532463
Ristocetin	III	*Amycolatopsis orientalis* subsp. *lurida* NRRL 2430
Ristomycin	III	*Proactinomyces fructiferi*
Synmonicin	II	*Synnemomyces mamnoorii* ATCC 53296
Teicoplanin	IV	*Actinoplanes teichomyceticus* ATCC 31121
UK-68597	III	*Actinoplanes* ATCC 53533
UK-69542	III	*Saccharothix aerocolonigenes*
UK-72051	I	*Amycolatopsis orientalis*
Vancomycin	I	*Amycolatoposis orientalis* NRRL 2450

According to another embodiment, the glycopeptide antibiotic used in the composition of the present invention includes, but is not limited to, A477, A35512, A40926, A41030, A42867, A47934, A80407, A82846, A83850, A84575, AB-65, Actaplanin, Actinoidin, Ardacin, Avoparcin, Azureomycin, Chloroorienticin Chloropolysporin, Decaplanin, N-demethylvancomycin, Eremomycin, Galacardin. Helvecardin Izupeptin, Kibdelin, LL-AM374, Mannopeptin, MM45289, MM47761, MM47766, MM55266, MM55270, OA-7653, Orienticin, Parvodicin, Ristocetin, Ristomycin, Synmonicin, Teicoplanin, UK-68597, UK-69542, UK-72051, vancomycin, and a mixture thereof.

According to one embodiment, the glycopeptide antibiotic of the present invention is vancomycin. Vancomycin is a water soluble amphoteric glycopeptide bactericidal antibiotic that inhibits gram-positive bacterial mucopeptide biosynthesis. It consists of a tricyclic nonribosomal heptapeptide core structure to which is attached a disaccharide unit consisting of the aminodeoxy sugar, vancosamine, and D-glucose (FIG. **1**). This natural antibiotic of ~1450 Daltons is obtained from *Streptomyces orientalis* (also known as; *Norcardia orientalis*, or *Amycolatopsis orientalis*). Vancomycin has one carboxyl group with pKa 2.18, and two amino groups: primary amine with pKa 7.75 and the secondary amine with pKa 8.89. At sub-physiological pH vancomycin has a net positive charge.

Although vancomycin has been reported to be bactericidal, it is not necessarily the case that the bacteria are killed. Without wishing to be bound by theory, the bacteria are instead prevented from growing by the saturation of the available growth points of the peptidoglycan. The non-covalent nature of the binding of vancomycin to the important target sites is indicated by the ease with which the inhibition of either bacterial growth or peptidoglycan synthesis could be reversed. Such reversal has been accomplished by the addition to the growth or incubation medium of a suitable peptide that competed effectively with the natural wall peptides at the growth points for the available glycopeptide (Nieto, M. et al., Biochemical Journal, 1972, 126: 139-149, incorporated by reference herein).

Studies have shown that vancomycin binds reversibly to the L-Lys-D-Ala-D-Ala fragment of the peptidoglycan monomer. This reversible, noncovalent interaction inhibits transglycosidation and transpeptidation from occurring. Inhibition of these processes leads to the collapse of the peptidoglycan by decisively shifting its dynamic equilibrium towards de-assembly, which precipitates cell lysis and bacterial death.

The strong binding of vancomycin to L-Lys-D-Ala-D-Ala is a consequence of five well-defined hydrogen bonds. In Gram-positive bacteria, the glycopeptide antibiotics easily diffuse through the peptidoglycan layer and reach the periplastic space where the peptidoglycan polymerization takes place. By grabbing onto the L-Lys-D-Ala-D-Ala tails of the monomers the antibiotic positions itself to inhibit the transglycosidase from joining the carbohydrate.

Due to the nature of the manufacturing process for vancomycin, the raw material usually contains a number of impurities. In addition, vancomycin is not very stable in solution and degrades to several products, known as product degradants. It is believed that the main degradation product of vancomycin is crystalline degradation product one (CDP-I), and results from deamidation of an asparagine residue. The structural changes during vancomycin degradation to CDP-I are shown in FIG. **2**. CDP-I has limited aqueous solubility and exists in two isomeric forms often referred to as CDP-I-m (minor) and CDP-I-M (major). These are the atropisomers involving different orientations of the CI substituted aromatic ring of residue 2. The order of the CDP formation is thought to be: vancomycin→succinimide intermediate→CDP-I-m→CDP-I-M (Harris, C. et al., 1983, Journal of the American Chemical Society, 105 (23):6915-6922, incorporated by reference herein). In equilibrium, the ratio of the two forms in solution is approximately 1:2 and the equilibrium time is 24 hours at pH 6.5 at 25° C. CDP-I can be converted further into crystalline hydrochloride CDP-II by incubating with 0.6N HCl (Marshall, 1965. J. Med Chem, 8:18-22, incorporated by reference herein in its entirety). CDP-II seems to not form in measurable quantities under normal conditions.

According to one embodiment, the glycopeptide antibiotic of the present invention is oritavancin (LY333328). Oritavancin is obtained by reductive alkylation with 4' chloro-biphenylcarboxaldehyde of the natural glycopeptide chloroeremomycin, which differs from vancomycin by the addition of a 4-epi-vancosamine sugar and the replacement of the vancosamine by a 4-epivancosamine (Cooper, R. et al., J Antibiot (Tokyo) 1996, 49:575-581, incorporated by reference herein in its entirety). The structure of oritavancin is shown in FIG. **3**. Although oritavancin presents a general spectrum of activity comparable to that of vancomycin, it offers considerable advantages in terms of intrinsic activity (especially against streptococci), and remains insensitive to the resistance mechanisms developed by staphylococci and *enterococci*. Because the binding affinity of vancomycin and oritavancin to free D-Ala-D-Ala and D-Ala-D-Lac are of the same order of magnitude, the difference in their activity has been attributed to the cooperative interactions that can occur between the drug and both types of precursors in situ. The previous study suggested that the effect is caused possibly by a much stronger ability to dimerize and the anchoring in the

cytosolic membrane of the chlorobiphenyl side chain (Allen, et al., FEMS Microbiol Rev, 2003, 26:511-532, incorporated by reference herein).

The efficacy of oritavancin has been demonstrated in animal models of meningitis caused by pneumococci susceptible or resistant to β-lactams (even though the concentration in cerebrospinal fluid is only 5% of the serum level) (Gerber et al., Antimicrob Agents Chemother, 2001, 45:2169-2172, incorporated by reference herein in its entirety; Cabellos et al., Antimicrob Agents Chemother, 2003, 47:1907-1911, incorporated by reference herein in its entirety); in models of central venous catheter-associated infection by vancomycin-resistant *Enterococcus faecium* (Rupp et al., J Antimicrob Chemother 2001, 47:705-707, incorporated by reference herein in its entirety); and in models of endocarditis caused by vancomycin-susceptible or -resistant *Enterococcus faecalis* (Lefort et al., Antimicrob Agents Chemother, 2000, 44:3017-3021, incorporated by reference herein in its entirety). Pharmacodynamic studies in a neutropenic mouse thigh model of *S. aureus* infection suggested that the parameter that best predicts oritavancin efficacy is the ratio between the free C_{max} concentration and the minimal inhibitory concentration (MIC) of the offending organism (free Cmax/MIC) (Boylan, C. et al., Antimicrob Agents Chemother, 2003, 47:1700-1706). Additional favorable pharmacodynamic characteristics include prolonged post-antibiotic effects, and synergy with 3-lactams or aminoglycosides (Lefort et al., Antimicrob Agents Chemother, 2000, 44:3017-3021, incorporated by reference herein; Baltch et al., Antimicrob Agents Chemother 1998, 42:2564-2568, incorporated by reference herein in its entirety).

Accordingly, oritavancin can be classified as a highly concentration-dependent bactericidal antibiotic with prolonged persistent effects, in the same way as aminoglycosides and, to some extent, quinolones (Craig, Infect Dis Clin North Am, 2003, 17:479-501, incorporated by reference herein in its entirety). This pharmacodynamic profile contrasts with that of conventional glycopeptides for which efficacy relies mainly upon the area under the curve/MIC ratio, because they show time-dependent activity and persistent effects (Craig, Infect Dis Clin North Am, 2003, 17:479-501, incorporated by reference herein in its entirety).

One pharmacokinetic property of oritavancin is its prolonged retention in the organism, which destines it to a once-a-day scheme of administration. The exceptionally long terminal half-life suggests the existence of storage sites within the organism. Studies on cultured macrophages indicated that the drug accumulates slowly (by an endocytic process) but importantly in the lysosomes, from which its efflux is extremely slow. This explains why it is bactericidal against intracellular forms of *Staphylococcus* or *Enterococcus* infections, but not against cytosolic bacteria such as *Listeria monocytogenes* (Al Nawas et al., Infection 2000, 28:214-218, incorporated by reference herein in its entirety; Seral et al., Antimicrob Agents Chemother, 2003, 47:2283-2292v). Corroborating these data, a recent study in volunteers demonstrated that oritavancin reaches high concentrations not only in epithelial lining fluid but also in alveolar macrophages (Rodvold et al., Clin Microbiol Infect 2004, incorporated by reference herein in its entirety).

According to one embodiment, the glycopeptide antibiotic of the present invention is telavancin (TD-6424). Telavancin is a semi-synthetic derivative of vancomycin, possessing a hydrophobic side chain on the vancosamine sugar (decylaminoethyl) and a (phosphonomethyl) aminomethyl substituent on the cyclic peptidic core (FIG. **3**; van Bambeke. F., Curr. Opin. Pharm., 4(5): 471-478; Judice, J. et al., Bioorg Med Chem Lett 2003, 13: 4165-4168, incorporated by reference herein in its entirety). The length of the hydrophobic side chain was chosen to reach a compromise between optimized activity against MRSA (8-10 carbons) and VanA *enterococci* (12-16 carbons). Pharmacological studies suggest that the enhanced activity of telavancin on *S. pneumoniae, S. aureus* (to a lesser extent), and staphylococci or *enterococci* harboring the vanA gene cluster results from a complex mechanism of action which, on the basis of data obtained with close analogs, involves a perturbation of lipid synthesis and possibly membrane disruption.

The polar substituent introduced on the resorcinol moiety improves the distribution of the molecule in the body and counterbalances the prolonging effect of the lipophilic side chain on the half-life, which is now approximately 7 h and still compatible with a once-daily administration. Pharmacodynamic properties include a prolonged post-antibiotic effect and a concentration-dependent bactericidal activity; therefore, one would propose to calculate the pharmacodynamic breakpoint on the basis of the free C_{max}/MIC ratio, as done for oritavancin.

According to one embodiment, the glycopeptide antibiotic of the present invention is dalbavancin (BI 397). Dalbavancin is a semi-synthetic derivative of A40926, a glycopeptide with a structure related to that of teicoplanin (FIG. **3**; Malabarba et al., Curr Med Chem 2001, 8:1759-1773, incorporated by reference herein in its entirety; Malabarba et al., J Antibiot (Tokyo) 1994, 47:1493-1506, incorporated by reference herein in its entirety).

As with oritavancin and telavancin, dalbavancin is more active against *S. pneumoniae* than are conventional glycopeptides, and its activity against *S. aureus* is also substantially improved, which was not observed with the semi-synthetic derivatives of vancomycin. However, studies have shown that it is not more active than teicoplanin against *enterococci* harboring the VanA phenotype of resistance to glycopeptides. Dalbavancin is also characterized by a marked bactericidal character and a synergism with penicillin. The pharmacodynamic breakpoint calculated (as for the other bactericidal glycopeptides) on the basis of the free C_{max}/MIC ratio is of the same order of magnitude. Pharmacokinetic parameters and pharmacodynamic breakpoints for glycopeptides at doses pertinent to their use in humans (or the foreseen doses for molecules in development) are shown in Table 3. Dalbavancin showed such a prolonged half-life that its plasma concentration exceeds the minimal bactericidal concentration of target organisms even at one week after administration of a single 1000 mg dose; free levels, however, are close to the MICs at these conditions (Steiert, M. et al., Curr Opin Investig Drugs 2002, 3:229-233, incorporated by reference herein in its entirety). These results indicate that a single dose of dalbavancin significantly reduces the bacterial load in animal models of granuloma pouch infection by MRSA (Jabes et al., Antimicrob Agents Chemother 2004, 48:1118-1123, incorporated by reference herein in its entirety), endocarditis by vancomycin-susceptible or -intermediate staphylococci (Lefort et al., Antimicrob Agents Chemother 2004, 48:1061-1064, incorporated by reference herein in its entirety), or pneumonia by penicillin-resistant pneumococci (Candiani et al., 41th Interscience Conference on Antimicrobial Agents and Chemotherapy 2001, Chicago, Ill. [Abstract 989], incorporated by reference herein in its entirety).

TABLE 3

Pharmacokinetic parameters and pharmacodynamic breakpoints for glycopeptides (van Bambeke, Curr. Opin. Pharm., 2004, 4: 471-78, incorporated by reference herein)

	Glycopeptide and dosage				
Parameter (units)	Vancomycin (15 mg/kg)	Oritavancin (3 mg/kg)	Telavancin (7.5 mg/kg)	Teicoplanin (6 mg/kg)	Dalbavancin (15 mg/kg)
C_{max} (mg/L)	20-50	31	89	43	312
V_d (L/kg)	0.3		0.1	0.9-1.6	0.11
Protein binding (%)	10-55	90	90-93	90	98
Terminal half-life (h)	4-8	360	7	83-168	149
AUC (mg · h/L)	260	152	600	550	27103
PD breakpoint based on (free AUC)/MIC ratio	2 (15 mg/kg twice-daily)	0.1 (3 mg/kg) 0.3 (10 mg/kg)	0.5	0.4 (6 mg/kg),	4
PD breakpoint based on (free C_{max})/MIC ratio		0.3 (3 mg/kg) 1 (10 mg/kg)	1		0.6

According to one embodiment, the glycopeptide antibiotic if the present invention is conjugated to an amino acid or a derivative thereof. In as further embodiment, conjugation of the glycopeptides is to the N terminus or C terminus of the amino acid or derivative thereof. In another embodiment, the glycopeptides antibiotic is conjugated to the amino acid side chain.

In one embodiment, the conjugation of the amino acid or derivative thereof to the glycopeptide antibiotic forms a stabilized glycopeptide antibiotic-amino acid complex. In one embodiment, the stabilized glycopeptide antibiotic-amino acid complex is associated with a lipid. For example, in one embodiment, the lipid is conjugated (e.g., bound) to the glycopeptide antibiotic-amino acid complex. In one embodiment, the glycopeptide antibiotic-amino acid complex is entrapped by the lipid component, for example, where the lipid is in the form of a liposome or plurality of liposomes.

In one embodiment, the stabilized glycopeptide antibiotic composition of the described invention includes an amino acid or derivative thereof. In one embodiment, the amino acid or derivative thereof is selected from the group consisting of alanine (ALA), D-alanine (D-ALA), alanine-alanine (ALA-ALA), beta-alanine (bALA), 3-aminobutanoic acid (3-ABA), gamma-aminobutyric acid (GABA), glutamic acid (GLU), D-glutamic acid (D-GLU), glycine (GLY), glycylglycine (GLY-GLY), aspartic acid (ASP), D-aspartic acid (D-ASP), bicine, tricine, sarcosine, iminodiacetic acid (IDAA), and combinations thereof. Structures of exemplary amino acids or derivatives thereof useful in the invention are shown below in Table 4.

TABLE 4

Structure of exemplary amino acids and derivatives thereof

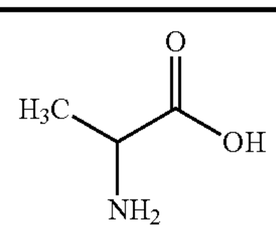
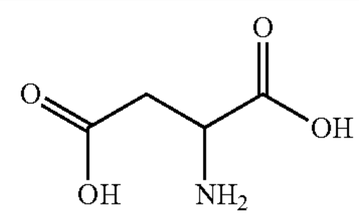
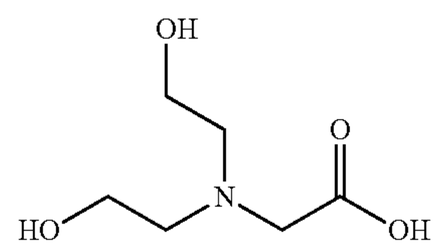
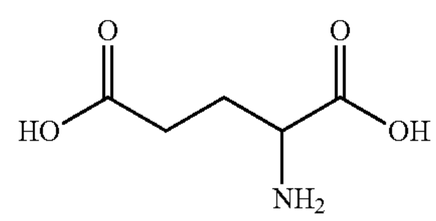
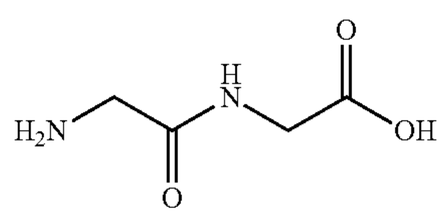
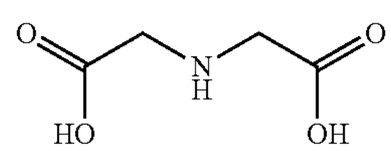
Amino acid/ Amino Acid Derivative	Structure
D-ALA D-Alanine	

TABLE 4-continued

Structure of exemplary amino acids and derivatives thereof

Amino acid/ Amino Acid Derivative	Structure
ASP Aspartic acid	
Bicine	
D-GLU D-Glutamic acid	
GLY-GLY Glycylglycine	
IDAA Iminodiacetic acid	

According to one embodiment, the stabilized lipid-based glycopeptide antibiotic composition maintains at least 98.0% of its original biological activity for at least 200 days at 4° C. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition maintains at least 98.5% of its original biological activity for at least 150 days at 4° C. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition maintains at least 99.0% of its original biological activity for at least 100 days at 4° C. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composi-

tion maintains at least 99.5% of its original biological activity for at least 50 days at 4° C. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition maintains at least 99.9% of its original biological activity for at least two weeks at 4° C.

According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition maintains at least 80% of its original biological activity for at least 200 days at room temperature (RT).

According to one embodiment, the stabilized lipid-based glycopeptide antibiotic composition of the present invention produces product degradants crystalline at a rate less than 0.05% by weight per week at 4° C. According to a further embodiment, the stabilized lipid-based glycopeptide antibiotic composition produces product degradants at a rate less than 0.04% by weight per week at 4° C. According to a further embodiment, the stabilized lipid-based glycopeptide antibiotic composition produces product degradants at a rate less than 0.03% by weight per week at 4° C. According to a further embodiment, the stabilized lipid-based glycopeptide antibiotic composition produces product degradants at a rate less than 0.02% by weight per week at 4° C. According to a further embodiment, the stabilized lipid-based glycopeptide antibiotic composition produces product degradants at a rate less than 0.01% by weight per week at 4° C. In one embodiment, the product degradants produced at 4° C. are crystalline degradation products (i.e., CDP-I-m plus CDP-I-M)

According to one embodiment, the stabilized lipid-based glycopeptide antibiotic composition of the present invention produces product degradants at a rate less than about 0.5% by weight per week at room temperature. According to a further embodiment, the stabilized lipid-based glycopeptide antibiotic composition of the present invention produces product degradants at a rate less than about 0.4% by weight per week at room temperature. According to a further embodiment, the stabilized lipid-based glycopeptide antibiotic composition of the present invention produces product degradants at a rate less than about 0.3% by weight per week at room temperature. According to a yet further embodiment, the stabilized lipid-based glycopeptide antibiotic composition of the present invention produces product degradants at a rate less than about 0.2% by weight per week at room temperature. In one embodiment, the product degradants produced at room temperature are crystalline degradation products (i.e., CDP-I-m plus CDP-I-M)

In one embodiment, the stabilized lipid-based glycopeptide antibiotic composition comprising a lipid component, a glycopeptide antibiotic component, and an amino acid or derivative thereof is at least 44% more stable than a lipid-based glycopeptide antibiotic that does not comprise an amino acid or derivative thereof. In a further embodiment, the stabilized lipid-based glycopeptide antibiotic composition comprising a lipid component, a glycopeptide antibiotic component, and an amino acid or derivative thereof is at least 55% more stable than a lipid-based glycopeptide antibiotic that does not comprise an amino acid or derivative thereof. In a further embodiment, the stabilized lipid-based glycopeptide antibiotic composition comprising a lipid component, a glycopeptide antibiotic component, and an amino acid or derivative thereof is at least 66% more stable than a lipid-based glycopeptide antibiotic that does not comprise an amino acid or derivative thereof. In a further embodiment, the stabilized lipid-based glycopeptide antibiotic composition comprising a lipid component, a glycopeptide antibiotic component, and an amino acid or derivative thereof is at least 77% more stable than a lipid-based glycopeptide antibiotic that does not comprise an amino acid or derivative thereof. In a yet further embodiment, the stabilized lipid-based glycopeptide antibiotic composition comprising a lipid component, a glycopeptide antibiotic component, and an amino acid or derivative thereof is at least 88% more stable than a lipid-based glycopeptide antibiotic that does not comprise an amino acid or derivative thereof.

According to another embodiment, the molar ratio of the glycopeptide antibiotic to the amino acid or amino acid derivative ranges from about 1:1 to about 1:4. According to another embodiment, the molar ratio of the glycopeptide antibiotic to the amino acid or amino acid derivative ranges from about 1:1 to about 1:3. According to another embodiment, the molar ratio of the glycopeptide antibiotic to the amino acid or amino acid derivative ranges from about 1:1 to about 1:2. According to another embodiment, the molar ratio of the glycopeptide antibiotic to the amino acid or amino acid derivative is about 1:4. According to another embodiment, the molar ratio of the glycopeptide antibiotic to the amino acid or amino acid derivative is about 1:3. According to another embodiment, the molar ratio of the glycopeptide antibiotic to the amino acid or amino acid derivative is about 1:2. According to another embodiment, the molar ratio of the glycopeptide antibiotic to the amino acid or amino acid derivative is about 1:1.

According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition has a pH ranging from about 5.0 to about 6.5. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition has a pH ranging from about 5.1 to about 6.5. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition has a pH ranging from about 5.2 to about 6.5. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition has a pH ranging from about 5.3 to about 6.5. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition has a pH ranging from about 5.4 to about 6.5. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition has a pH ranging from about 5.5 to about 6.5. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition has a pH ranging from about 5.6 to about 6.5. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition has a pH ranging from about 5.7 to about 6.5. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition has a pH ranging from about 5.8 to about 6.5. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition has a pH ranging from about 5.9 to about 6.5. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition has a pH ranging from about 6.0 to about 6.5. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition has a pH ranging from about 6.1 to about 6.5. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition has a pH ranging from about 6.2 to about 6.5. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition has a pH ranging from about 6.3 to about 6.5. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition has a pH ranging from about 6.4 to about 6.5. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition has a pH of 5.0. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition has a pH of 5.5. According to another embodiment, the stabilized lipid-based glycopeptide antibi-

otic composition has a pH of 6.0. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition has a pH of 6.5.

According to another embodiment, the concentration of the glycopeptide antibiotic in the composition ranges from 20 mg/mL to 200 mg/mL. According to another embodiment, the concentration of the glycopeptide antibiotic in the composition ranges from 30 mg/mL to 200 mg/mL. According to another embodiment, the concentration of the glycopeptide antibiotic in the composition ranges from 40 mg/mL to 200 mg/mL. According to another embodiment, the concentration of the glycopeptide antibiotic in the composition ranges from 50 mg/mL to 200 mg/mL. According to another embodiment, the concentration of the glycopeptide antibiotic in the composition ranges from 60 mg/mL to 200 mg/mL. According to another embodiment, the concentration of the glycopeptide antibiotic in the composition ranges from 70 mg/mL to 200 mg/mL. According to another embodiment, the concentration of the glycopeptide antibiotic in the composition ranges from 80 mg/mL to 200 mg/mL. According to another embodiment, the concentration of the glycopeptide antibiotic in the composition ranges from 90 mg/mL to 200 mg/mL. According to another embodiment, the concentration of the glycopeptide antibiotic in the composition ranges from 100 mg/mL to 200 mg/mL. According to another embodiment, the concentration of the glycopeptide antibiotic in the composition ranges from 110 mg/mL to 200 mg/mL. According to another embodiment, the concentration of the glycopeptide antibiotic in the composition ranges from 120 mg/mL to 200 mg/mL. According to another embodiment, the concentration of the glycopeptide antibiotic in the composition ranges from 130 mg/mL to 200 mg/mL. According to another embodiment, the concentration of the glycopeptide antibiotic in the composition ranges from 140 mg/mL to 200 mg/mL. According to another embodiment, the concentration of the glycopeptide antibiotic in the composition ranges from 150 mg/mL to 200 mg/mL. According to another embodiment, the concentration of the glycopeptide antibiotic in the composition ranges from 160 mg/mL to 200 mg/mL. According to another embodiment, the concentration of the glycopeptide antibiotic in the composition ranges from 170 mg/mL to 200 mg/mL. According to another embodiment, the concentration of the glycopeptide antibiotic in the composition ranges from 180 mg/mL to 200 mg/mL. According to another embodiment, the concentration of the glycopeptide antibiotic in the composition ranges from 190 mg/mL to 200 mg/mL. According to another embodiment, the concentration of the glycopeptide antibiotic in the composition is 200 mg/mL. According to another embodiment, the concentration of the glycopeptide antibiotic in the composition is 100 mg/mL.

According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition of the present invention comprises an aqueous dispersion of liposomes. The formulation can contain lipid excipients to form the liposomes, and salts/buffers to provide the appropriate osmolarity and pH. The formulation can comprise a pharmaceutical excipient. The pharmaceutical excipient can be a liquid, diluent, solvent or encapsulating material, involved in carrying or transporting any subject composition or component thereof from one organ, or portion of the body, to another organ, or portion of the body. Each excipient must be "acceptable" in the sense of being compatible with the subject composition and its components and not injurious to the patient. Suitable excipients include trehalose, raffinose, mannitol, sucrose, leucine, trileucine, and calcium chloride. Examples of other suitable excipients include (1) sugars, such as lactose, and glucose; (2) starches, such as corn starch and potato starch; (3) cellulose, and its derivatives, such as sodium carboxymethyl cellulose, ethyl cellulose and cellulose acetate; (4) powdered tragacanth; (5) malt; (6) gelatin; (7) talc; (8) excipients, such as cocoa butter and suppository waxes; (9) oils, such as peanut oil, cottonseed oil, safflower oil, sesame oil, olive oil, corn oil and soybean oil; (10) glycols, such as propylene glycol; (11) polyols, such as glycerin, sorbitol, and polyethylene glycol; (12) esters, such as ethyl oleate and ethyl laurate; (13) agar; (14) buffering agents, such as magnesium hydroxide and aluminum hydroxide; (15) alginic acid; (16) pyrogen-free water; (17) isotonic saline; (18) Ringer's solution; (19) ethyl alcohol; (20) phosphate buffer solutions; and (21) other non-toxic compatible substances employed in pharmaceutical formulations.

Representative lipid-based glycopeptide antibiotic formulations are shown in Table 5.

TABLE 5

Representative formulation components

Glycopeptide	Lipid Component	Amino Acid
Vancomycin	DPPC	Bicine
Vancomycin	DPPC	GLU
Vancomycin	DPPC	GLY-GLY
Vancomycin	DPPC	IDAA
Vancomycin	DPPC	ASP
Vancomycin	DPPC	D-ALA
Vancomycin	DPPC + Cholesterol	Bicine
Vancomycin	DPPC + Cholesterol	GLU
Vancomycin	DPPC + Cholesterol	GLY-GLY
Vancomycin	DPPC + Cholesterol	IDAA
Vancomycin	DPPC + Cholesterol	ASP
Vancomycin	DPPC + Cholesterol	D-ALA
Vancomycin	DPPG	Bicine
Vancomycin	DPPG	GLU
Vancomycin	DPPG	GLY-GLY
Vancomycin	DPPG	IDAA
Vancomycin	DPPG	ASP
Vancomycin	DPPG	D-ALA
Vancomycin	DPPG + Cholesterol	Bicine
Vancomycin	DPPG + Cholesterol	GLU
Vancomycin	DPPG + Cholesterol	GLY-GLY
Vancomycin	DPPG + Cholesterol	IDAA
Vancomycin	DPPG + Cholesterol	ASP
Vancomycin	DPPG + Cholesterol	D-ALA
Vancomycin	DPPC + DPPG + Cholesterol	Bicine
Vancomycin	DPPC + DPPG + Cholesterol	GLU
Vancomycin	DPPC + DPPG + Cholesterol	GLY-GLY
Vancomycin	DPPC + DPPG + Cholesterol	IDAA
Vancomycin	DPPC + DPPG + Cholesterol	ASP
Vancomycin	DPPC + DPPG + Cholesterol	D-ALA
Vancomycin	POPC	Bicine
Vancomycin	POPC	GLU
Vancomycin	POPC	GLY-GLY
Vancomycin	POPC	IDAA
Vancomycin	POPC	ASP
Vancomycin	POPC	D-ALA

In one embodiment, the present invention provides a stabilized glycopeptides composition comprising a lipid component, a glycopeptides antibiotic and an amino acid or derivative thereof. In one embodiment, the lipid to glycopeptide molar ratio is 10:1 or less, 9:1 or less, 8:1 or less, 7:1 or less, 6:1 or less, 5:1 or less, 4:1 or less, 3:1 or less, 2:1 or less, 1:1 or less, 0.75:1 or less or 0.5:1 or less. In another embodiment, the lipid to glycopeptide molar ratio is about 1:1, about 2:1, about 3:1, about 4:1 or about 5:1.

In one embodiment, the present invention relates to a stabilized lipid-glycopeptide antibiotic composition com-

prising a lipid component, a glycopeptide antibiotic, and an amino acid or derivative thereof, wherein the weight ratio of the total lipid component to the glycopeptide antibiotic is from about 0.1:1 to about 5:1. In a further embodiment, the weight ratio of the lipid component to the glycopeptide antibiotic is about 3:1 or less. In a further embodiment, the weight ratio of the lipid component to the glycopeptide antibiotic is about 1:1 or less. In another embodiment, the weight ratio of the lipid component to the glycopeptide antibiotic is less than 1:1.

It is understood that for the ranges of values provided above, each intervening value, to the tenth of the unit of the lower limit unless the context clearly dictates otherwise, between the upper and lower limit of that range and any other stated or intervening value in that stated range is encompassed within the invention. The upper and lower limits of these smaller ranges which may independently be included in the smaller ranges is also encompassed within the invention, subject to any specifically excluded limit in the stated range. Where the stated range includes one or both of the limits, ranges excluding either both of those included limits are also included in the invention.

Representative lipid-based glycopeptide antibiotic formulations with exemplary lipid to glycopeptide ratios are shown in Table 6.

TABLE 6

Representative formulations with lipid to drug ratios

Glycopeptide Antibiotic	Lipid Component	Amino Acid	Lipid: glycopeptide
Vancomycin	DPPC	Bicine	5:1
Vancomycin	DPPC	GLU	5:1
Vancomycin	DPPC	GLY-GLY	5:1
Vancomycin	DPPC	IDAA	5:1
Vancomycin	DPPC	ASP	5:1
Vancomycin	DPPC	D-ALA	5:1
Vancomycin	DPPC + Cholesterol	Bicine	5:1
Vancomycin	DPPC + Cholesterol	GLU	5:1
Vancomycin	DPPC + Cholesterol	GLY-GLY	5:1
Vancomycin	DPPC + Cholesterol	IDAA	5:1
Vancomycin	DPPC + Cholesterol	ASP	5:1
Vancomycin	DPPC + Cholesterol	D-ALA	5:1
Vancomycin	DPPG	Bicine	5:1
Vancomycin	DPPG	GLU	5:1
Vancomycin	DPPG	GLY-GLY	5:1
Vancomycin	DPPG	IDAA	5:1
Vancomycin	DPPG	ASP	5:1
Vancomycin	DPPG	D-ALA	5:1
Vancomycin	DPPG + Cholesterol	Bicine	5:1
Vancomycin	DPPG + Cholesterol	GLU	5:1
Vancomycin	DPPG + Cholesterol	GLY-GLY	5:1
Vancomycin	DPPG + Cholesterol	IDAA	5:1
Vancomycin	DPPG + Cholesterol	ASP	5:1
Vancomycin	DPPG + Cholesterol	D-ALA	5:1
Vancomycin	DPPC + DPPG + Cholesterol	Bicine	5:1
Vancomycin	DPPC + DPPG + Cholesterol	GLU	5:1
Vancomycin	DPPC + DPPG + Cholesterol	GLY-GLY	5:1
Vancomycin	DPPC + DPPG + Cholesterol	IDAA	5:1
Vancomycin	DPPC + DPPG + Cholesterol	ASP	5:1
Vancomycin	DPPC + DPPG + Cholesterol	D-ALA	5:1
Vancomycin	POPC	Bicine	5:1
Vancomycin	POPC	GLU	5:1
Vancomycin	POPC	GLY-GLY	5:1
Vancomycin	POPC	IDAA	5:1
Vancomycin	POPC	ASP	5:1
Vancomycin	POPC	D-ALA	5:1
Vancomycin	DPPC	Bicine	3:1

TABLE 6-continued

Representative formulations with lipid to drug ratios

Glycopeptide Antibiotic	Lipid Component	Amino Acid	Lipid: glycopeptide
Vancomycin	DPPC	GLU	3:1
Vancomycin	DPPC	GLY-GLY	3:1
Vancomycin	DPPC	IDAA	3:1
Vancomycin	DPPC	ASP	3:1
Vancomycin	DPPC	D-ALA	3:1
Vancomycin	DPPC + Cholesterol	Bicine	3:1
Vancomycin	DPPC + Cholesterol	GLU	3:1
Vancomycin	DPPC + Cholesterol	GLY-GLY	3:1
Vancomycin	DPPC + Cholesterol	IDAA	3:1
Vancomycin	DPPC + Cholesterol	ASP	3:1
Vancomycin	DPPC + Cholesterol	D-ALA	3:1
Vancomycin	DPPG	Bicine	3:1
Vancomycin	DPPG	GLU	3:1
Vancomycin	DPPG	GLY-GLY	3:1
Vancomycin	DPPG	IDAA	3:1
Vancomycin	DPPG	ASP	3:1
Vancomycin	DPPG	D-ALA	3:1
Vancomycin	DPPG + Cholesterol	Bicine	3:1
Vancomycin	DPPG + Cholesterol	GLU	3:1
Vancomycin	DPPG + Cholesterol	GLY-GLY	3:1
Vancomycin	DPPG + Cholesterol	IDAA	3:1
Vancomycin	DPPG + Cholesterol	ASP	3:1
Vancomycin	DPPG + Cholesterol	D-ALA	3:1
Vancomycin	DPPC + DPPG + Cholesterol	Bicine	3:1
Vancomycin	DPPC + DPPG + Cholesterol	GLU	3:1
Vancomycin	DPPC + DPPG + Cholesterol	GLY-GLY	3:1
Vancomycin	DPPC + DPPG + Cholesterol	IDAA	3:1
Vancomycin	DPPC + DPPG + Cholesterol	ASP	3:1
Vancomycin	DPPC + DPPG + Cholesterol	D-ALA	3:1
Vancomycin	POPC	Bicine	3:1
Vancomycin	POPC	GLU	3:1
Vancomycin	POPC	GLY-GLY	3:1
Vancomycin	POPC	IDAA	3:1
Vancomycin	POPC	ASP	3:1
Vancomycin	POPC	D-ALA	3:1
Vancomycin	DPPC	Bicine	2:1
Vancomycin	DPPC	GLU	2:1
Vancomycin	DPPC	GLY-GLY	2:1
Vancomycin	DPPC	IDAA	2:1
Vancomycin	DPPC	ASP	2:1
Vancomycin	DPPC	D-ALA	2:1
Vancomycin	DPPC + Cholesterol	Bicine	2:1
Vancomycin	DPPC + Cholesterol	GLU	2:1
Vancomycin	DPPC + Cholesterol	GLY-GLY	2:1
Vancomycin	DPPC + Cholesterol	IDAA	2:1
Vancomycin	DPPC + Cholesterol	ASP	2:1
Vancomycin	DPPC + Cholesterol	D-ALA	2:1
Vancomycin	DPPG	Bicine	2:1
Vancomycin	DPPG	GLU	2:1
Vancomycin	DPPG	GLY-GLY	2:1
Vancomycin	DPPG	IDAA	2:1
Vancomycin	DPPG	ASP	2:1
Vancomycin	DPPG	D-ALA	2:1
Vancomycin	DPPG + Cholesterol	Bicine	2:1
Vancomycin	DPPG + Cholesterol	GLU	2:1
Vancomycin	DPPG + Cholesterol	GLY-GLY	2:1
Vancomycin	DPPG + Cholesterol	IDAA	2:1
Vancomycin	DPPG + Cholesterol	ASP	2:1
Vancomycin	DPPG + Cholesterol	D-ALA	2:1
Vancomycin	DPPC + DPPG + Cholesterol	Bicine	2:1
Vancomycin	DPPC + DPPG + Cholesterol	GLU	2:1
Vancomycin	DPPC + DPPG + Cholesterol	GLY-GLY	2:1
Vancomycin	DPPC + DPPG + Cholesterol	IDAA	2:1
Vancomycin	DPPC + DPPG + Cholesterol	ASP	2:1
Vancomycin	DPPC + DPPG + Cholesterol	D-ALA	2:1

TABLE 6-continued

Representative formulations with lipid to drug ratios

Glycopeptide Antibiotic	Lipid Component	Amino Acid	Lipid: glycopeptide
Vancomycin	POPC	Bicine	2:1
Vancomycin	POPC	GLU	2:1
Vancomycin	POPC	GLY-GLY	2:1
Vancomycin	POPC	IDAA	2:1
Vancomycin	POPC	ASP	2:1
Vancomycin	POPC	D-ALA	2:1
Vancomycin	DPPC	Bicine	1:1
Vancomycin	DPPC	GLU	1:1
Vancomycin	DPPC	GLY-GLY	1:1
Vancomycin	DPPC	IDAA	1:1
Vancomycin	DPPC	ASP	1:1
Vancomycin	DPPC	D-ALA	1:1
Vancomycin	DPPC + Cholesterol	Bicine	1:1
Vancomycin	DPPC + Cholesterol	GLU	1:1
Vancomycin	DPPC + Cholesterol	GLY-GLY	1:1
Vancomycin	DPPC + Cholesterol	IDAA	1:1
Vancomycin	DPPC + Cholesterol	ASP	1:1
Vancomycin	DPPC + Cholesterol	D-ALA	1:1
Vancomycin	DPPG	Bicine	1:1
Vancomycin	DPPG	GLU	1:1
Vancomycin	DPPG	GLY-GLY	1:1
Vancomycin	DPPG	IDAA	1:1
Vancomycin	DPPG	ASP	1:1
Vancomycin	DPPG	D-ALA	1:1
Vancomycin	DPPG + Cholesterol	Bicine	1:1
Vancomycin	DPPG + Cholesterol	GLU	1:1
Vancomycin	DPPG + Cholesterol	GLY-GLY	1:1
Vancomycin	DPPG + Cholesterol	IDAA	1:1
Vancomycin	DPPG + Cholesterol	ASP	1:1
Vancomycin	DPPG + Cholesterol	D-ALA	1:1
Vancomycin	DPPC + DPPG + Cholesterol	Bicine	1:1
Vancomycin	DPPC + DPPG + Cholesterol	GLU	1:1
Vancomycin	DPPC + DPPG + Cholesterol	GLY-GLY	1:1
Vancomycin	DPPC + DPPG + Cholesterol	IDAA	1:1
Vancomycin	DPPC + DPPG + Cholesterol	ASP	1:1
Vancomycin	DPPC + DPPG + Cholesterol	D-ALA	1:1
Vancomycin	POPC	Bicine	1:1
Vancomycin	POPC	GLU	1:1
Vancomycin	POPC	GLY-GLY	1:1
Vancomycin	POPC	IDAA	1:1
Vancomycin	POPC	ASP	1:1
Vancomycin	POPC	D-ALA	1:1

According to another aspect, the described invention provides a method for preparing a stabilized lipid-based glycopeptide antibiotic composition, wherein the method comprises:

infusing, in an in-line fashion, a first stream of a lipid solution containing a lipid component in a solvent with a second stream of an aqueous solution comprising a glycopeptide antibiotic and an amino acid or a derivative thereof, wherein the amino acid or the derivative thereof binds to the glycopeptide antibiotic and forms a stabilized glycopeptide antibiotic-amino acid complex, and the stabilized glycopeptide antibiotic-amino acid complex is entrapped by or complexed with the a lipid component (i.e., one lipid or a mixture of multiple lipids).

According to some embodiments, the first stream in step (a) contains a lipid dissolved in a solvent. According to some such embodiments, the solvent is ethanol.

According to another embodiment, the lipid solution comprises from about 2 mg/mL to 200 mg/mL of lipids. According to another embodiment, the lipid solution comprises about 20 mg/mL of lipids.

Examples of the lipid component that can be used in preparing the stabilized lipid-based glycopeptide antibiotic composition of the present invention includes, but is limited to, phosphatidylcholine (PC), phosphatidylglyccrol (PG), phosphatidylinositol (PI), phosphatidylserine (PS), phosphatidylethanolamine (PE), phosphatidic acid (PA), egg phosphatidylcholine (EPC), egg phosphatidylglycerol (EPG), egg phosphatidylinositol (EPI), egg phosphatidylserine (EPS), phosphatidylethanolamine (EPE), phosphatidic acid (EPA), soy phosphatidylcholine (SPC), soy phosphatidylglycerol (SPG), soy phosphatidylserine (SPS), soy phosphatidylinositol (SPI), soy phosphatidylethanolamine (SPE), soy phosphatidic acid (SPA), hydrogenated egg phosphatidylcholine (HEPC), hydrogenated egg phosphatidylglycerol (HEPG), hydrogenated egg phosphatidylinositol (HEPI), hydrogenated egg phosphatidylserine (HEPS), hydrogenated phosphatidylethanolamine (HEPE), hydrogenated phosphatidic acid (HEPA), hydrogenated soy phosphatidylcholine (HSPC), hydrogenated soy phosphatidylglycerol (HSPG), hydrogenated soy phosphatidylserine (HSPS), hydrogenated soy phosphatidylinositol (HSPI), hydrogenated soy phosphatidylethanolamine (HSPE), hydrogenated soy phosphatidic acid (HSPA), dipalmitoylphosphatidylcholine (DPPC), dimyristoylphosphatidylcholine (DMPC), dimyristoylphosphatidylglycerol (DMPG), dipalmitoylphosphatidylglycerol (DPPG), distearoylphosphatidylcholine (DSPC), distearoylphosphatidylglycerol (DSPG), dioleoylphosphatidylcholine (DOPC), dioleylphosphatidylethanolamine (DOPE), palmitoylstearoylphosphatidyl-choline (PSPC), palmitoylstearolphosphatidylglycerol (PSPG), mono-oleoyl-phosphatidylethanolamine (MOPE), tocopherol, tocopherol hemisuccinate, cholesterol sulfate, cholesteryl hemisuccinate, cholesterol derivatives, ammonium salts of fatty acids, ammonium salts of phospholipids, ammonium salts of glycerides, myristylamine, palmitylamine, laurylamine, stearylamine, dilauroyl ethylphosphocholine (DLEP), dimyristoyl ethylphosphocholine (DMEP), dipalmitoyl ethylphosphocholine (DPEP) and distearoyl ethylphosphocholine (DSEP), N-(2,3-di-(9-(Z)-octadecenyloxy)-prop-1-yl-N,N,N-trimethylammonium chloride (DOTMA), 1,2-bis(oleoyloxy)-3-(trimethylammonio) propane (DOTAP), distearoylphosphatidylglycerol (DSPG), dimyristoylphosphatidylacid (DMPA), dipalmitoylphosphatidylacid (DPPA), distearoylphosphatidylacid (DSPA), dimyristoylphosphatidylinositol (DMPI), dipalmitoylphosphatidylinositol (DPPI), distearoylphospatidylinositol (DSPI), dimyristoylphosphatidylserine (DMPS), dipalmitoylphosphatidylserine (DPPS), distearoylphosphatidylserine (DSPS), or a mixture thereof.

According to another embodiment, the lipid component that can be used in preparing a stabilized lipid-based glycopeptide antibiotic composition of the present invention includes mixed phospholipids, e.g., palmitoylstearoylphosphatidylcholine (PSPC) and palmitoylstearoylphosphatidylglycerol (PSPG)), triacylglycerol, diacylglycerol, seranide, sphingosine, sphingomyelin, and single acylated phospholipids, such as mono-oleoyl-phosphatidylethanol amine (MOPE).

According to another embodiment, the lipid component that can be used in preparing the stabilized lipid-based glycopeptide antibiotic composition of the present invention includes ammonium salts of fatty acids, phospholipids and glycerides, sterols, phosphatidylglycerols (PGs), phosphatidic acids (PAs), phosphotidylcholines (PCs), phosphatidylinositols (PIs) and the phosphatidylserines (PSs). The fatty acids include fatty acids of carbon chain lengths of 12 to 26 carbon atoms that are either saturated or unsaturated.

Some specific examples include, but are not limited to, myristylamine, palmitylamine, laurylamine and stearylamine, dilauroyl ethylphosphocholine (DLEP), dimyristoyl ethylphosphocholine (DMEP), dipalmitoyl ethylphosphocholine (DPEP) and distearoyl ethylphosphocholine (DSEP), N-(2,3-di-(9 (Z)-octadecenyloxy)-prop-1-yl-N,N,N-trimethylammonium chloride (DOTMA) and 1,2-bis(oleoyloxy)-3-(trimethylammonio)propane (DOTAP).

According to another embodiment, the lipid component consists essentially of a phosphatidylcholine. According to another embodiment, the lipid component consists essentially of dipalmitoylphosphatidylcholine (DPPC). According to another embodiment, the lipid component consists essentially of palmitoyloleoylphosphatidylcholine (POPC).

According to another embodiment, the lipid component consists essentially of phosphatidylglycerol. According to another embodiment, the lipid component consists essentially of 1-palmitoyl-2-oleoyl-sn-glycero-3-phosphoglycerol (POPG).

According to another embodiment, the lipid component includes a sterol, including, but not limited to, cholesterol and ergosterol. In one embodiment, the lipid component consists of a sterol and one additional lipid. In a further embodiment, the sterol is cholesterol.

According to another embodiment, the first flow rate is between 0.1 L/min and 100 L/min. According to another embodiment, the first flow rate is between 0.5 L/min and 10 L/min. According to another embodiment, the first flow rate is between 0.5 L/min and 1.5 L/min. According to another embodiment, the first flow rate is about 10 L/min. According to another embodiment, the first flow rate is about 1 L/min.

According to another embodiment, the molar ratio of the glycopeptide antibiotic to the amino acid or amino acid derivative ranges from about 1:1 to about 1:4. According to another embodiment, the molar ratio of the glycopeptide antibiotic to the amino acid or amino acid derivative ranges from about 1:1 to about 1:3. According to another embodiment, the molar ratio of the glycopeptide antibiotic to the amino acid or amino acid derivative ranges from about 1:1 to about 1:2. According to another embodiment, the molar ratio of the glycopeptide antibiotic to the amino acid or amino acid derivative is about 1:4. According to another embodiment, the molar ratio of the glycopeptide antibiotic to the amino acid or amino acid derivative is about 1:3. According to another embodiment, the molar ratio of the glycopeptide antibiotic to the amino acid or amino acid derivative is about 1:2. According to another embodiment, the molar ratio of the glycopeptide antibiotic to the amino acid or amino acid derivative is about 1:1.

According to another embodiment, the aqueous solution comprises between about 20 mg/mL and about 500 mg/mL of the glycopeptide antibiotic. According to another embodiment, the first stream comprises between about 50 mg/mL and about 250 mg/mL of the glycopeptide antibiotic. According to another embodiment, the first stream comprises between about 100 mg/mL and about 200 mg/mL of the glycopeptide antibiotic. According to another embodiment, the first stream comprises about 100 mg/mL of the glycopeptide antibiotic. According to another embodiment, the first stream comprises about 200 mg/mL of the glycopeptide antibiotic.

According to another embodiment, the aqueous solution has pH of from 5.0 to 6.5. According to another embodiment, the aqueous solution has pH of from 5.1 to 6.5. According to another embodiment, the aqueous solution has pH of from 5.2 to 6.5. According to another embodiment, the aqueous solution has pH of from 5.3 to 6.5. According to another embodiment, the aqueous solution has pH of from 5.4 to 6.5. According to another embodiment, the aqueous solution has a pH ranging from 5.5 to 6.5. According to another embodiment, the aqueous solution has pH of from 5.6 to 6.5. According to another embodiment, the aqueous solution has pH of from 5.7 to 6.5. According to another embodiment, the aqueous solution has pH of from 5.8 to 6.5. According to another embodiment, the aqueous solution has pH of from 5.9 to 6.5. According to another embodiment, the aqueous solution has pH of from 6.0 to 6.5. According to another embodiment, the aqueous solution has pH of from 6.1 to 6.5. According to another embodiment, the aqueous solution has pH of from 6.2 to 6.5. According to another embodiment, the aqueous solution has pH of from 6.3 to 6.5. According to another embodiment, the aqueous solution has pH of from 6.4 to 6.5. According to another embodiment, the aqueous solution has a pH of 5.0. According to another embodiment, the aqueous solution has a pH of 5.5. According to another embodiment, the aqueous solution has a pH of 6.0. According to another embodiment, the aqueous solution has a pH of 6.5.

According to one embodiment, the second flow rate is between 0.1 L/min and 100 L/min. According to another embodiment, the second flow rate is between 0.5 L/min and 10 L/min. According to another embodiment, the second flow rate is between 0.5 L/min and 2 L/min. According to another embodiment, the second flow rate is between 1 L/min and 2 L/min. According to another embodiment, the second flow rate is about 1.5 L/min. According to another embodiment, the second flow rate is about 10 L/min.

According to one embodiment, the ratio of the second flow rate to the first flow rate is from about 0.1:1.0 to about 1:0.1.0. According to another embodiment, the ratio of the second flow rate to the first flow rate is from about 0.5:1.0 to about 2.0:1.0. According to another embodiment, the ratio of the second flow rate to the first flow rate is from about 1.0:1.0 to about 2.0:1.0. According to one embodiment, the ratio of the second flow rate to the first flow rate is about 1.5:1.0.

According to another embodiment, the saline solution comprises from about 0.9% wt/wt to about 1.5% wt/wt of sodium chloride (NaCl). According to another embodiment, the saline solution comprises less than 0.9% wt/wt of sodium chloride (NaCl). According to another embodiment, the saline solution comprises about 0.9% wt/wt of sodium chloride (NaCl). According to another embodiment, the saline solution comprises from about 1.0% wt/wt to about 1.5% wt/wt of sodium chloride (NaCl). According to another embodiment, the saline solution comprises from 1.1% wt/wt to 1.5% wt/wt of sodium chloride (NaCl). According to another embodiment, the saline solution comprises from about 1.2% wt/wt to about 1.5% wt/wt of sodium chloride (NaCl). According to another embodiment, the saline solution comprises from about 1.3% wt/wt to about 1.5% wt/wt of sodium chloride (NaCl). According to another embodiment, the saline solution comprises from 1.4% wt/wt to about 1.5% wt/wt of sodium chloride (NaCl). According to another embodiment, the saline solution comprises about 1.5% wt/wt of sodium chloride (NaCl). According to another embodiment, the saline solution comprises at least 1.5% wt/wt of sodium chloride (NaCl).

According to one embodiment, the saline solution flow rate is between 0.1 L/min and 10 L/min. According to another embodiment, the saline solution flow rate is between 0.5 L/min and 2 L/min. According to another embodiment,

the saline solution flow rate is about 1.5 L/min. According to another embodiment, the saline solution flow rate is about 10 L/min.

According to another embodiment, the method produces an infused mixture, wherein the infused mixture comprises a first population of glycopeptide antibiotics entrapped with the lipid and a second population of glycopeptide antibiotics unentrapped with the lipid.

According to another embodiment, the method of preparation further comprises washing the infused mixture comprising lipid-associated or lipid-unassociated glycopeptide antibiotics by infusing a washing feed at a fourth flow rate, wherein the washing feed comprises a saline solution.

According to another embodiment, the washing step is carried out following the formation of infused mixture, wherein the infused mixture comprises a first population of glycopeptide antibiotics entrapped with the lipid and a second population of glycopeptide antibiotics unentrapped with the lipid.

According to another embodiment, the saline solution comprises from about 0.9% wt/wt to about 1.5% wt/wt of sodium chloride (NaCl). According to another embodiment, the saline solution comprises 0.9% wt/wt of sodium chloride (NaCl). According to another embodiment, the saline solution comprises from about 1.0% wt/wt to about 1.5% wt/wt of sodium chloride (NaCl). According to another embodiment, the saline solution comprises from 1.1% wt/wt to 1.5% wt/wt of sodium chloride (NaCl). According to another embodiment, the saline solution comprises from about 1.2% wt/wt to about 1.5% wt/wt of sodium chloride (NaCl). According to another embodiment, the saline solution comprises from about 1.3% wt/wt to about 1.5% wt/wt of sodium chloride (NaCl). According to another embodiment, the saline solution comprises from 1.4% wt/wt to about 1.5% wt/wt of sodium chloride (NaCl). According to another embodiment, the saline solution comprises 1.5% wt/wt of sodium chloride (NaCl).

According to another embodiment, the method further comprises a step for concentrating lipid-associated glycopeptide antibiotics in the formulation.

According to another aspect, the described invention provides a method for treating a bacterial pulmonary infection, the method comprising administering to a subject in need thereof a therapeutically effective amount of a stabilized lipid-based glycopeptide antibiotic composition, wherein the composition comprises:

(a) a lipid component, (b) a glycopeptide antibiotic component, and (c) an amino acid or a derivative thereof, wherein the amino acid or derivative thereof binds to the glycopeptide antibiotic and forms a stabilized glycopeptide antibiotic-amino acid complex, and wherein the stabilized glycopeptide antibiotic-amino acid complex is entrapped by the lipid.

According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition can treat infections caused by Gram-positive bacteria, including, but not limited to, genera *Staphylococcus, Streptococcus, Enterococcus, Bacillus, Corynebacterium, Nocardia, Clostridium*, and *Listeria*.

Staphylococci are Gram-positive spherical bacteria that occur in microscopic clusters resembling grapes. While there are 20 species of *Staphylococcus*, only *Staphylococcus aureus* and *Staphylococcus epidermis* are known to be significant in their interactions with humans. *S. aureus* colonizes mainly the nasal passages, but it may be found regularly in most anatomical locales, including skin oral cavity, and gastrointestinal tract. *S. epidermis* is an inhabitant of the skin. Examples of Staphylocci treatable with the lipid-based glycopeptide antibiotic composition of the present invention, include, but are not limited to, *S. aureus, S. auricularis, S. carnosus, S. epidermidis, S. haemolvticus, S. hyicus, S. intermedius, S. lugdunensis, S. saprophyticus, S. sciuri, S. simulans*, and *S. warneri*.

Streptococci are Gram-positive, non-motile cocci that divide in one plane, producing chains of cells. The Streptococci are a very heterogeneous group of bacteria. The primary pathogens include *S. pyrogenes* and *S. pneumoniae* but other species can be opportunistic. *S. pyrogenes* is the leading cause of bacterial pharyngitis and tonsillitis. It can also produce sinusitis, otitis, arthritis, and bone infections. Some strains prefer skin, producing either superficial (impetigo) or deep (cellulitis) infections. *S. pneumoniae* is the major cause of bacterial pneumonia in adults. Its virulence is dictated by its capsule. Toxins produced by streptococci include: streptolysins (S & O), NADase, hyaluronidase, streptokinase, DNAses, erythrogenic toxin (which causes scarlet fever rash by producing damage to blood vessels; requires that bacterial cells are lysogenized by phage that encodes toxin). Examples of Streptococci treatable with the lipid-based glycopeptide antibiotic composition of the present invention include, but are not limited to, *S. agalactiae, S. anginosus, S. bovis, S. canis, S. constellatus, S. dysgalactiae, S. equi, S. equinus, S. iniae, S. intermedius, S. mitis, S. mutans, S. oralis, S. parasanguinis, S. peroris, S. pneumoniae, S. pyogenes, S. ratti, S. salivarius, S. salivarius* ssp. *thermophilus, S. sanguinis, S. sobrinus, S. suis, S. uberis, S. vestibularis, S. viridans*, and *S. zooepidemicus*.

The genus *Enterococci* consists of Gram-positive, facultatively anaerobic organisms that are ovoid in shape and appear on smear in short chains, in pairs, or as single cells. *Enterococci* are important human pathogens that are increasingly resistant to antimicrobial agents. These organisms were considered previously part of the genus *Streptococcus* but have recently been reclassified into their own genus, called *Enterococcus*. To date, 12 species pathogenic for humans have been described, including the most common human isolates, *Enterococcus faecalis* and *Enterococcus faecium*. *Enterococci* cause between 5 and 15% of cases of endocarditis, which is treated best by the combination of a cell wall-active agent (such as penicillin or vancomycin) and an aminoglycoside to which the organism is not highly resistant; this characteristically results in a synergistic bactericidal effect. Examples of *Enterococci* treatable with the lipid-based glycopeptide antibiotic composition of the present invention include, but are not limited to, *E. avium, E. durans, E. faecalis, E. faecium, E. gallinarum*, and *E. solitarius*.

Bacteria of the genus *Bacillus* are acrobic, endospore-forming, gram-positive rods. The genus is one of the most diverse and commercially useful groups of microorganisms. Representatives of this genus are distributed widely in soil, air, and water where they are involved in a range of chemical transformations. Some *Bacillus* species are known to cause health problems in humans. For example, Anthrax is caused by *Bacillus anthracis*. Humans acquire the disease directly from contact with infected herbivores or indirectly via their products. The clinical forms include (1) cutaneous anthrax, from handling infected material; (2) intestinal anthrax, from eating infected meat; and (3) pulmonary anthrax from inhaling spore-laden dust. Several other *Bacillus* spp., in particular *B. cereus* and to a lesser extent *B. subtilis* and *B. licheniformis*, are associated periodically with bacteremia/septicemia, endocarditis, meningitis, and infections of wounds, the ears, eyes, respiratory tract, urinary tract, and

gastrointestinal tract. *Bacillus cereus* causes two distinct food poisoning syndromes: a rapid-onset emetic syndrome characterized by nausea and vomiting, and a slower-onset diarrheal syndrome. Examples of pathogenic *Bacillus* species whose infection is treatable with the lipid-based glycopeptide antibiotic composition of the present invention, include, but are not limited to, *B. anthracis, B. cereus*, and *B. coagulans*.

Corynebacteria are small, generally non-motile, Gram-positive, non sporulating, pleomorphic bacilli. They are chemoorganotrophic, aerobic, or facultatively anaerobic, and they exhibit a fermentative metabolism under certain conditions. *Corybacterium diphtheriae* is the etiological agent of diphtheria, an upper respiratory disease mainly affecting children. The virulence factors (i.e., diphtheria toxin) have been studied extensively. Examples of Corynebacterial species treatable with the lipid-based glycopeptide antibiotic composition of the present invention include, for example, but are not limited to, *Corynebacterium diphtheria, Corynebacterium pseudotuberculosis, Corynebacterium tenuis, Corynebacterium striatum*, and *Corynebacterium minutissimum*.

The bacteria of the genus *Nocardia* are Gram-positive, partially acid-fast rods, which grow slowly in branching chains resembling fungal hyphae. Three species cause nearly all human infections: *N. asteroides, N. brasiliensis*, and *N. caviae*. Infection is by inhalation of airborne bacilli from an environmental source (soil or organic material); the disease is not contagious. Skin lesions caused by *N. brasiliensis* often result from direct inoculation. *Nocardia* subverts antimicrobial mechanisms of phagocytes, causing abscess or rarely granuloma formation with hematogenous or lymphatic dissemination to the skin or central nervous system. Examples of Nocardial species treatable with the lipid-based glycopeptide antibiotic composition of the present invention, include, for example, but are not limited to, *N. aerocolonigenes, N. africana, N. argentinensis, N. asteroides, N. blackwelli, N. brasiliensis, N. brevicatena, N. carnea, N. caviae, N. cerradoensis, N. corallina, N. cyriacigeorgica, N. dassonvillei, N. elegans, N. farcinica, N. nigiitansis, N. nova, N. opaca, N. otitidis-cavarium, N. paucivorans, N. pseudobrasiliensis, N. rubra, N. transvelencesis, N. uniformis, N. vaccinii*, and *N. veterana*.

Clostridia are spore-forming. Gram-positive, anaerobes. Clostridia are rod-shaped, but when producing spores they appear more like drumsticks with a bulge at one end. There are three species of clostridia that cause widely recognized and often-deadly diseases. *C. tetani* is the etiological agent of tetanus, *C. botulinum* is the etiological agent of botulism, and *C. perfringens* is one of the etiological agents of gas gangrene. Tetanus is contracted through contact between spores of *C. tetani* and an open wound, such as stepping on a rusty nail. If an anaerobic environment is present, the spores will germinate. Tetanus is a neurological disease in which *C. tetani* releases an exotoxin called tetanus toxin, which blocks the release of neurotransmitters from the presynaptic membrane of inhibitory interneurons of spinal cord and brainstem of mammals that regulate muscle contraction. Examples of *Clostridium* species treatable with the lipid-based glycopeptide antibiotic composition of the present invention, include, for example, but are not limited to, *C. botulinum, C. tetani, C. difficile. C. perfringens*, and *C. sordellii*.

Listeria are non spore-forming, nonbranching Gram-positive rods that occur individually or form short chains. *Listeria* are intracellular pathogens that use host-produced actin filaments for motility within the host cell. *L. monocytogenes* is the causative agent of listeriosis. *L. monocytogenes* is a food-borne pathogen, which can survive normal refrigeration processes. It can cause severe disease in immunocompromised individuals, and pregnant women. Examples of *Listeria* species treatable with the lipid-based glycopeptide antibiotic composition of the present invention, include, for example, but are not limited to, *L. grayi, L. innocua, L. ivanovii, L. monocytogenes, L. seeligeri, L. murrayi*, and *L. welshimeri*.

Other Examples of Gram-positive bacterial species, whose infection is treatable with the lipid-based glycopeptide antibiotic composition of the present invention, include, but are not limited to, Methicillin-resistant *Staphylococcus aureus* (MRSA), *Escherichia coli, Klebsiella, Enterobacter, Serratia, Haemophilus, Yersinia pesos, Burkholderia pseudomallei, Burkholderia cepacia, Burkholderia gladioli, Burkholderia multivorans, Burkholderia vietnamiensis, Mycobacterium tuberculosis, Mycobacterium avium* complex (MAC) (*Mycobacterium avium* and *Mycobacterium intracellulare*), *Mycobacterium kansasii, Mycobacterium xenopi, Mycobacterium marinum, Mycobacterium mucogenicum, Mycobacgerium gordonae, Mycobacterium ulcerans*, and *Mycobacterium fortuitum* complex (including, but not limited to, *Mycrobacterium fortuitum, Mycrobacterium peregrinum, Mycrobacterium chelonae, Mycrobacterium abscessus*, and *Mycrobacterium mucogenicum*.

Methicillin-resistant *Staphyloccus aureus* (MRSA) is a type of *staphylococcus* bacteria that is resistant to certain antibiotics called beta-lactams. These antibiotics include methicillin and other more common antibiotics such as oxacillin, penicillin, and amoxicillin.

Mycobacteria are non-motile, pleomorphic rods, related to the *Actinomyces*. They are relatively impermeable to various basic dyes but once stained, they retain the dyes with tenacity. They resist decolorization with acidified organic solvents and are therefore called acid-fast. They may appear to be Gram positive, but they take up the stain weakly and irregularly and without requiring iodine treatment to retain it.

On the basis of growth rate, catalase and niacin production, and pigmentation in light or dark, *mycobacteria* are classified into members of the *Mycobacterium tuberculosis* complex (including, but not limited to, *M. tuberculosis. M. bovis, Mycobacterium bovis* BCG, *Mycobacterium africanum, Mycobacterium microti, Mycobacterium canettii, Mycobacterium caprae*, and *Mycobacterium pinnipedii*) and nontuberculous species. Most *Mycobacteria* are found in habitats such as water or soil. However, a few are intracellular pathogens of animals and humans. *Mycobacterium tuberculosis*, along with *M. bovis, M. africanum*, and *M. microti,* all cause the disease known as tuberculosis (TB). Each member of the TB complex is pathogenic, but *M. tuberculosis* is pathogenic for humans while *M. bovis* is usually pathogenic for animals. Tuberculous *mycobacteria* enter the alveoli by airborne transmission. They resist destruction by alveolar macrophages and multiply, forming the primary lesion or tubercle; they then spread to regional lymph nodes, enter circulation, and reseed the lungs. Tissue destruction results from cell-mediated hypersensitivity.

Mycobacterium abscessus is part of the *Mycobacterium fortuitum* complex, a group of rapidly-growing *Mycobacteria* that are ubiquitous in the environment (soil and water). *Mycobacterium fortuitum* complex, for example, includes: *Mycobacterium fortuitum, Mycobacterium peregrinum, Mycobacterium chelonae, Mycobacterium abscessus*, and *Mycobacterium mucogenicum. Mycobacterium fortuitum* complex isolates are responsible for almost all human infec-

tions caused by rapidly-growing *Mycobacteria*. Infections range from localized wound infections to respiratory disease to serious disseminated infections. *Mycobacterium abscessus* usually causes respiratory and soft tissue/skin infections.

Mycobacterium avium complex (MAC) is a commonly isolated group of *Mycobacteria* and is widely distributed in nature (water, soils, birds and other animals and dust). The *M. avium* complex includes *M. avium* and *M. intracellulare*. Infections in immunocompetent patients are usually pulmonary; infections in immunosuppressed patients (e.g., patients who contracted AIDS or patients whose CD4+ cell counts are less than 200) are usually disseminated. MAC isolates are often drug resistant and difficult to treat; treatment is only recommended for the immunosuppressed and in cases of repeated isolation where clinical symptoms exist.

Mycobacterium chelonae is part of the *Mycobacterium fortuitum* complex, a group of rapidly-growing *Mycobacteria* that are ubiquitous in the environment (soil and water). *Mycobacterium chelonae* usually causes soft tissue and skin infections. It is necessary to differentiate the *Mycobacterium fortuitum* group (*Mycobacterium fortuitum* and *Mycobacterium peregrinum*) from *Mycobacterium chelonae* and *Mycobacterium abscessus* as the latter two species of the complex are very resistant to anti-mycobacterial drug therapies.

Mycobacterium fortuitum and *Mycobacterium peregrinum* are part of the *Mycobacterium fortuitum* complex. *Mycobacterium fortuitum* complex includes: *Mycobacterium fortuitum, Mycobacterium peregrinum, Mycobacterium chelonae, Mycobacterium abscessus*, and *Mycobacterium mucogenicum. Mycobacterium fortuitum* complex isolates are responsible for almost all human infections caused by rapidly-growing *Mycobacteria*. The spectrum of diseases caused by these organisms includes soft-tissue abscesses, sternal wound infections after cardiac surgery, prosthetic valve endocarditis, disseminated and localized infection in haemodialysis and peritoneal dialysis patients, pulmonary disease, traumatic wound infection, and disseminated disease often with cutaneous lesions.

Mycobacterium kansasii is a significant cause of chronic pulmonary disease in humans, which resembles the disease caused by *Mycobacterium tuberculosis*. In contrast to *Mycobacterium tuberculosis* infection, however, there is minimal risk of human to human transmission. Risk factors often predispose infection (underlying pulmonary disease, cancer, alcoholism, and the like). *Mycobacterium kansasii* is commonly isolated from water samples; infection is thought to be via aerosol route. *Mycobacterium kansasii* is the second most common cause of mycobacterial infection in AIDS patients (after *Mycobacterium avium* complex).

Mycobacterium marinum is a fish pathogen found in environmental waters. It grows best below 33° C. and causes a tuberculosis-like disease in fish and a chronic skin lesion known as "swimming pool granuloma" in humans. Infection is acquired by injury of a limb around a home aquarium or marine environment and can lead to a series of ascending subcutaneous abscesses. *M. marinum* resembles *M. kansasii* in being photochromogenic. *M. marinum* varies in susceptibility to antimicrobial agents.

Previously termed "*Mycobacterium chelonae*-like organisms (MCLO)" *Mycobacterium mucogenicum* is part of the *Mycobacterium fortuitum* complex. *Mycobacterium mucogenicum* is the rare cause of human disease; it is estimated that most respiratory isolates are non-pathogenic (except in immunocompromised patients) while most non-respiratory isolates are pathogenic (usually wound infections). *Mycobacterium mucogenicum* isolates have a mucoid appearance on laboratory media.

Mycobacterium scrofulaceum is a common cause of lymphadenitis in children aged 1 to 3 years. Lymphadenitis usually involves a single node or a cluster of nodes in the submandibular area. Characteristically, the nodes enlarge slowly over a period of weeks. There are very few local or systemic symptoms. Untreated, the infection will usually point to the surface, rupture, form a draining sinus and eventually calcify. Infection in other tissues occurs occasionally. A very few cases resembling progressive primary tuberculosis have been encountered in children. In children, metastatic bone disease may be prominent. Colonies are usually yellow-orange even when grown in the dark (scotochromogenic). They are usually resistant to antituberculosis drugs in vitro.

Mycobacterium ulcerans, found mainly in Africa and Australia, grow only below 33° C. It causes chronic deep cutaneous ulcers in man and usually produces lesions in the cooler parts of the body. *Mycobacterium ulcerans* has a unique drug sensitivity pattern, i.e., resistance to INH and ethambutol and susceptibility to streptomycin and rifampin. Human disease responds poorly to drug treatment and extensive excision followed by skin grafting is often necessary.

Studies have suggested that the source of human *Mycobacterium xenopi* infection is aerosolized water, similar to *Mycobacterium avium* complex. *Mycobacterium xenopi* is not as ubiquitous in all water supplies as *Mycobacterium avium*, preferring to grow in hot water supplies. For immunocompetent patients, pulmonary disease is most common; risk factors include underlying lung disease, heavy smoking, alcohol abuse and exposure to water containing these *Mycobacteria*. AIDS is another risk factor for *Mycobacterium xenopi* infection, often leading to disseminated infection in these patients.

The subject or patient in need of treatment, in one embodiment, has a pulmonary disease. In one embodiment, the pulmonary disease is cystic fibrosis, bronchiectasis, pneumonia, or chronic obstructive pulmonary disease (COPD).

In another embodiment, the subject or patient in need of treatment has osteomyelitis. In another embodiment, the subject or patient in need of treatment has endocarditis, bronchitis, hepatitis, myocarditis, and/or nephritis. In another embodiment, the subject or patient in need of treatment has bacteremia. In another embodiment, the subject or patient in need of treatment has a skin or connective tissue infection, including, but not limited to, folliculitis, cellulitis, furuncules, or pymyositis. In another embodiment, the subject or patient in need of treatment has a wound or surgical site infection.

The therapeutic agents in the compositions of the present invention are delivered in therapeutically effective amounts. Combined with the teachings provided herein, by choosing among the various active compounds and weighing factors such as potency, relative bioavailability, patient body weight, severity of adverse side-effects and mode of administration, an effective prophylactic or therapeutic treatment regimen may be planned which does not cause substantial toxicity and yet is effective to treat the particular subject. The effective amount for any particular application may vary depending on such factors as the disease or condition being treated, the particular therapeutic agent(s) being administered, the size of the subject, or the severity of the disease or condition. One of ordinary skill in the art may determine empirically the effective amount of a particular therapeutic agent(s) without necessitating undue experimentation. In one embodiment, the highest safe dose according to some

medical judgment is employed. The terms "dose" and "dosage" are used interchangeably herein.

For any compound described herein the therapeutically effective amount may be initially determined from preliminary in vitro studies and/or animal models. A therapeutically effective dose also may be determined from human data for therapeutic agent(s), which have been tested in humans and for compounds, which are known to exhibit similar pharmacological activities, such as other related active agents. The applied dose may be adjusted based on the relative bioavailability and potency of the administered compound. Adjusting the dose to achieve maximal efficacy based on the methods described above and other methods is well within the capabilities of the ordinarily skilled artisan.

According to some embodiments, the stabilized lipid-based glycopeptide antibiotic is administered in an amount greater than a minimum inhibitory concentration (MIC) for the pulmonary infection. For example, the MIC of the pulmonary infection is at least about 0.10 micrograms/mL, about 0.10 to 10 micrograms/mL, or about 0.10 to 5 micrograms/mL.

According to another embodiment, following administration of the stabilized lipid-based glycopeptide antibiotics, the Log_{10} CFU (colony-forming unit) in the lung of the subject, or in sputum or tissue collected from the lung, are reduced. Log_{10} CFU is the log value of colony-forming unit (CFU). In microbiology, colony-forming unit (CFU or cfu) refers to a measure of viable bacterial numbers. Unlike direct microscopic counts where all cells, dead and living, are counted, CFU measures viable cells. According to some embodiments, following administration of the stabilized lipid-based glycopeptide antibiotics, the Log_{10} CFU in the lung of the subject can be reduced by at least about 0.5, about 1.0, about 1.5, about 2.0, or about 2.5. According to another embodiment, the total CFU in the lung is less than about 1.0, about 0.75, about 0.5, or about 0.25 after administration of the stabilized lipid-based glycopeptide antibiotic formulation. According to another embodiment, the pulmonary infection in the lung of the subject is reduced following administration of the stabilized lipid-based glycopeptide antibiotics. According to another embodiment, the pulmonary infection in the lung of the subject is eradicated following administration of the stabilized lipid-based glycopeptide antibiotics. According to another embodiment, the pulmonary infection is reduced more than by inhalation treatment with the same dose of free glycopeptide antibiotic. According to another embodiment, the rate of reduction or eradication of the pulmonary infection in a population of subjects is higher with treatment with the lipid based glycopeptide antibiotic formulation when compared to a population treated with the same dose of free inhaled glycopeptide antibiotic. According to another embodiment, the reduction of infection across a population treated with the inhaled stabilized glycopeptide antibiotic formulation is at least about 20, about 30, about 40, about 50, about 70, about 80, or about 90% greater when compared to treatment with inhaled free glycopeptide antibiotic. According to another embodiment, the pulmonary infection is reduced in a shorter period of time when compared to treatment with the same dose of inhaled free vancomycin. According to another embodiment, the time to recurrence of pulmonary infection or need for medical intervention is extended to a longer period of time when compared to treatment with the same dose of inhaled free vancomycin.

According to another embodiment, the stabilized lipid-based glycopeptide antibiotic of the described invention can be administered by inhalation as a nebulized spray, powder, or aerosol, or by intratracheal administration. According to another embodiment, the administration is less frequent and/or has an enhanced therapeutic index compared to inhalation of the free drug or a parenteral form of the drug. Additionally, the time for administering the desired therapeutic dose of glycopeptide antibiotic is reduced compared to inhalation of the free drug. Thus, in some embodiments, the lipid-based glycopeptide antibiotic formulation is more effective than inhalation of the same amount of the free drug. Liposomes or other lipid formulations are particularly advantageous due to their ability to protect the drug while being compatible with the lung lining or lung surfactant. While not being bound by any particular theory, it is believed that the lipid-based glycopeptide antibiotic formulation of the present invention has a depot effect in the lung. As such, the lipid-based glycopeptide antibiotic maintains its therapeutic bioavailability for a period of time after administration by inhalation is complete. According to some embodiments, this period of time is longer than the amount of time that free glycopeptide antibiotic remains therapeutically available. For example, the therapeutic bioavailability of the lipid-based glycopeptide antibiotic may be longer than 3, 4, 5, 6, 7, 8, 9 or 10 days after treatment, or even longer than two weeks after administration.

According to some embodiments, at least about 25% of the glycopeptide antibiotic is associated with the liposome after nebulization. According to another embodiment, at least about 50% or at least about 60% of the glycopeptide antibiotic is associated with the liposome after nebulization. According to another embodiment, about 50 to 95%, about 50 to 80% or about 60 to 75% of the glycopeptide antibiotic is associated with the liposome after nebulization.

According to some embodiments, the stabilized lipid-based glycopeptide antibiotic is administered intravenously, subcutaneously, orally, nasally, intraperitoneally, sublingually, bucally, transdermally, by subcutaneous or subdermal implantation, or intramuscularly.

According to some embodiments, the stabilized lipid-based glycopeptide antibiotic is administered by injection. According to further embodiments, the stabilized lipid-based glycopeptide antibiotic is administered by intravenous injection. According to another embodiment, the administration is less frequent and/or has an enhanced therapeutic index compared to injection of the free drug or a parenteral form of the drug. Additionally, the time for administering the desired therapeutic dose of glycopeptide antibiotic is reduced compared to injection of the free drug. Thus, in some embodiments, the lipid-based glycopeptide antibiotic formulation is more effective than injection of the same amount of the free drug. According to another embodiment, the time to recurrence of a bacterial infection or need for medical intervention is extended to a longer period of time when compared to treatment with the same dose of injected free vancomycin. According to some embodiments, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 50 to 1000 mg/day, about 100 to 500 mg/day, or about 250 to 500 mg/day. According to another embodiment, the dose is about 100 mg/day. According to another embodiment, the dose is about 200 mg, about 300 mg, about 400 mg, or about 500 mg per day.

According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of from about 0.000001 mg/kg body weight to about 10 g/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of from about 0.000002 mg/kg body weight to about 10 g/kg body weight. According to another

embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of from about 0.000003 mg/kg body weight to about 10 g/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of from about 0.000004 mg/kg body weight to about 10 g/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of from about 0.000005 mg/kg body weight to about 10 g/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of from about 0.000006 mg/kg body weight to about 10 g/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of from about 0.000007 mg/kg body weight to about 10 g/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of from about 0.000008 mg/kg body weight to about 10 g/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of from about 0.000009 mg/kg body weight to about 10 g/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of from about 0.00001 mg/kg body weight to about 10 g/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of from about 0.00002 mg/kg body weight to about 10 g/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of from about 0.0003 mg/kg body weight to about 10 g/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of from about 0.00004 mg/kg body weight to about 10 g/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of from about 0.00005 mg/kg body weight to about 10 g/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of from about 0.00006 mg/kg body weight to about 10 g/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of from about 0.00007 mg/kg body weight to about 10 g/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of from about 0.00008 mg/kg body weight to about 10 g/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of from about 0.00009 mg/kg body weight to about 10 g/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of from about 0.0001 mg/kg body weight to about 10 g/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 0.0005 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 0.001 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 0.005 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 0.01 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 0.1 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 1 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 10 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 20 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 30 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 40 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 50 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 60 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 70 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 80 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 90 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 100 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 110 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 120 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 130 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 140 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 150 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 160 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 170 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 180 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 190 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 200 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 250 mg/kg body weight. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered at a dose of about 500 mg/kg body weight.

According to some embodiments, the stabilized lipid-based glycopeptide antibiotic composition is administered

intratracheally. According to another embodiment, the stabilized lipid-based glycopeptide antibiotic composition is administered via inhalation. According to some embodiments, the stabilized lipid-based glycopeptide antibiotic composition is administered via a nebulizer. According to another embodiment, administering occurs parenterally. According another embodiment, administering occurs intravenously. According to another embodiment, administering occurs intramuscularly. According to another embodiment, administering occurs intraperitoneally.

According to another embodiment, the composition is administered 1 time to 4 times a day. According to another embodiment, the composition is administered once a day, twice a day, three times a day or four times a day. According to another embodiment, the composition is administered in a daily treatment cycle for a period of time, or is administered in a cycle of every other day, every third day, every fourth day, every fifth day, every 6th day or once a week for a period of time, the period of time being from one week to several months, for example, 1, 2, 3, or 4 weeks, or 1, 2, 3, 4, 5, or 6 months.

The described invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof and, accordingly, reference should be made to the appended claims, rather than to the foregoing specification, as indicating the scope of the invention.

EXAMPLES

The following examples are put forth so as to provide those of ordinary skill in the art with a complete disclosure and description of how to make and use the present invention, and are not intended to limit the scope of what the inventors regard as their invention nor are they intended to represent that the experiments below are all or the only experiments performed. Unless indicated otherwise, parts are parts by weight, molecular weight is weight average molecular weight, temperature is in degrees Centigrade, and pressure is at or near atmospheric.

Example 1. Vancomycin Stability in Aqueous Solution Reagents and Equipment

Cholesterol (Cat. No. 700000P) and dipalmitoylphosphatidylcholine (DPPC, Cat. No. 850355P) were purchased from Avanti Polar Lipids Certified Reference Standard. Vancomycin Chloride (Lot HVN0701303) was purchased from North China Pharmaceutical Group. Methanol (HPLC grade, Cat No. AH230-4), Acetonitrile (HPLC grade), Ammonium Hydroxide (HPLC grade) were purchased from Burdick & Jackson. Glacial Acetic Acid (HPLC grade; JT9515-3) and Sodium Chloride (ACS Reagent; Cat. No. 3628-05) were purchased from JT Baker. Purified water was prepared by using Milli-Q 18.0 MΩ water.

High Performance Liquid Chromatography (HPLC) is from Shimadzu (10 AVP equipped UV-detector and CORONA Charged Aerosol Detector (CAD) and HPLC software is from LC Solutions™. Refrigerated multipurpose centrifuge (5810R) is from Eppendorf (Westbury, N.Y.).

Vancomycin Normal Phase HILIC HPLC Assay

A vancomycin Normal Phase HILIC HPLC assay was performed using a Shimadzu 10AVP HPLC system equipped with UV detector (CAD optional) under the following conditions:

Column: ZIC-HILIC 150×4.6 mm, 3.5 um, 200 A (SeQuant)

Column temperature: 30 C

Mobile phase: Acetonitrile 37%, Methanol 24%, water 39%, Acetic acid 0.08%, Ammonium hydroxide 0.02%

Flow rate: 0.5 mL/min, Isocratic

Injection volume: 20 μL

Samples are dissolved in mobile phase. A mix of mobile phase with n-propanol 4:1 can be used when preparing lipid containing samples.

Vancomycin standards: useful range 10-200 mg/mL, dissolved in mobile phase. Calibration curve is fitted by a linear function

UV detector: Wavelength 280 nm

Chromatogram: retention time for

CDP-I-M: about 14 min

CDP-I-m: about 16 min

Vancomycin: about 24 min

additional major peaks are at: 20, 22, 27 min. Total recording time 35 min

Vancomycin Reverse Phase HPLC Assay

A vancomycin Reverse phase HPLC assay (which cannot be used for lipid containing samples) was performed using a Shimadzu 10AVP HPLC system equipped with UV detector (CAD optional) under the following conditions:

Column: Atlantis-® dC18, 5μ, 250×4.6 mm (Waters)

Mobile phase A: acetonitrile 5%, ammonium acetate 15 mM, pH 6.0. Mobile phase B: acetonitrile 20%, ammonium acetate 15 mM, pH 6.0. Ammonium acetate 1 M solution pH 6.0: approximately 6% glacial acetic acid (1 M) and 9% ammonium hydroxide 30% solution.

Flow rate: 1 mL/min, Binary gradient

Time (minutes)	Solvent B (%)
0	15
15	20
25	35
35	60
40	100
45	100
50	15
55	15

Injection volume: 20 ILL

Samples are dissolved in mobile phase.

Vancomycin standards: useful range 10-200 mg/mL, dissolved in mobile phase. Calibration curve is fitted by a linear function

UV detector: Wavelength 280 nm

Chromatogram: retention time for

CDP-I-M: about 7 min

CDP-I-m: about 16 min

Vancomycin: about 26 min

Total recording time 55 min

Vancomycin Assay by UV-Vis

The samples to be analyzed were dissolved in n-propanol/H_2O solution (60/40, vol/vol) so that the final vancomycin HCl concentrations were between 0 μg/ml and 200 μg/ml. Pre-dilution with H_2O may be necessary if the vancomycin concentration in the original sample is >10 mg/mL. The concentrations of the samples were calculated by comparing their absorbance at 280 nm with that of a linear standard curve (standards were prepared from raw material at 0, 50, 100, 150 and 200 g/ml).

Alternatively, samples were dissolved in the mobile phase used for the HILIC HPLC method mixed with n-propanol at 3:1 vol. In the latter case, the vancomycin extinction coefficient was 5.4 mg/mL^{-1} cm^{-1}, or about 7800 M^{-1} cm^{-1} (1 A per 185 μg/ml)

Lipid HPLC Assay

A lipid HPLC assay was performed using a Shimadzu 10AVP HPLC system equipped with a Corona Charge Aerosol Detector (CAD) under the following conditions and parameters:

Column: Phenomenex Luna 3μ, C8(2), 75×4.6 mm
Column temperature: 30° C.
Mobile phase: Acetonitrile 43%, n-Propanol 43%, water 14%, Acetic acid 0.1%, TEA 0.1%
Flow rate: 1 mL/min, Isocratic
Injection volume: 20 μL
Samples were dissolved in Solution A: Acetonitrile 30%, n-Propanol 30%, water 40%
Lipid standards (DPPC/Cholesterol 20/10, 30/15, and 40/20 μg/mL)
Calibration is fitted by a linear function
Chromatogram: retention time for cholesterol~4 min, DPPC~6 min, total recording time 10 min

Samples of Vancomycin Solution for Stability Study

Vancomycin solution samples (1 mL of 200 mg/mL) were put in 4 mL glass vials and incubated at the indicated temperature. Selected samples were also incubated at a lower concentration (20 mg/mL).

Normal Phase HILIC HPLC Assay for Vancomycin

Previously, a reverse phase HPLC assay was developed and used in the first study on development of liposomal vancomycin (U.S. Publication No. US 2009-0104257, entitled "Liposomal Vancomycin Formulations," which is incorporated herein by reference in its entirety). The method employed an Atlantis® dC18 column (Waters) and used a binary mobile phase gradient with Acetonitrile concentration changing 7% to 20% in water. The mobile phase, however, was too polar to dissolve lipid containing samples. Organic phase extraction was tried but had challenges.

In the present invention, a new assay, i.e., Normal phase HILIC (Hydrophilic Interaction Liquid Chromatography) HPLC assay was developed. The new assay utilizes a ZIC-HILIC column (SeQuant) and separates compounds by polar differences. Moreover, the HILIC method can use less polar mobile phase and thus is able to dissolve both vancomycin and lipid (see Materials and Methods section). Particularly, the mobile phase was selected as: Acetonitrile 37%, Methanol 24%, water 39%. Acetic acid 0.08%, Ammonium hydroxide 0.02%. The drawbacks of this method are: high (but manageable) sensitivity to mobile phase composition, and wider peaks compared to RP assay. See FIG. **4** for a typical chromatograph.

Chemical Stability of Vancomycin in Aqueous Solution

Samples of vancomycin solutions at a concentration of 200 mg/mL and pH 5.0, 5.5, 6.0, and 6.5 were prepared by adding the appropriate amount of NaOH solution (50 mM or 100 mM). In buffered samples, an appropriate amount of buffer or amino acid additive was added. The pH values were chosen to cover the range between the lowest and highest acceptable values of pH, including pH 5.0 for lipid stability reasons and pH 6.5, above which degradation is expected to be impractically fast.

The concentration of 200 mg/mL was chosen to mimic what a high intra-liposomal might be but was no higher than this for practical handling purposes. All samples were liquid solutions upon preparation. During incubation, most samples turned into a gel-like consistency and later solidified further into a wax-like form. In some samples with a high level of degradation, crystal granules were observed embedded in the formed gel.

The Experiment was started with vancomycin samples, in which pH was adjusted by adding NaOH or an organic base (e.g., Tris-base, Ethanol Amine (EOA), or Tri-Ethanol Amine (TEOA)) as shown in Table 7. For comparison, lower concentration solutions (20 mg/mL) also were prepared by diluting 200 mg/mL samples 10-fold in water. Samples were incubated at 4° C. (in refrigerator) and at ambient temperature (about 23° C., which is referred herein to as "room temperature" or "RT").

TABLE 7

Samples with pH adjusted by NaOH or organic bases

Base Used	pH	Base added mol/mol
NaOH	5.0	0.16
	5.5	0.18
	6.0	0.20
	6.5	0.28
TRIS	6.0	0.22
	6.5	0.31
TEOA	6.0	0.23
EOA	6.5	0.30

TEOA (Tri-Ethanol amine),
EOA (Ethanol amine)

TABLE 8

Degradation of vancomycin: Effect of pH, presence of organic buffers, ethanol, and ammonium ions, Temperature = 4° C.

	(CDPI-m + CDPI-M) % at week:						Slope	
Sample	0	1	2	4	8	12	%/w	R^2
200 mg/mL								
NaOHpH5	0.5	0.68	0.74	0.93	1.40	1.54	0.09	0.97
NaOHpH55	0.5	0.73	1.07	1.11	1.67	2.39	0.15	0.98
NaOHpH6	0.5	0.74	1.38	1.69	2.60	2.90	0.20	0.94
NaOHpH65	0.5	1.07	1.66	2.55	5.78	4.46	0.39	0.78
NaOHpH5 + NH4Cl	0.5	0.77	0.80	0.92	1.60	1.77	0.11	0.96
NaOHpH6	0.5	0.74	1.38	1.69			0.31	0.92
NaOHpH6 + EtOH	0.5	0.67	1.19	2.28			0.46	0.97
TrispH6	0.5	0.69	1.47	1.82			0.35	0.91
TEOApH6	0.5	0.79	1.04	2.11			0.40	0.97
EOApH6	0.5	0.79	1.22	2.19			0.43	0.99
NaOHpH6.5	0.5	1.07	1.66	2.55			0.51	0.99
NaOHpH6.5 + EtOH	0.5	0.93	2.06	2.15			0.43	0.81
TrispH6.5	0.5	1.32	2.20	2.78			0.56	0.93
TEOApH6.5	0.5	1.15	1.78	2.87			0.59	1.00
EOApH6.5	0.5	0.98	1.94	3.08			0.66	0.99
20 mg/mL								
NaOHpH5	0.5	0.90	1.24	1.69	3.29	4.52	0.34	1.00
NaOHpH55	0.5	1.23	1.34	2.29	3.59	4.80	0.35	0.99
NaOHpH6	0.5	1.34	1.61	2.09	3.09	3.31	0.22	0.90
NaOHpH65	0.5	1.11	2.05	2.97	2.16	2.42	0.12	0.38

A higher concentration and lower pH, vancomycin was more stable (Table 8, FIG. **5**). At low concentration, the effect seemed to be unclear or even reversed. The main difference in low and high concentration samples was their physical state. At high concentration vancomycin over time formed a gel-like structure. At low concentration, it stayed liquid until a white precipitate started to form. Excluding sodium ions and using instead organic buffer bases to adjust pH did not change degradation kinetics noticeably (FIG. **6**).

Overall, the summary plot in FIG. **7** shows that at high concentration and low pH vancomycin can be somewhat stable with a degradation rate of about 0.1% per week. This, however, is not believed to be good enough to develop a

practical commercial product. Addition of an equimolar amount of ammonium ions (NH_4Cl) did not improve vancomycin stability. Ethanol at 10% efficiently prevented vancomycin gelation and precipitation, but again did not slow down its degradation rate.

At room temperature, degradation rates were about tenfold higher but the data showed greater variability (Table 9 and FIGS. **8-10**).

TABLE 9

The Effect of pH, presence of organic buffers, ethanol, and ammonium ions on degradation of vancomycin at room temperature (RT)

	(CDPI-m + CDPI-M) % at week:						Slope	
Sample	0	1	2	4	8	12	%/w	R^2
200 mg/mL								
NaOHpH5	0.5	1.34	2.47	6.28	10.37	17.3	1.39	0.99
NaOHpH55	0.5	1.86	3.30	5.97	11.0	16.2	1.30	1.00
NaOHpH6	0.5	2.04	3.23	6.66	14.0		1.69	1.00
NaOHpH65	0.5	3.16	5.36	11.1	11.8		1.42	0.83
NaOHpH5 + NH4Cl	0.5	1.49	1.99	3.63	9.4		1.10	0.97
NaOHpH6	0.5	2.04	3.23	6.66			1.53	1.00
NaOHpH6 + EtOH	0.5	2.27	3.65	5.86			1.32	0.99
TrispH6	0.5	2.25	4.23	11.9			2.88	0.96
TEOApH6	0.5	2.85	5.12	7.36			1.70	0.96
EOApH6	0.5	2.45	5.79	7.38			1.75	0.92
NaOHpH6.5	0.5	3.16	9.65	11.1			2.77	0.86
NaOHpH6.5 + EtOH	0.5	2.92	4.51	7.87			1.80	0.99
TrispH6.5	0.5	3.32	5.05	8.16			1.86	0.98
TEOApH6.5	0.5	3.38	7.97				3.73	0.98
EOApH6.5	0.5	3.70	8.25	9.79			2.34	0.88
Temp RT								
NaOHpH5	0.5	2.12	2.87	6.03	10.8	19.5	1.53	0.98
NaOHpH55	0.5	2.22	4.44	5.15	5.08	13.6	0.89	0.84
NaOHpH6	0.5	2.80	4.89	7.97	9.85		1.13	0.89
NaOHpH65	0.5	4.16	9.65	10.8	11.3		1.20	0.64

There was no clear effect of buffers, ammonium ions, or added ethanol. The high variability in data might be explained by the non-homogeneous nature of samples after long incubation at room temperature. Samples solidified and exhibited a number of crystalline granules embedded within. Taking an aliquot of sample for analysis often resulted in getting a portion of sample of varying consistency.

Example 2. Effect of Amino Acid Additives on Chemical Stability of Vancomycin

It has been known that some peptides as short as two or three amino acids can bind tightly to vancomycin and thus stabilize its structure against deamidation (Harris et al., 1985, J. Antibiot, 38(1):51-7). Two such peptides have been identified, i.e., Ac-D-Ala-D-Ala and Di-Ac-L-Lys-D-Ala-D-Ala. While they potentially could be used to provide improved vancomycin stability, they are not cost-effective means of improving vancomycin stability.

Below is a list of amino acids identified for testing (Table 10). Amino acids were added on a mole per mole base unless otherwise stated. Final pH was adjusted to pH 5.0 or pH 5.5 where indicated by adding an appropriate amount of NaOH. Samples at a concentration 200 mg/mL were placed 1 mL each into 4 mL glass vials and incubated at a certain controlled temperature. Samples were analyzed by HILIC HPLC, and CDP % was calculated as a sum of CDP-I-m and CDP-1-M % to total vancomycin and its products.

TABLE 10

Amino Acids And Derivatives Used In Stability Study.

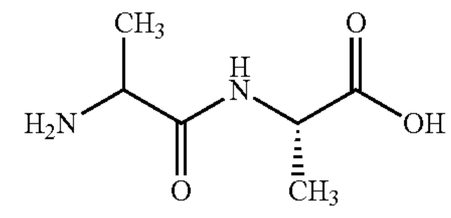
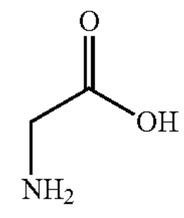
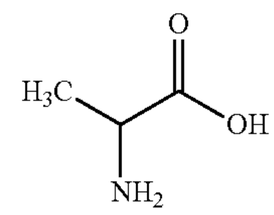
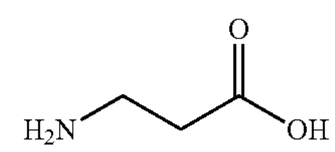
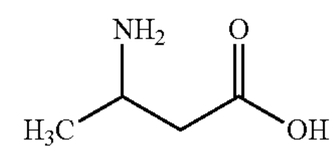
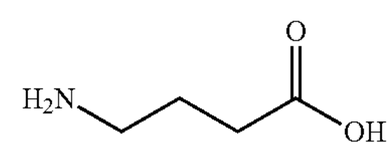
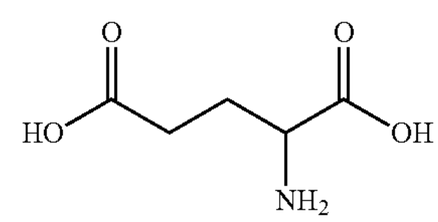
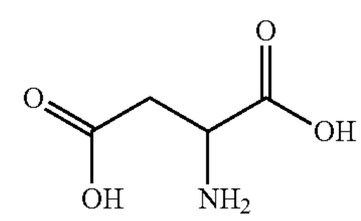
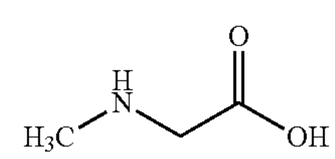
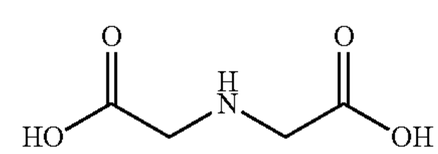
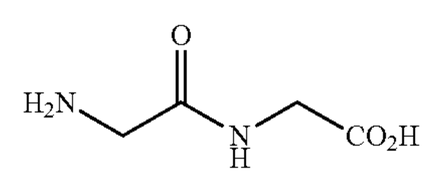
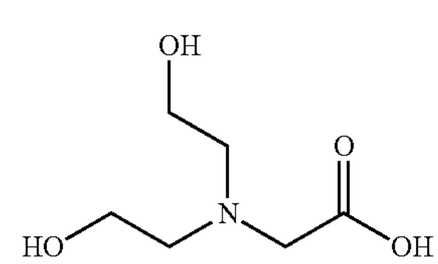
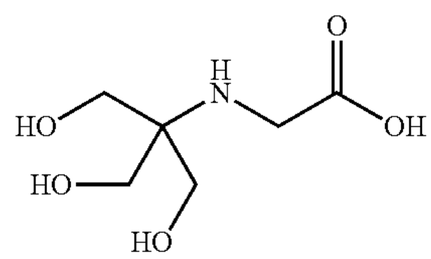
Amino acid	Chemical structure
ALA-ALA	
GLY, Glycine	
ALA, Alanine 2-Aminopropionic acid	
bALA, beta-Alanine 3-Aminopropionic acid	
3-ABA 3-Aminobutanoic acid	
GABA 4-Aminobutanoic acid	
GLU, Glutamic acid 2-Aminopentanedioic acid	
ASP, Aspartic acid 2-Aminobutanedioic acid	
Sarcosine N-Methylglycine	
IDAA Iminodiacetic acid	
GLY-GLY Glycyl-glycine	
Bicine	

TABLE 10-continued

Amino Acids And Derivatives Used In Stability Study.

Amino acid	Chemical structure
Tricine	

A detailed stability data table at 4° C. is presented in Table 11 and FIG. **11**. A significant difference was found in the rate of degradation, with the worst rate found for samples incubated with L-ALA, b-ALA, 3-ABA, and GLY. At the same time, great improvement was seen when using Bicine, Imino-diacetic acid (IDAA), glycylglycine (GLY-GLY), and GLU at 2:1 mol ratio with vancomycin. A rate of as low as 0.01% per week was observed for some compounds, including Bicine, IDAA, and GLY-GLY. In comparison, control compounds that do not comprise an amino acid or derivative thereof exhibited a rate of 0.09%. Thus, the stabilized glycopeptide antibiotic composition comprising an amino acid such as, for example, Bicine. IDAA, or GLY-GLY was at least 88% more stable at 4° C. than a glycopeptide antibiotic that does not comprise an amino acid or derivative thereof.

TABLE 11

Degradation of vancomycin data table: Effect of amino additives at 4° C.

Amino acid	(CDPI-m + CDPI-M) % at week:						Slope
added	0	1	2	4	8	12	%/w
NaOHpH5	0.50	0.61	0.69	0.98	1.39	1.49	0.00
bALA	0.60	0.81	0.80	1.07	2.09	3.18	0.21
ALA	0.60	0.69	0.76	0.97	1.46	2.34	0.14
GABApH5.5	0.60	0.91	0.89	1.11	1.08	1.81	0.08
GLY	0.60	0.76	0.77	0.96	1.68	2.14	0.13
D-ALA	0.60	0.74	0.70	0.92	1.48	1.27	0.07
B-ABA	0.60	0.65	0.57	0.85	1.57	2.29	0.15
GLUt_NH3	0.60	0.83	0.72	0.84	1.44	2.08	0.12
D-GlUt	0.60	0.68	0.75	0.89	1.14	1.43	0.07
ASP	0.60	0.75	0.65	0.82	1.20	1.09	0.05
D-ASP	0.60	0.74	0.74	0.63	1.03	1.35	0.06
Bicine	0.60	0.66	0.58	0.61	0.77	0.67	0.01
Tricine	0.60	0.62	0.78	0.69	1.02	1.32	0.06
Sarcosine	0.54	0.69	0.70	1.11	1.08		0.07
IDAA	0.50	0.54	0.66	0.74	0.56		0.01
GLY-GLY	0.60	0.66	0.50	0.66	0.69		0.01
GLUt2pH5	0.60	0.61	0.67	0.86	0.92	0.87	0.03
GLUt2pH5.5	0.60	0.82	1.06	0.79	0.83	1.29	0.04

TABLE 12

Degradation of vancomycin data table: Rate of degradation at 4° C. with amino acid additives relative to control.

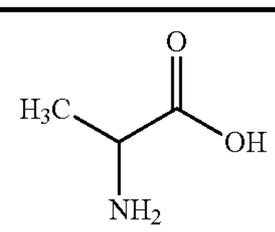
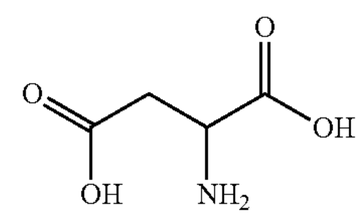
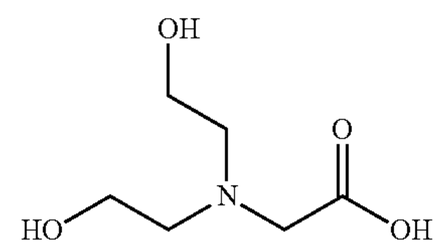
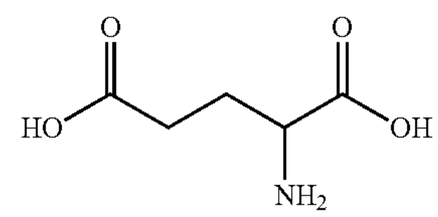
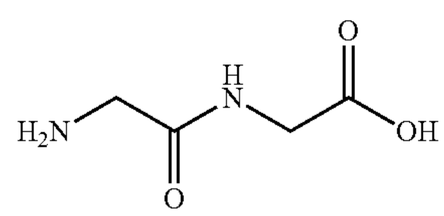
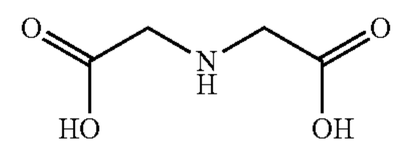
Amino acid	Structure	Rate of degradation relative to control
D-ALA D-Alanine		0.36% weight/week

TABLE 12-continued

Degradation of vancomycin data table: Rate of degradation at 4° C. with amino acid additives relative to control.

Amino acid	Structure	Rate of degradation relative to control
ASP Aspartic acid		0.42% weight/week
Bicine		0.18% weight/week
D-GLU D-Glutamic acid		0.37% weight/week
GLY-GLY Glycylglycine		0.31% weight/week
IDAA Iminodiacetic acid		0.24% weight/week

A similar study conducted for samples at room temperature is presented in Table 13 and FIG. **12**. Some of the amino acids that did not perform very well at 4° C. were much better in stabilizing vancomycin at room temperature. GABA, D-ALA, D-GLU, and ASP reduced degradation to about 0.2-0.4% per week, compared to about 1.4% per week in control. Thus, the stabilized glycopeptide antibiotic composition comprising amino acid or derivative thereof such as, for example, GABA, D-ALA, D-GLU, or ASP was about 71.4% to about 85.7% more stable at RT than a glycopeptide antibiotic that does not comprise an amino acid or derivative thereof.

TABLE 13

Degradation of vancomycin data table: Effect of amino acid additives at room temperature (RT).

	(CDPI-m + CDPI-M) % at week:						Slope	Ratio
Sample	0	1	2	4	8	12	%/w	Rt/4 C.
NaOHpH5	0.50	1.38	2.80	6.58	9.89	18.10	1.43	16.3
b-ALA	0.50	2.31	3.40	9.04	12.27	25.30	1.95	9.3
ALA	0.50	1.76	3.35	9.39	9.02	31.48	2.29	16.3
GABApH5.5	0.50	2.20	3.18	4.23	4.44	6.44	0.41	5.0
GLY	0.50	1.56	3.24	6.14	17.19	21.04	1.85	14.0
D-ALA	0.50	1.35	1.61	1.73	2.49	3.56	6.22	3.3
B-ABA	0.50	1.51	3.03	6.03	9.23	19.28	1.48	10.1
GLUt_NH3	0.50	1.54	5.20	4.05	7.42	10.22	0.71	6.1
B-GLUt	0.50	1.57	1.98	1.68	4.17	5.86	8.38	5.6
ASP	0.50	0.80	2.22	2.27	3.24	6.81	0.33	7.5
B-ASP	0.50	1.46	2.47	3.80	5.97	7.08	0.94	9.3
Bicine	0.50	0.89	1.47	3.21	6.26	10.96	8.89	89.4
Tricine	0.50	1.15	2.09	6.21	8.66	17.63	1.41	23.9

TABLE 13-continued

Degradation of vancomycin data table: Effect of amino acid additives at room temperature (RT).

	(CDPI-m + CDPI-M) % at week:						Slope	Ratio
Sample	0	1	2	4	8	12	%/w	Rt/4 C.
Sarcosine	0.54	1.17	2.33	6.48	11.47		1.44	19.8
IDAA	0.50	2.29	2.76	5.39	10.07		1.17	145
GLY-GLY	0.66	0.72	1.24	2.80	5.92		0.69	60.3

The ratio of the rate of conversion at room temperature (RT) to the rate at 4° C. is calculated in the last column in Table 13. This ratio varies dramatically, from 3.3 for D-ALA to 145 for IDAA. This could indicate that different AA affect differently the conversion reaction of vancomycin to CDP. Without being limited by theory, the rate could have changed through a change in activation energy, or through change in other factors such as the functional group orientation or the probability of collision.

One way to study those factors is to determine the rate of conversion at different temperatures and present the data in the form of an Arrhenius plot. An Arrhenius plot displays the logarithm of kinetic constants (ln(k), ordinate axis) plotted against inverse temperature (1/T, abscissa). For a single rate-limited thermally activated process, an Arrhenius plot gives a straight line from which the activation energy and the pre-exponential factor can both be determined.

The Arrhenius equation can be written as:

$$\ln(k) = \ln(A) - \frac{E_a}{R}\left(\frac{1}{T}\right)$$

where:

k=Rate constant

A=Pre-exponential factor

E_a=Activation energy

R=Gas constant

T=Absolute temperature, K

When plotted in the manner described above, the value of the "y-intercept" will correspond to ln(A), and the gradient of the line will be equal to $-E_a/R$. The pre-exponential factor, A, is a constant of proportionality that takes into account a number of factors, such as the frequency of collision between and the orientation of the reacting particles.

TABLE 14

Degradation of vancomycin at number of different controlled temperatures.

	Temp								
	50	40	30	23	15	4	Slope	E	
	$10^3/T$								
Sample	3.10	3.19	3.30	3.38	3.47	3.61	K	kJ/mol	R^2
	CDP-I rate %/week								
V_NaOH	42.44	13.53	3.48	1.67	0.81	0.15			
V_Bicine2	28.88	4.91	1.01	0.40	0.14	0.01			
V_GLYGLY1	33.90	6.00	2.03	1.14	0.22	0.05			
V_GLYGLY1.5	25.78	3.69	1.57	0.87	0.23	0.04			
V_GLYGLY2	33.12	6.19	1.70	0.97	0.25	0.04			
V_GLU2	38.46	5.18	1.50	0.95	0.33	0.05			
	Ln (CDP-I rate)								
V_NaOH	3.75	2.60	1.25	0.51	−0.21	−1.92	−10.8	89.7	0.99
V_Bicine2	3.36	1.59	0.01	−0.92	−2.00	−4.57	−14.8	123	0.99
V_GLYGLY1	3.52	1.79	0.71	0.13	−1.52	−3.06	−12.5	104	0.99
V_GLYGLY1.5	3.25	1.31	0.45	−0.14	−1.46	−3.23	−11.9	99	0.98
V_GLYGLY2	3.50	1.82	0.53	−0.03	−1.39	−3.32	−12.8	106	0.99
V_GLU2	3.65	1.64	0.40	−0.06	−1.11	−3.07	−12.2	102	0.98

For this evaluation vancomycin samples at 200 mg/mL and pH adjusted to pH 5.5 were used. From the slope of the fitted line on Arrhenius plot (FIG. **13**), the activation energy for vancomycin to CDP conversion has been determined (Table 14). In a control sample with no amino acid, the activation energy was 89.7 kJ/ml. All tested amino acids increased activation energy, with Bicine leading to an increase of about 123 kJ/mol.

Example 3. Stability of Liposomal Vancomycin-Amino Acid Formulations

Three formulations (see Table 15) of liposomal vancomycin were prepared using the 3-stream infusion process shown in FIG. **14**.

TABLE 15

Composition of liposomal vancomycin batches used for stability study.

Batch	AA	Lipid Composition	Washing NaCl
L-VGLUt0330	GLU	DPPC/Chol (50:50 mol %)	0.90%
L-VDGLUt0405	D-GLU	DPPC/DPPG/Chol (47.5:5:47.5 mol %)	1.50%

TABLE 15-continued

Composition of liposomal vancomycin batches used for stability study.

Batch	AA	Lipid Composition	Washing NaCl
LPG-VGLUto408	GLU	DPPC/Chol (50:50 mol %)	1.50%

Liposomes were washed and concentrated to about 20 mg/mL lipid. The drug:lipid ratio was about 0.2. Approximately 1 mL each sample was incubated at 4° C. and at RT. Over time liposomes settled in the first two batches. Supernatant in those samples were analyzed for vancomycin as a measure of free vancomycin. Degradation of total vancomycin was measured after vortexing the sample and taking an aliquot of 10 μL.

The data are presented in Table 16 and FIGS. **15** and **16**. From this limited incubation time one can see that vancomycin stability inside liposomes is comparable or better than in a solution of vancomycin with GLU added. For example, the rate for vancomycin-GLU (1:1) was 0.12% per week (Table 11), compared to 0.025 to 0.035% per week (Table 16) when encapsulated in liposomes.

In addition, an estimate of free vancomycin based on the vancomycin level in supernatant indicates modest or low leak at 4° C. and at RT (FIGS. **17** and **18**, respectively). Thus, the stabilized lipid-based glycopeptide antibiotic compositions of the present invention are unexpectedly more stable in comparison to glycopeptide antibiotic compositions that are not lipid-based and/or do not comprise an amino acid or derivative thereof.

TABLE 16

Degradation rates of vancomycin-GLU inside liposomes

Batch	Degradation rate, %/w 4° C.	RT
L-VGLU0330	0.035	0.76
L-VDGLU0405	0.028	0.47
LPG-VGLU0408	0.025	0.89

In summary, the data indicate that the addition of amino acids and their derivatives remarkably affected the degradation rate of vancomycin. The most promising amino acids were Bicine, Imino-diacetic acid (IDAA), glycylglycine (GLY-GLY), and GLU (when used at 2:1 mol ratio with vancomycin). At 4° C., degradation rates as low as 0.01% per week were observed. Arrhenius plots for degradation in the presence of key amino acids could be fitted well to a linear function. The data suggested that improvement in stability is caused by an increase in activation energy value from 87 kJ/mol to up to 120 kJ/mol. Furthermore, encapsulation in liposomes of the vancomycin-amino acid compositions exhibited superior chemical stability.

Example 4. Stability of Liposomal Glycopeptide Antibiotic-Amino Acid Formulations

Formulations of liposomal glycopeptide antibiotic comprising teicoplanin, telavancin, oritavancin, decaplanin or dalbavancin are prepared using the 3-stream infusion process shown in FIG. **14**. Lipid components in the formulations comprise DPPC, DPPC+cholesterol, DPPG, DPPG+cholesterol, DPPC+DPPC+cholesterol, or POPC. Amino acid components in the formulations comprise Bicine, GLU, GLY-GLY, IDAA, ASP, or D-ALA.

Liposomes are washed and concentrated to about 20 mg/mL lipid. Approximately 1 mL each sample is incubated at 4° C. and at RT. To assess the stability of the glycopeptide antibiotic in the formulation, supernatant is analyzed for free glycopeptide antibiotic. Degradation of total glycopeptide antibiotic is measured after vortexing the sample and taking an aliquot of 10 μL.

All publications, protocols, patents and patent applications cited herein are incorporated herein by reference in their entireties for all purposes.

While the described invention has been described with reference to the specific embodiments thereof it should be understood by those skilled in the art that various changes may be made and equivalents may be substituted without departing from the true spirit and scope of the invention. In addition, many modifications may be made to adopt a particular situation, material, composition of matter, process, process step or steps, to the objective spirit and scope of the invention. All such modifications are intended to be within the scope of the claims appended hereto.

The invention claimed is:

1. A stabilized lipid-based glycopeptide antibiotic composition comprising:

a lipid component;

a glycopeptide antibiotic component; and

an amino acid or derivative thereof,

wherein the amino acid or the derivative thereof reduces the degradation rate of the glycopeptide antibiotic, and wherein the antibiotic composition is at least 44% more stable than an antibiotic composition comprising the same lipid component and the same glycopeptide antibiotic component, that does not comprise an amino acid or a derivative thereof.

2. The stabilized lipid-based glycopeptide antibiotic composition according to claim **1**, wherein the stabilized glycopeptide antibiotic-amino acid complex is entrapped by the lipid component.

3. The stabilized lipid-based glycopeptide antibiotic composition according to claim **1**, wherein the antibiotic composition is at least 77% more stable, or at least 88% more stable, than an antibiotic composition comprising the same lipid component and the same glycopeptide antibiotic component, that does not comprise an amino acid or a derivative thereof.

4. The stabilized lipid-based glycopeptide antibiotic composition according to claim **1**, wherein the composition produces product degradants at a rate less than 0.05% by weight per week at 4° C., or a rate less than 0.02% by weight per week at 4° C., or a rate less than 0.01% by weight per week at 4° C.

5. The stabilized lipid-based glycopeptide antibiotic composition according to claim **1**, wherein the lipid component comprises a phospholipid.

6. The stabilized lipid-based glycopeptide antibiotic composition according to claim **5**, wherein the phospholipid is selected from the group consisting of phosphatidylcholine (PC), phosphatidylglycerol (PG), phosphatidylinositol (PI), phosphatidylserine (PS), phosphatidylethanolamine (PE), phosphatidic acid (PA), and a mixture thereof.

7. The stabilized lipid-based glycopeptide antibiotic composition according to claim **1**, wherein the lipid component comprises a sterol.

8. The stabilized lipid-based glycopeptide antibiotic composition according to claim **7**, wherein the sterol is cholesterol.

9. The stabilized lipid-based glycopeptide antibiotic composition according to claim **1**, wherein the lipid component comprises a phospholipid and a sterol.

10. The stabilized lipid-based glycopeptide antibiotic composition according to claim **1**, wherein the lipid component comprises dipalmitoylphosphatidylcholine (DPPC).

11. The stabilized lipid-based glycopeptide antibiotic composition according to claim **1**, wherein the lipid component comprises dipalmitoylphosphatidylcholine (DPPC) and cholesterol.

12. The stabilized lipid-based glycopeptide antibiotic composition according to claim **1**, wherein the lipid component comprises dipalmitoylphosphatidylglycerol (DPPG).

13. The stabilized lipid-based glycopeptide antibiotic composition according to a claim **1**, wherein the lipid component comprises dipalmitoylphosphatidylglycerol (DPPG) and cholesterol.

14. The stabilized lipid-based glycopeptide antibiotic composition according to claim **1**, wherein the lipid component comprises dipalmitoylphosphatidylcholine (DPPC), dipalmitoylphosphatidylglycerol (DPPG), and cholesterol.

15. The stabilized lipid-based glycopeptide antibiotic composition according to claim **2**, wherein the lipid component is a liposome, a lipid clathrate or a proliposome.

16. The stabilized lipid-based glycopeptide antibiotic composition according to claim **1**, wherein the glycopeptide antibiotic is vancomycin.

17. The stabilized lipid-based glycopeptide antibiotic composition according to claim **1**, wherein the amino acid is D-alanine, aspartic acid, bicine, D-glutamic acid, glycylglycine (Gly-Gly) or iminodiacetic acid.

18. The stabilized lipid-based glycopeptide antibiotic composition according to claim **1**, wherein a molar ratio of the glycopeptide antibiotic component to the amino acid or derivative thereof is from about 1:1 to about 1:4, from about 1:1 to about 1:2, about 1:1 or about 1:2.

19. The stabilized lipid-based glycopeptide antibiotic composition according to claim **1**, wherein the composition comprises an amino acid or derivative thereof is a dipeptide or a tripeptide.

20. A method for treating a bacterial infection in a patient in need thereof, the method comprising administering to the patient, a therapeutically effective amount of a stabilized lipid-based glycopeptide antibiotic composition comprising a lipid component, a glycopeptide antibiotic component, and an amino acid or derivative thereof, wherein the amino acid or the derivative thereof reduces the degradation rate of the glycopeptide antibiotic, and wherein the antibiotic composition is at least 44% more stable than an antibiotic composition comprising the same lipid component and the same glycopeptide antibiotic component, that does not comprise an amino acid or a derivative thereof.

* * * * *