

DESCRIPTION

TEXAPHYRIN-PT(IV) CONJUGATES AND COMPOSITIONS FOR USE IN OVERCOMING PLATINUM RESISTANCE

This application claims the benefit of priority to United States Provisional Application
5 Serial No. 62/010,841, filed on June 11, 2014, and Serial No. 62/135,502, filed on March 19,
2015, the entire contents of both are incorporated herein by reference.

BACKGROUND OF THE INVENTION

This invention was made with government support under Grant Numbers CA160687
and CA068682 awarded by the National Institutes of Health. The government has certain
10 rights in the invention.

1. Field of the Invention

The present disclosure relates generally to the fields of medicine, pharmaceutical
agents, and chemotherapeutics. The present disclosure relates to texaphyrin conjugates and
compositions, which can be used to treat cancer.

15 2. Description of Related Art

The use of platinum(IV) chemotherapeutic pro-drugs has several advantages over the
use of platinum(II) chemotherapeutic agents including improved stability, diminished side
effects, or increased kinetic inertness (Rosenberg, B. *et al.*, *Nature* 205:698, 1965; Shi, Y. *et al.*,
Biochem. 107:6, 2012). While, these pro-drug formulations are potentially useful, in order
20 to increase pharmaceutical activity, the compound must be activated by reduction to the
cytotoxic platinum(II) complex to obtain high cytotoxicity. Activation is typically carried out
by intracellular processes, photoreduction, or through the use of ligands activated under
specific conditions (Elding, L.I. and Gustafson, L., *Inorg. Chim. Acta* 19:165, 1976; Davies,
M.S. *et al.*, *Inorg. Chem.* 47:7673, 2008; Drougge, L. and Elding, L.I., *Inorg. Chim. Acta*
25 121:175, 1986; Lemma, K. *et al.*, *Inorg. Chem.* 39:1728, 2000; Huang, J.C. *et al.*, *Proc. Natl.*
Acad. Sci. USA 1:10394-10398, 1994; Chau, K.Y. *et al.*, *Exp. Cell Res.* 241:269-272, 1998;
He, Q. *et al.*, *Proc. Natl. Acad. Sci. USA*, 97:5768-5772, 2000; Barnes, K.R. *et al.*, *J. Chem.*
Biol. 11:557, 2004). Unfortunately, these processes rely on other cellular processes or
application of external stimuli, such as light, and typically must be optimized to obtain

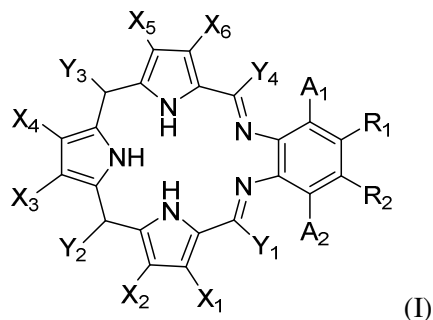
effective results. Furthermore, many of these activation methods lack specificity for cancer cells.

The limitations found in FDA approved platinum(II) agents, which are often unable to overcome pharmacologic and molecular mechanisms in resistant cancers, have provided an incentive to use texaphyrins to help localize platinum(II) drugs to cancer sites via formation of so-called texaphyrin conjugates as detailed in US Patent 6,207,660, incorporated herein by reference. However, the prior art agents described in US Patent 6,207,660 and subsequent reports (Arambula, *et al.* 2009; Arambula, J. F.; Siddik, Z.; *et al.* 2011; Arambula, J. F.; Preihs, C. *et al.* 2011; Arambula, *et al.* 2012), proved unsatisfactory, either because the compounds lacked appropriate stability features, did not display appropriate solubility profiles, or failed to overcome completely platinum resistance in platinum resistant cell lines. Moreover, these prior texaphyrin-based systems relied on the use of a conjugated Pt(II) center rather than a Pt(IV) species. Thus, these conjugates did not benefit from the advantages associated with the use of a Pt(IV) center, including improved stability, diminished side effects, or increased kinetic inertness, as enunciated above. Developing new texaphyrin-platinum(IV) therapeutic agents or compositions that overcome these recognized limitations, while still providing an appropriate activation mechanism, would be of pharmaceutical importance; it would provide *inter alia* improved treatments for cancers and be especially advantageous in treating those cancers that exhibit resistance to current Pt(II) and Pt(IV) chemotherapeutic agents.

As can be clearly seen, the development of new therapeutic agents and compositions containing a texaphyrin and a platinum(IV) complex are needed.

SUMMARY

The present invention refers to subject matter as defined in the attached set of claims. In some examples, the present disclosure describes compounds of the formula:



5 wherein:

R_1 and R_2 are each independently selected from hydrogen, halo, hydroxy, amino, mercapto, alkoxy_(C≤12), substituted alkoxy_(C≤12), or $\left(\text{OCH}_2 \right)_n \text{R}_3$, wherein n is 1-20 and R_3 is hydrogen, alkyl_(C≤6), or substituted alkyl_(C≤6), or a platinum(IV) chelating group;

10 A_1 and A_2 are each independently selected from hydrogen, halo, hydroxy, alkyl_(C≤12), substituted alkyl_(C≤12), alkoxy_(C≤12), substituted alkoxy_(C≤12), or $\left(\text{OCH}_2 \right)_n \text{R}_3$, wherein n is 1-20 and R_3 is hydrogen, alkyl_(C≤6), or substituted alkyl_(C≤6), or a platinum(IV) chelating group;

15 Y_1 , Y_2 , Y_3 , and Y_4 are each independently selected from hydrogen, halo, alkyl_(C≤12), aryl_(C≤12), substituted alkyl_(C≤12), or substituted aryl_(C≤12);

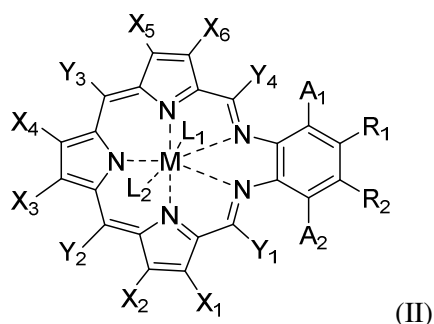
X_1 , X_2 , X_3 , X_4 , X_5 , and X_6 are each independently selected from hydrogen, hydroxy, halo, amino, carboxy, nitro, or cyano,

alkyl_(C≤12), alkenyl_(C≤12), alkynyl_(C≤12), aryl_(C≤12), aralkyl_(C≤12), acyl_(C≤12), amido_(C≤12), or a substituted version of any of these groups, or

20 a platinum(IV) chelating group;

provided that at least one of X_1 , X_2 , X_3 , X_4 , X_5 , and X_6 is a platinum(IV) chelating group;

or an oxidized metal complex, a pharmaceutically acceptable salt, organometallic isomer, or tautomer thereof. In some examples, the compound is further defined as an oxidized metal complex with the formula:



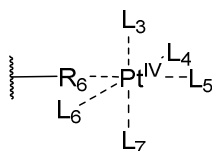
wherein: R₁, R₂, A₁, A₂, Y₁, Y₂, Y₃, Y₄, X₁, X₂, X₃, X₄, X₅, and X₆ are as defined above;

M is a monovalent metal ion, a divalent metal ion, or a trivalent metal ion; and

5 L₁ and L₂ are each absent or anionic ligands independently selected from fluoride, chloride, bromide, carbonate, hydroxide, perchlorate, nitrate, sulfate, trifluoromethylsulfonate, acetylacetonate, acetate, or trifluoroacetate;

provided that when M is a monovalent metal ion then L₁ and L₂ are absent, and when M is a divalent metal ion, then L₁ or L₂ is absent;

or a pharmaceutically acceptable salt, organometallic isomer, or tautomer thereof. In some examples, the platinum(IV) chelating group is -A₃-X₇-A₄-R₄, wherein A₃ and A₄ are each independently alkanediyl_(C≤12), alkenediyl_(C≤12), arenediyl_(C≤12), alkoxydiyl_(C≤12), alkylaminodiyl_(C≤12), or a substituted version of any of these groups, X₇ is -O-, -S-, -NR₅-, -C(O)NR₅-, or -NR₅C(O)-, wherein R₅ is hydrogen, alkyl_(C≤6), or substituted alkyl_(C≤6), and R₄ is



amino, hydroxy, mercapto, carboxy, dicarboxy, or

15 wherein:

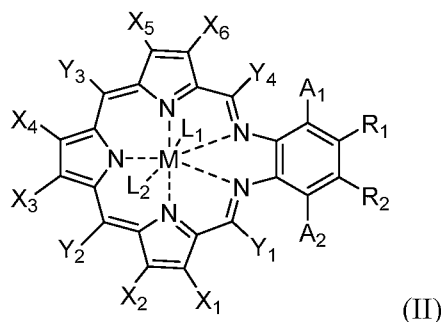
R₆ is amino, hydroxy, mercapto, carboxy, or dicarboxy;

L₃, L₄, L₅, and L₆ are each ligands independently selected from aqua, ammonia, nitrate, sulfate, halide, hydroxide, phosphate, or glucose-6-phosphate,

20 alkylamine_(C≤12), cycloalkylamine_(C≤12), dialkylamine_(C≤18), dicycloalkylamine_(C≤18), arylamine_(C≤12), diarylamine_(C≤18), diaminoalkane_(C≤12), diaminocycloalkane_(C≤12), diaminoarene_(C≤12), heteroarene_(C≤12), alkylcarboxylate_(C≤12), alkylldicarboxylate_(C≤18), arylcarboxylate_(C≤12), aryldicarboxylate_(C≤18), or a substituted version of any of these groups

provided that R₆, L₃, L₄, L₅, and L₆ are appropriately charged to obtain a neutral complex. In

25 some examples, the formula is further defined as:



wherein:

R_1 and R_2 are each independently selected from hydrogen, halo, hydroxy, amino, mercapto, alkoxy_(C≤12), substituted alkoxy_(C≤12), or $\text{-(OCH}_2\text{)}_n\text{-R}_3$, wherein n is 1-20 and R_3 is hydrogen, alkyl_(C≤6), or substituted alkyl_(C≤6), or a platinum(IV) chelating group;

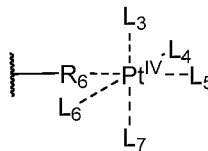
A_1 and A_2 are each independently selected from hydrogen, halo, hydroxy, alkyl_(C≤12), substituted alkyl_(C≤12), alkoxy_(C≤12), substituted alkoxy_(C≤12), or $\text{-(OCH}_2\text{)}_n\text{-R}_3$, wherein n is 1-20 and R_3 is hydrogen, alkyl_(C≤6), or substituted alkyl_(C≤6), or a platinum(IV) chelating group;

Y_1 , Y_2 , Y_3 , and Y_4 are each independently selected from hydrogen, halo, alkyl_(C≤12), or substituted alkyl_(C≤12);

X_1 , X_2 , X_3 , X_4 , X_5 , and X_6 are each independently selected from hydrogen, hydroxy, halo, amino, carboxy, nitro, or cyano,

alkyl_(C≤12), alkenyl_(C≤12), aryl_(C≤12), or a substituted version of any of these groups, or

a platinum chelating group of the formula: $\text{-A}_3\text{-X}_7\text{-A}_4\text{-R}_4$, wherein A_3 and A_4 are each independently alkanediyl_(C≤12), alkoxydiyl_(C≤12), alkylaminodiyl_(C≤12), or a substituted version of any of these groups, X_7 is $\text{-NR}_5\text{-}$, $\text{-C(O)NR}_5\text{-}$, or $\text{-NR}_5\text{C(O)-}$, wherein R_5 is hydrogen, alkyl_(C≤12), or substituted alkyl_(C≤12), and



R_4 is hydroxy, carboxy, dicarboxy, or

wherein:

R_6 is amino, hydroxy, mercapto, carboxy, or dicarboxy;

L_3 , L_4 , L_5 , and L_6 are each ligands independently selected from aqua, ammonia, halide, or hydroxide,

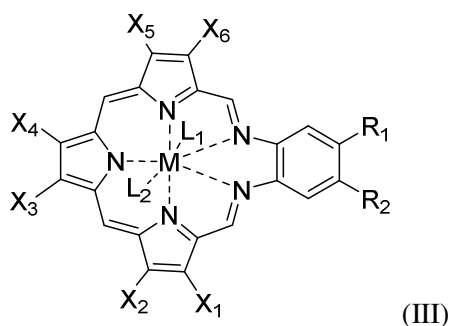
diaminoalkane_(C≤12), diaminocycloalkane_(C≤12), diaminoarene_(C≤12),
alkyldicarboxylate_(C≤18), aryldicarboxylate_(C≤18), or a substituted
version of any of these groups.

provided that at least one of X₁, X₂, X₃, X₄, X₅, and X₆ is a platinum(IV) chelating group;

5 M is a trivalent lanthanide metal ion; and

L₁ and L₂ are each anionic ligands independently selected from fluoride, chloride,
bromide, perchlorate, nitrate, sulfate, trifluoromethylsulfonate, acetate, or
trifluoroacetate;

or a pharmaceutically acceptable salt, organometallic isomer, or tautomer thereof. In some
10 examples, the formula is further defined as:

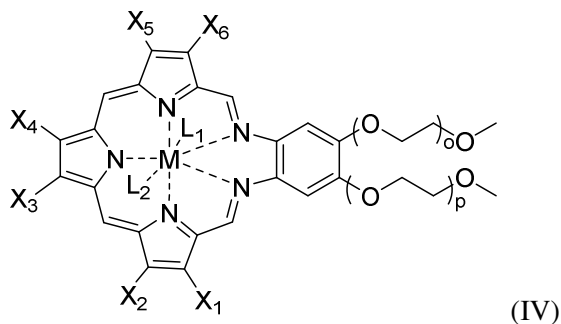


wherein:

R₁ and R₂ are each independently selected from hydroxy, alkoxy_(C≤12), substituted

15 alkoxy_(C≤12), or $\left(\text{OCH}_2\text{CH}_2 \right)_n \text{OR}_3$ wherein n is 1-20 and R₃ is hydrogen, alkyl_(C≤6),
or substituted alkyl_(C≤6);

or a pharmaceutically acceptable salt, organometallic isomer, or tautomer thereof. In some
examples, the formula is further defined as:



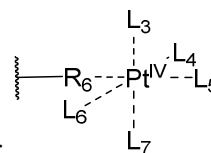
wherein:

o and p are each independently 1, 2, 3, 4, 5, or 6 or any range derivable therein;

X₁, X₂, X₃, X₄, X₅, and X₆ are each independently selected from hydrogen, hydroxy, or halo,

5 alkyl_(C≤12) or substituted alkyl_(C≤12), or

a platinum chelating group of the formula: -A₃-X₇-A₄-R₄, wherein A₃ and A₄ are each independently alkanediyl_(C≤12), alkoxydiyl_(C≤12), or a substituted version of any of these groups, X₇ is -C(O)NR₅-, or -NR₅C(O)-, wherein R₅ is hydrogen,



alkyl_(C≤12), or substituted alkyl_(C≤12), and R₄ is carboxy or

10 wherein:

R₆ is carboxy or dicarboxy;

L₃, L₄, L₅, and L₆ are each ligands independently selected from aqua, ammonia, halide, or hydroxide,

15 diaminoalkane_(C≤12), diaminocycloalkane_(C≤12), alkyldicarboxylate_(C≤18), or a substituted version of any of these groups.

provided that at least one of X₁, X₂, X₃, X₄, X₅, and X₆ is a platinum(IV) chelating group;

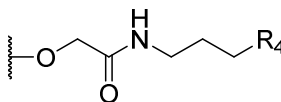
M is a trivalent lanthanide metal ion; and

L₁ and L₂ are each anionic ligands independently selected from nitrate, acetate, or trifluoroacetate;

20 or a pharmaceutically acceptable salt, organometallic isomer, or tautomer thereof.

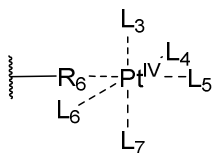
In some examples, o is 2, 3, or 4. In some examples, o is 3. In some examples, p is 2, 3, or 4. In some examples, p is 3.

In some examples, R₁ or R₂ is a platinum(IV) chelating group. In some examples, R₂ is a platinum(IV) chelating group of the formula:



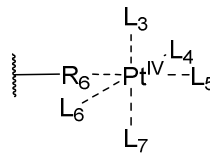
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wherein: R_4 is as defined above. In some examples, X_1 is $\text{alkyl}_{(C\leq 12)}$ or substituted $\text{alkyl}_{(C\leq 12)}$. In some examples, X_1 is methyl. In some examples, X_2 is a platinum(IV) chelating group of the formula: $-A_3-X_7-A_4-R_4$, wherein A_3 and A_4 are each independently $\text{alkanediyl}_{(C\leq 12)}$, alkoxydiyl $_{(C\leq 12)}$, or a substituted version of any of these groups, X_7 is $-\text{C}(\text{O})\text{NR}_5-$ or $-\text{NR}_5\text{C}(\text{O})-$, wherein R_5 is hydrogen, $\text{alkyl}_{(C\leq 12)}$, or substituted $\text{alkyl}_{(C\leq 12)}$, and R_4 is carboxy, dicarboxy, or



wherein: R_6 is carboxy or dicarboxy; L_3 , L_4 , L_5 , and L_6 are each ligands independently selected from aqua, ammonia, halide, or hydroxide, diaminoalkane $_{(C\leq 12)}$, diaminocycloalkane $_{(C\leq 12)}$, alkyldicarboxylate $_{(C\leq 18)}$, or a substituted version of any of these groups.

In some examples, A_3 is $\text{alkanediyl}_{(C\leq 12)}$ or substituted $\text{alkanediyl}_{(C\leq 12)}$. In some examples, A_3 is $\text{alkanediyl}_{(C\leq 8)}$. In some examples, A_3 is $-\text{CH}_2\text{CH}_2\text{CH}_2-$. In some embodiments, X_7 is $-\text{C}(\text{O})\text{NH}-$ or $-\text{NHC}(\text{O})-$. In some examples, X_7 is $-\text{NHC}(\text{O})-$. In some examples, A_4 is $\text{alkanediyl}_{(C\leq 12)}$ or substituted $\text{alkanediyl}_{(C\leq 12)}$. In some examples, A_4 is $\text{alkanediyl}_{(C\leq 8)}$. In some



examples, A_4 is $-\text{CH}_2\text{CH}_2-$. In some embodiments, R_4 is

R_6 is carboxy. In some examples, L_3 is halide, such as chloride. In some examples, L_4 is hydroxide. In some examples, L_5 is amino. In some examples, L_6 is halide, such as chloride. In some examples, L_3 and L_6 are taken together and are alkyldicarboxylate $_{(C\leq 18)}$. In some examples, L_3 and L_6 are $^-\text{O}_2\text{CCO}_2^-$. In some examples, L_7 is amino. In some examples, L_5 and L_7 are taken together and are diaminocycloalkane $_{(C\leq 12)}$. In some examples, L_5 and L_7 are each the amino group of 1,2-diaminocyclohexane.

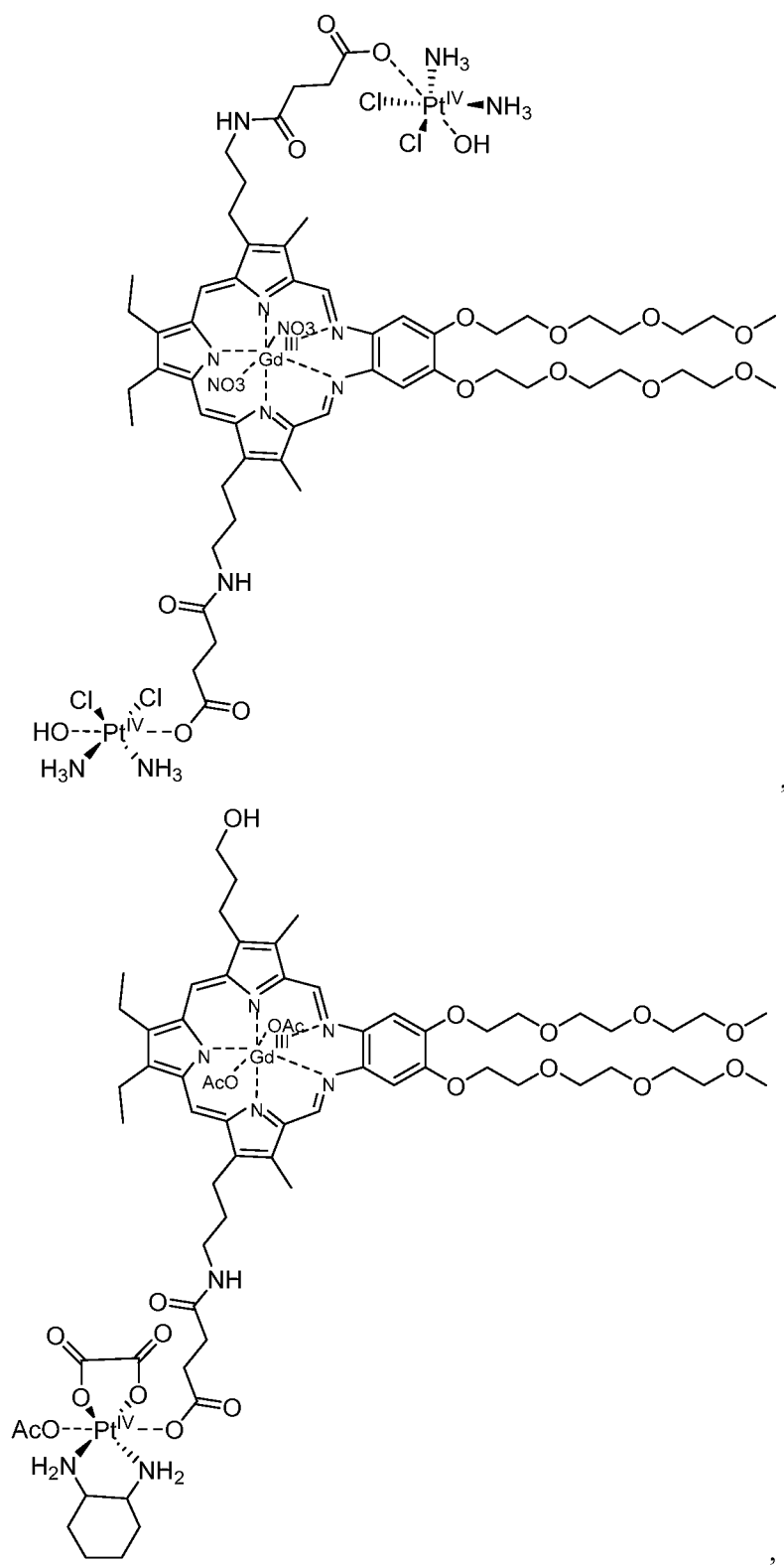
In some examples, X_3 is $\text{alkyl}_{(C\leq 12)}$ or substituted $\text{alkyl}_{(C\leq 12)}$. In some examples, X_3 is $\text{alkyl}_{(C\leq 8)}$. In some examples, X_3 is ethyl. In some examples, X_4 is $\text{alkyl}_{(C\leq 12)}$ or substituted $\text{alkyl}_{(C\leq 12)}$. In some examples, X_4 is $\text{alkyl}_{(C\leq 8)}$. In some examples, X_4 is ethyl. In some examples, X_5 is $\text{alkyl}_{(C\leq 12)}$ or substituted $\text{alkyl}_{(C\leq 12)}$. In some examples, X_5 is substituted $\text{alkyl}_{(C\leq 8)}$. In some examples, X_5 is $-\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$. In some examples, X_5 is a platinum(IV) chelating group. In some

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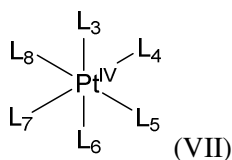
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In some examples, the high oxidation state metal-containing chemotherapeutic complex is a platinum(IV) complex. The platinum(IV) complex may have a formula:

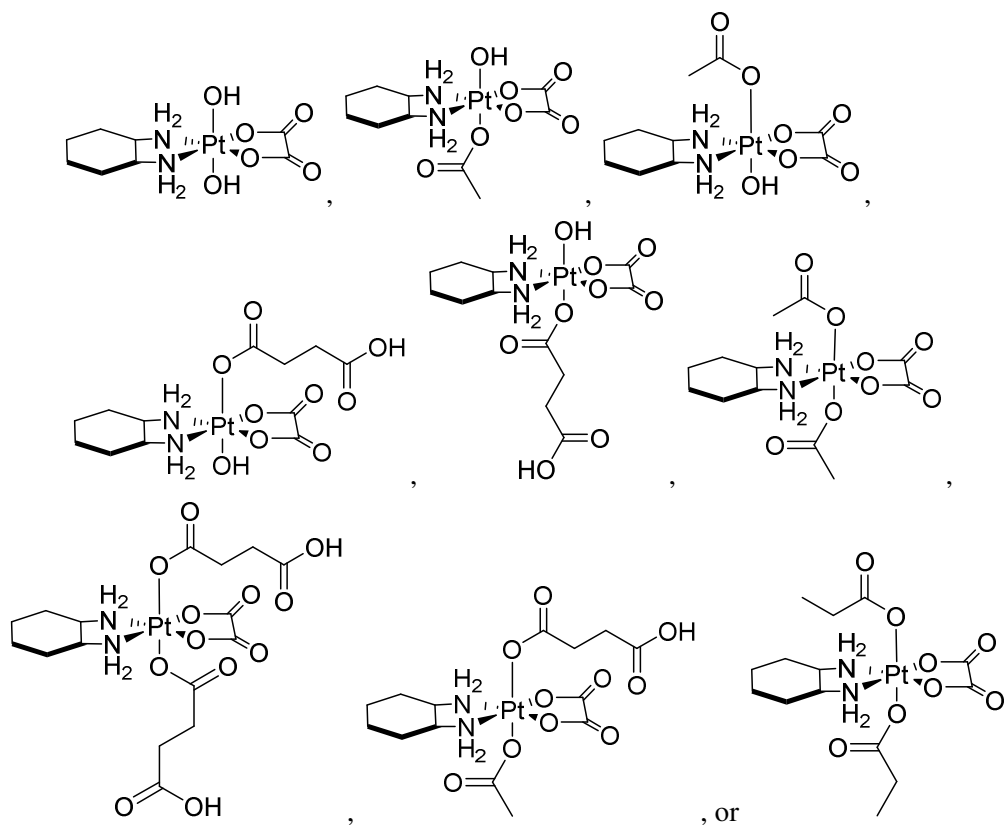


wherein:

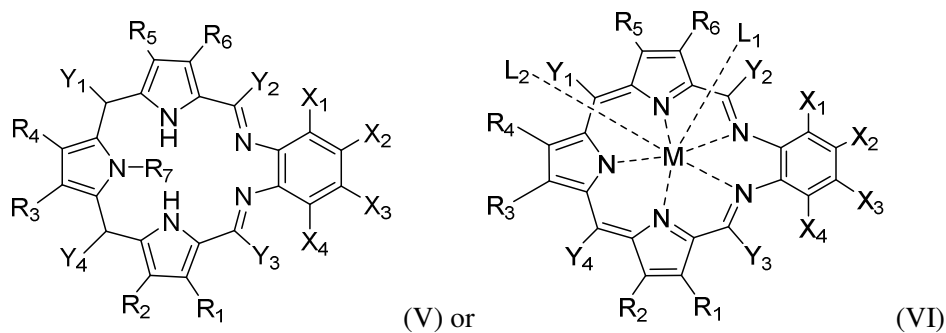
5 $\text{L}_3\text{-L}_6$ are each independently selected from: hydroxide, water, nitrate, carbonyl, phosphate, sulfate, amine, halide, phosphine_(C≤24), alkylcarboxylate_(C≤12), cycloalkylcarboxylate_(C≤12), alkylcarbamate_(C≤12), cycloalkylcarbamate_(C≤12), alkoxide_(C≤12), aryloxy_(C≤12), alkylamine_(C≤12), cycloalkylamine_(C≤12), dialkylamine_(C≤12), dicycloalkylamine_(C≤12), heterocycloalkane_(C≤12),
 10 heteroarene_(C≤12), or a substituted version of any of these groups; or

a divalent ligand wherein two or more of $\text{L}_3\text{-L}_6$ are taken together and wherein each $\text{L}_3\text{-L}_6$ variable is a chelating group selected from: hydroxide, amine, alkylcarboxylate_(C≤12), cycloalkylcarboxylate_(C≤12), alkylcarbamate_(C≤12), cycloalkylcarbamate_(C≤12), alkoxide_(C≤12), aryloxy_(C≤12), alkylamine_(C≤12),
 15 cycloalkylamine_(C≤12), dialkylamine_(C≤12), dicycloalkylamine_(C≤12), heterocycloalkane_(C≤12), or heteroarene_(C≤12), or a substituted version of any of these groups; and joined together to the one or more other $\text{L}_3\text{-L}_6$ variables by a linking group selected from: a covalent bond, an alkanediyl_(C≤12), an alkenediyl_(C≤12), an arenediyl_(C≤12), a heteroarenediyl_(C≤12), or a
 20 heterocycloalkanediyl_(C≤12) wherein the linking group replaces one or more hydrogens from the chelating group

provided that $\text{L}_3\text{-L}_6$ have a total charge of -4 . In some examples, L_3 or L_6 is hydroxide, alkylcarboxylate_(C≤8) or substituted alkylcarboxylate_(C≤8). In other examples, L_3 or L_6 is hydroxide. In other examples, L_3 and L_6 are hydroxide. In some examples, the platinum(IV)
 25 complex is satraplatin or LA-12. In other examples, the platinum(IV) complex is a platinum(IV) analogue of cisplatin, carboplatin, oxaliplatin, lobaplatin, nedaplatin, heptaplatin, picoplatin, or BBR3464. In some examples, the platinum(IV) complex is a platinum(IV) analogue of cisplatin, carboplatin, or oxaliplatin. In some examples, the platinum(IV) complex is of the formula:



In some examples, the texaphyrin compound is of the formula:



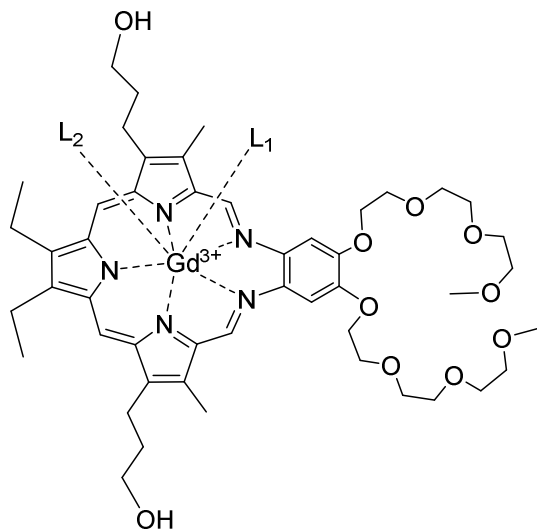
wherein:

Y_1 - Y_4 are each independently selected from: hydrogen, amino, cyano, halo, hydroxy, or hydroxyamino,

alkyl_(C≤12), cycloalkyl_(C≤12), alkenyl_(C≤12), cycloalkenyl_(C≤12), alkynyl_(C≤12), aryl_(C≤12), aralkyl_(C≤12), heteroaryl_(C≤12), heterocycloalkyl_(C≤12), acyl_(C≤12), alkoxy_(C≤12), acyloxy_(C≤12), aryloxy_(C≤12), heteroaryloxy_(C≤12), heterocycloalkoxy_(C≤12), amido_(C≤12), alkylamino_(C≤12), dialkylamino_(C≤12), alkylthio_(C≤12), arylthio_(C≤12), alkylsulfinyl_(C≤12), arylsulfinyl_(C≤12), alkylsulfonyl_(C≤12), arylsulfonyl_(C≤12), or a substituted version of any of these groups; or

- R₁-R₆ are each independently selected from: hydrogen, amino, cyano, halo, hydroxy, hydroxyamino, or nitro,
- alkyl_(C≤12), cycloalkyl_(C≤12), alkenyl_(C≤12), cycloalkenyl_(C≤12), alkynyl_(C≤12), aryl_(C≤12), aralkyl_(C≤12), heteroaryl_(C≤12), heterocycloalkyl_(C≤12), acyl_(C≤12), alkoxy_(C≤12), acyloxy_(C≤12), aryloxy_(C≤12), heteroaryloxy_(C≤12), heterocycloalkoxy_(C≤12), amido_(C≤12), alkylamino_(C≤12), dialkylamino_(C≤12), or a substituted version of any of these groups; or
- a PEG moiety wherein the PEG moiety is of the formula: $-(OCH_2CH_2)_nOR_8$; wherein:
n is 1-20; and
- R₈ is hydrogen, alkyl_(C≤8), or substituted alkyl_(C≤8);
- R₇ is hydrogen,
alkyl_(C≤8), cycloalkyl_(C≤8), alkenyl_(C≤8), cycloalkenyl_(C≤8), alkynyl_(C≤8), alkoxy_(C≤8), or a substituted version of any of these groups, or
an amino protecting group;
- X₁-X₄ are each independently selected from: hydrogen, amino, cyano, halo, hydroxy, hydroxyamino, or nitro,
- alkyl_(C≤12), cycloalkyl_(C≤12), alkenyl_(C≤12), cycloalkenyl_(C≤12), alkynyl_(C≤12), aryl_(C≤12), aralkyl_(C≤12), heteroaryl_(C≤12), heterocycloalkyl_(C≤12), acyl_(C≤12), alkoxy_(C≤12), acyloxy_(C≤12), aryloxy_(C≤12), heteroaryloxy_(C≤12), heterocycloalkoxy_(C≤12), amido_(C≤12), alkylamino_(C≤12), dialkylamino_(C≤12), or a substituted version of any of these groups; or
- a PEG moiety wherein the PEG moiety is of the formula: $-(OCH_2CH_2)_nOR_8$; wherein:
n is 1-20; and
- R₈ is hydrogen, alkyl_(C≤8), or substituted alkyl_(C≤8);
- L₁ and L₂ are each independently absent, a neutral ligand, or an anionic ligand; and
- M is a metal ion;
- provided that L₁ and L₂ are present or absent as appropriate to balance the charge on the metal ion;
- or a pharmaceutically acceptable salt or tautomer thereof. In other examples, the texaphyrin is a compound of formula VB. In some examples, M is a transition metal in the +2 oxidation state or +3 oxidation state such as gadolinium(III). In some examples, the texaphyrin compound wherein at least two of X₁-X₄ are a PEG moiety wherein the PEG

moiety is of the formula: $-(\text{OCH}_2\text{CH}_2)_n\text{OR}_8$; wherein: n is 1-20; and R_8 is hydrogen, $\text{alkyl}_{(\text{C}\leq 8)}$, or substituted $\text{alkyl}_{(\text{C}\leq 8)}$. In some examples, the texaphyrin compound has the following formula:



wherein:

5 L_1 and L_2 are each independently an anionic ligand; and

or a pharmaceutically acceptable salt or tautomer thereof. In some examples, the texaphyrin compound is motexafin gadolinium. In some examples, the texaphyrin compound is a compound of formula I or formula II. In some examples, the texaphyrin and the high oxidation state metal-

10 containing chemotherapeutic complex are administered in a ratio from about 10:1 to about 1:10. In some examples, the ratio is from about 3:1 to about 1:3. In some examples, the ratio is about 1:2.

In some examples, the pharmaceutical composition further comprises a reducing agent. The reducing agent may be sodium ascorbate, thioredoxin reductase, a biological thiol, a platinum(II) complex, or light. In some examples, the biological thiol is cysteine, homocysteine, or glutathione. In some examples, the pharmaceutical composition further comprises a pharmaceutically acceptable carrier. In some examples, the pharmaceutical composition is formulated for administration: orally, intraadiposally, intraarterially, intraarticularly, intracranially, intradermally, intralesionally, intramuscularly, intranasally, intraocularly, intrapericardially, intraperitoneally, intrapleurally, intraprostatically, intrarectally, intrathecally, intratracheally, intratumorally, intraumbilically, intravaginally, intravenously, intravesicularly, intravitreally, liposomally, locally, mucosally, parenterally,

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rectally, subconjunctivally, subcutaneously, sublingually, topically, transbuccally, transdermally, vaginally, in crèmes, in lipid compositions, via a catheter, via a lavage, via continuous infusion, via infusion, via inhalation, via injection, via local delivery, or via localized perfusion. In some examples, the pharmaceutical composition is formulated for oral or intravenous administration.

5 In some examples, the composition is formulated as a unit dose.

In still yet another example, the present disclosure describes methods of treating a disease in a patient comprising administering to the patient in need thereof a therapeutically effective amount of:

- (A) a compound or pharmaceutical composition of the present disclosure;
- 10 (B) a pharmaceutical composition of the present disclosure; or
- (C) a first agent selected from a texaphyrin compound and a second agent selected from a high oxidation state metal-containing chemotherapeutic complex.

In some examples, the disease is cancer, such as a carcinoma, sarcoma, lymphoma, leukemia, melanoma, mesothelioma, multiple myeloma, or seminoma or the cancer is of the
15 bladder, blood, bone, brain, breast, central nervous system, cervix, colon, endometrium, esophagus, gall bladder, genitalia, genitourinary tract, head, kidney, larynx, liver, lung, muscle tissue, neck, oral or nasal mucosa, ovary, pancreas, prostate, skin, spleen, small intestine, large intestine, stomach, testicle, or thyroid. In some examples, the cancer is ovarian cancer, testicular cancer, or bladder cancer. The ovarian cancer may be ovarian carcinoma. The cancer may be
20 colon cancer or colorectal cancer. In some examples, the cancer is resistant to a metal chemotherapeutic. The cancer may be resistant to a platinum chemotherapeutic. In some examples, the cancer is resistant to cisplatin, carboplatin, or oxaliplatin.

In some examples, the methods comprise administering a compound or composition of the present disclosure. In some examples, the platinum complex is reduced *in vivo* to form an
25 active complex. The compound may be localized to a tumor before the reduction of the platinum complex.

In some examples, the methods comprise administering a composition comprising a texaphyrin compound and high oxidation state metal-containing chemotherapeutic complex. The methods comprise administering a first agent selected from a texaphyrin compound and a

30

second agent selected from a high oxidation state metal-containing chemotherapeutic complex. In some examples, the high oxidation state metal-containing chemotherapeutic complex is a metal-containing chemotherapeutic complex that is capable of undergoing reduction. The high oxidation state metal-containing chemotherapeutic complex may be in a pro-drug form. In some examples, the high oxidation state metal-containing chemotherapeutic complex is in an oxidized form and is reduced *in vivo* to form a chemotherapeutically more active species. In some examples, the high oxidation state metal-containing chemotherapeutic complex is activated in the presence of the texaphyrin compound. In some embodiments, the high oxidation state metal-containing chemotherapeutic complex is activated by a reduced form of the texaphyrin compound. In some examples, the reduced form of the texaphyrin compound is produced *in vivo* by one or more reducing species. The high oxidation state metal-containing chemotherapeutic complex may be preferentially activated in a cancer cell. The high oxidation state metal-containing chemotherapeutic complex may be preferentially activated in the presence of a cancer cell. In some examples, the texaphyrin compound localizes to a cancer cell and the high oxidation state metal-containing chemotherapeutic complex is preferentially activated by the texaphyrin compound in the cancer cell. In some examples, the texaphyrin compound localizes to the extracellular matrix around a cancer cell and the high oxidation state metal-containing chemotherapeutic complex is preferentially activated by the texaphyrin compound in the presence of the cancer cell. The high oxidation state metal-containing chemotherapeutic complex may be selectively activated in the cancer cell. The high oxidation state metal-containing chemotherapeutic complex may be selectively activated in the presence of the cancer cell.

In some examples, the metal in the high oxidation state metal-containing chemotherapeutic complex is selected from: gold, platinum, osmium, ruthenium, titanium, iron, cobalt, copper, iridium, gallium, arsenic, molybdenum, tin, rhodium, and lanthanum. In some examples, the metal is platinum. In some examples, the high oxidation state metal-containing chemotherapeutic complex is a platinum(IV) complex. The platinum(IV) complex may comprise one or more hydroxide ligands. The platinum(IV) complex may comprise two axial hydroxide ligands. In some examples, the platinum(IV) complex is of the formula:

alkyl_(C≤12), cycloalkyl_(C≤12), alkenyl_(C≤12), cycloalkenyl_(C≤12), alkynyl_(C≤12), aryl_(C≤12), aralkyl_(C≤12), heteroaryl_(C≤12), heterocycloalkyl_(C≤12), acyl_(C≤12), alkoxy_(C≤12), acyloxy_(C≤12), aryloxy_(C≤12), heteroaryloxy_(C≤12), heterocycloalkoxy_(C≤12), amido_(C≤12), alkylamino_(C≤12), dialkylamino_(C≤12), alkylthio_(C≤12), arylthio_(C≤12), alkylsulfinyl_(C≤12), arylsulfinyl_(C≤12), alkylsulfonyl_(C≤12), arylsulfonyl_(C≤12), or a substituted version of any of these groups; or

R₁-R₆ are each independently selected from: hydrogen, amino, cyano, halo, hydroxy, hydroxyamino, or nitro,

alkyl_(C≤12), cycloalkyl_(C≤12), alkenyl_(C≤12), cycloalkenyl_(C≤12), alkynyl_(C≤12), aryl_(C≤12), aralkyl_(C≤12), heteroaryl_(C≤12), heterocycloalkyl_(C≤12), acyl_(C≤12), alkoxy_(C≤12), acyloxy_(C≤12), aryloxy_(C≤12), heteroaryloxy_(C≤12), heterocycloalkoxy_(C≤12), amido_(C≤12), alkylamino_(C≤12), dialkylamino_(C≤12), or a substituted version of any of these groups; or

a PEG moiety wherein the PEG moiety is of the formula: $-(OCH_2CH_2)_nOR_8$; wherein:

n is 1-20; and

R₈ is hydrogen, alkyl_(C≤8), or substituted alkyl_(C≤8);

R₇ is hydrogen,

alkyl_(C≤8), cycloalkyl_(C≤8), alkenyl_(C≤8), cycloalkenyl_(C≤8), alkynyl_(C≤8), alkoxy_(C≤8), or a substituted version of any of these groups, or

an amino protecting group;

X₁-X₄ are each independently selected from: hydrogen, amino, cyano, halo, hydroxy, hydroxyamino, or nitro,

alkyl_(C≤12), cycloalkyl_(C≤12), alkenyl_(C≤12), cycloalkenyl_(C≤12), alkynyl_(C≤12), aryl_(C≤12), aralkyl_(C≤12), heteroaryl_(C≤12), heterocycloalkyl_(C≤12), acyl_(C≤12), alkoxy_(C≤12), acyloxy_(C≤12), aryloxy_(C≤12), heteroaryloxy_(C≤12), heterocycloalkoxy_(C≤12), amido_(C≤12), alkylamino_(C≤12), dialkylamino_(C≤12), or a substituted version of any of these groups; or

a PEG moiety wherein the PEG moiety is of the formula: $-(OCH_2CH_2)_nOR_8$; wherein:

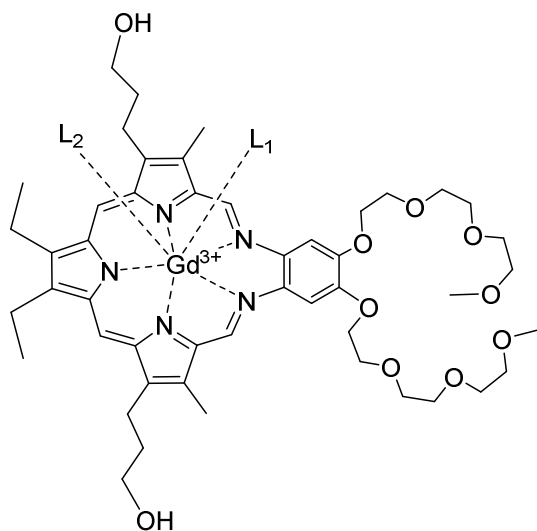
n is 1-20; and

R₈ is hydrogen, alkyl_(C≤8), or substituted alkyl_(C≤8);

L₁ and L₂ are each independently absent, a neutral ligand, or an anionic ligand; and

M is a metal ion, provided that L₁ and L₂ are absent or a neutral ligand as needed to balance the charge on the metal ion;

or a pharmaceutically acceptable salt or tautomer thereof. In some examples, the texaphyrin compound is of the formula:



wherein:

5 L_1 and L_2 are each independently an anionic ligand; and

or a pharmaceutically acceptable salt or tautomer thereof. In some examples, the texaphyrin compound is motexafin gadolinium.

10 In some examples, the texaphyrin and the high oxidation state metal-containing chemotherapeutic complex are administered in a ratio from about 10:1 to about 1:10. In some examples, the texaphyrin and the high oxidation state metal-containing chemotherapeutic complex are administered together. In some examples, the texaphyrin or the high oxidation state metal-containing chemotherapeutic complex is administered and then the other is administered within a time period of 1 week, or the time period is 24 hours., or the time period is 12 hours.

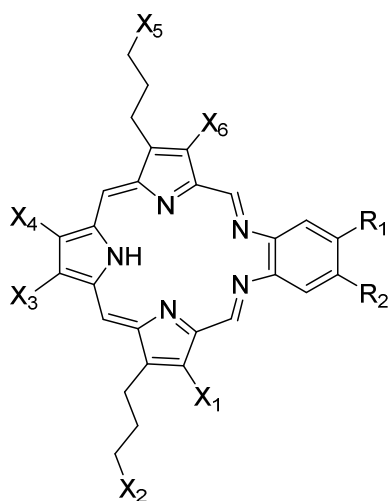
15 In other examples, the texaphyrin is administered first and then the high oxidation state metal-containing chemotherapeutic complex is administered. In other examples, the high oxidation state metal-containing chemotherapeutic complex is administered first and then the texaphyrin is administered. In some examples, the texaphyrin is administered once. In other examples, the texaphyrin is administered two or more times. In some examples, the high oxidation state metal-containing chemotherapeutic complex is

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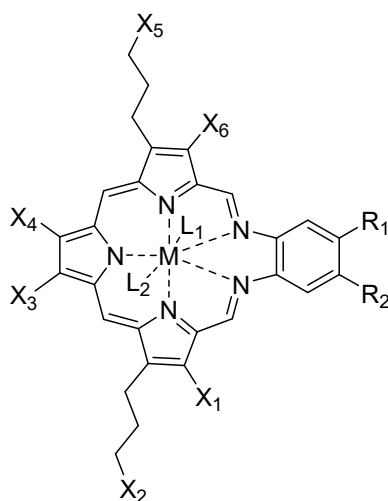
administered once. In other examples, the high oxidation state metal-containing chemotherapeutic complex is administered two or more times.

In some examples, the method further comprises administering a reducing agent. In some examples, the method is administered in conjunction with a second therapy, wherein the second therapy is a third chemotherapeutic drug, surgery, radiotherapy, photodynamic therapy, sonodynamic therapy, cryotherapy, or immunotherapy. In some examples, the third chemotherapeutic drug is bleomycin, doxorubicin, taxol, taxotere, etoposide, 4-OH cyclophosphamide, or 5-fluorouracil or the third chemotherapeutic drug is cisplatin, carboplatin, oxaliplatin, or a Pt(IV) complex.

In yet another example, the present disclosure describes methods of preparing a platinum-tetraphyrin complex of the formula:



(VII) or



(VIII)

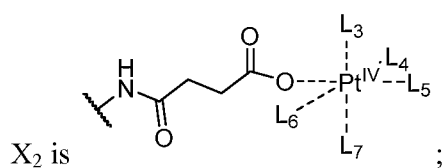
wherein:

R_1 and R_2 are each independently selected from hydrogen, halo, hydroxy, amino,

mercapto, alkoxy_(C≤12), substituted alkoxy_(C≤12), or $\left(\text{OCH}_2 \right)_n \text{R}_3$ wherein n is 1-8 and R_3 is hydrogen, alkyl_(C≤6), or substituted alkyl_(C≤6);

X_1 , X_3 , X_4 , and X_6 are each independently selected from hydrogen, hydroxy, halo, amino, carboxy, nitro, or cyano,

alkyl_(C≤12), alkenyl_(C≤12), alkynyl_(C≤12), aryl_(C≤12), aralkyl_(C≤12), acyl_(C≤12), amido_(C≤12), or a substituted version of any of these groups,

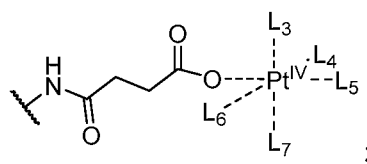


wherein:

L₃, L₄, L₅, and L₆ are each ligands independently selected from aqua, ammonia, nitrate, sulfate, halide, hydroxide, phosphate, or glucose-6-phosphate,

alkylamine_(C≤12), cycloalkylamine_(C≤12), dialkylamine_(C≤18),
dicycloalkylamine_(C≤18), arylamine_(C≤12), diarylamine_(C≤18),
diaminoalkane_(C≤12), diaminocycloalkane_(C≤12),
diaminoarene_(C≤12), heteroarene_(C≤12), alkylcarboxylate_(C≤12),
alkyldicarboxylate_(C≤18), arylcarboxylate_(C≤12),
aryldicarboxylate_(C≤18), or a substituted version of any of these
groups;

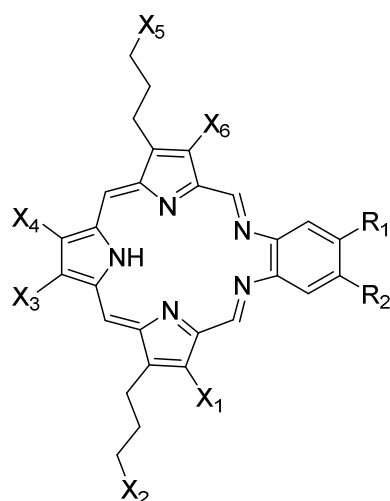
X₅ are each independently selected from amino, hydroxy, alkoxy_(C≤12), substituted alkoxy_(C≤12), aralkoxy_(C≤24), or substituted aralkoxy_(C≤24), or



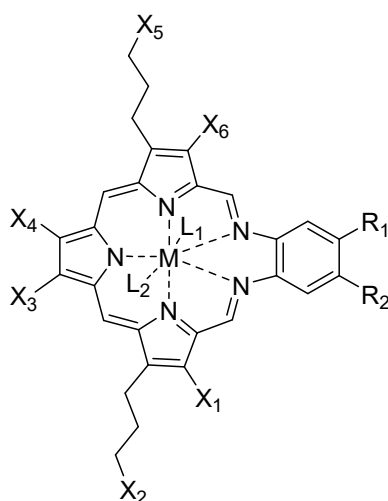
M is a metal ion; and

L₁ and L₂ are each anionic ligands independently selected from fluoride, chloride, bromide, carbonate, hydroxide, perchlorate, nitrate, sulfate, trifluoromethylsulfonate, acetylacetonate, acetate, or trifluoroacetate;

provided that L₁ and L₂ are present or absent as necessary to balance the charge on M;
comprising reacting a compound of the formula



(VII) or



(VIII)

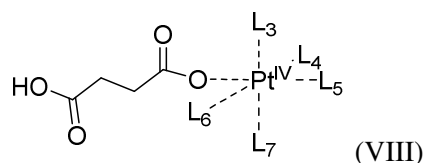
wherein:

X₂ is amino;

5 X₅ is amino, hydroxy, alkoxy_(C≤12), substituted alkoxy_(C≤12), aralkoxy_(C≤24), or substituted aralkoxy_(C≤24); and

R₁, R₂, X₁, X₃, X₄, and X₆ are as defined above;

with a compound of the formula:



(VIII)

10 in a solvent and in the presence of an activating agent. In some examples, the solvent is an aqueous organic mixture, such as a water and acetonitrile mixture. In some examples, the activating agent is N-hydroxysuccinimide, 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide (EDC), dicyclohexylcarbodiimide (DCC), diisopropylcarbodiimide (DIC), PyBOP, BOP, HOBT, or N,N'-carbonyldiimidazole (CDI). In some examples, the activating agent is a N-hydroxysuccinimide and 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide.

15 It is contemplated that any method or composition described herein can be implemented with respect to any other method or composition described herein.

The terms “comprise” (and any form of comprise, such as “comprises” and “comprising”), “have” (and any form of have, such as “has” and “having”), “contain” (and any form of contain, such as “contains” and “containing”), and “include” (and any form of

include, such as “includes” and “including”) are open-ended linking verbs. As a result, a method, composition, kit, or system that “comprises,” “has,” “contains,” or “includes” one or more recited steps or elements possesses those recited steps or elements, but is not limited to possessing only those steps or elements; it may possess (*i.e.*, cover) elements or steps that are not recited. Likewise, an element of a method, composition, kit, or system that “comprises,” “has,” “contains,” or “includes” one or more recited features possesses those features, but is not limited to possessing only those features; it may possess features that are not recited.

Any embodiment of any of the present methods, composition, kit, and systems may consist of or consist essentially of—rather than comprise/include/contain/have—the described steps and/or features. Thus, in any of the claims, the term “consisting of” or “consisting essentially of” may be substituted for any of the open-ended linking verbs recited above, in order to change the scope of a given claim from what it would otherwise be using the open-ended linking verb.

The use of the term “or” in the claims is used to mean “and/or” unless explicitly indicated to refer to alternatives only or the alternatives are mutually exclusive, although the disclosure supports a definition that refers to only alternatives and “and/or.”

Throughout this application, the term “about” is used to indicate that a value includes the standard deviation of error for the device or method being employed to determine the value.

Following long-standing patent law, the words “a” and “an,” when used in conjunction with the word “comprising” in the claims or specification, denotes one or more, unless specifically noted.

Other objects, features and advantages of the present invention will become apparent from the following detailed description. It should be understood, however, that the detailed description and the specific examples, while indicating specific embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

The following drawings form part of the present specification and are included to further demonstrate certain aspects of the present invention. The invention may be better understood by reference to one or more of these drawings in combination with the detailed description of specific embodiments presented herein.

FIG. 1 shows a generalized synthesis scheme for preparation of new Pt(IV) texaphyrin analogues.

FIG. 2 shows the previous generation of platinum(II)-texaphyrin conjugates.

FIG. 3 shows some of the structures of compounds described in this disclosure.

FIG. 4 shows the synthesis of the platinum(IV)-texaphyrin conjugates **4** and **5**. R1 = (OCH₂CH₂)₃OCH₃. Conditions: i = 4,4'-dimethoxytriphenylmethylchloride (DMT-Cl), diisopropylethylamine (DIPEA) in dichloromethane, 30%; ii = triphenylphosphine, phthalimide, diisopropylazocaboxylate in dichloromethane, methylamine in methanol/acetonitrile, 25%; iii = N-ethyl-N'-(3-dimethylaminopropyl)carbodiimide hydrochloride (EDC•HCl), N-hydroxysuccinimide (NHS) and **3** in water. Yields were 40% (**4**) and 20% (**5**).

FIG. 5 shows a partial RP-HPLC chromatograms (top) and ¹H-NMR spectra (bottom, D₂O, pH = 7, 300 K, 400 MHz) of complex **3** recorded in the presence of 5'-GMP (2 equiv.) before (A) and after being exposed to laboratory light for 2 days (B); (C) cisplatin incubated in presence of 5'-GMP (2 equiv.) for 10 h at 37°C; circle = free 5'-GMP; triangle = Pt(II)-coordinated 5'-GMP; black square = Pt(IV)-coordinated succinate anion; square = free succinate dianion.

FIGS. 6A-C show the (FIG. 6A) Schematic representation of the photo-activation of **4** followed by formation of a DNA-Pt adduct. Note: The star represents the texaphyrin moiety; (FIG. 6B) stability (RP-HPLC analysis) of **4** in PBS solution in the dark (black circles) or exposed to laboratory light (black squares), The designation 1 indicates the hydrolysis phase (absence of light), while the 2 indicates the phase corresponding to light exposure; (FIG. 6C) quantification by FAAS (Pt) and by nanodrop (DNA) of the number of Pt-DNA adducts formed after reaction of **4** with DNA in the dark (black circles) or exposed to natural light (black squares).

FIG. 7 shows the high-resolution ESI-MS spectrum of **4** recorded from an aqueous sample.

FIGS. 8A & B show the RP-HPLC chromatogram monitoring at 470 nm (**FIG. 8A**) and UV-vis spectrum (**FIG. 8B**) of conjugate **4** studied in water.

5 **FIGS. 9A & B** show the high-resolution ESI-MS spectra of deprotected species **1(OH)(NH₂)** after isolation using a C18 column. **FIG. 9A**: Entire spectrum; **FIG. 9B**: magnified view of the major peak with theoretical isotopic relative abundance also shown.

FIG. 10 shows the high-resolution spectrum of **6** (zoomed on the major peak).

10 **FIGS. 11A-C** show RP-HPLC chromatogram monitored at 470 nm (**FIG. 11A**) and UV-vis spectrum (**FIG. 11B**) of **6** recorded in water. **FIG. 11C** shows the high resolution mass spectrum.

FIGS. 12A & B show the high resolution ESI-MS spectrum of **6** obtained after exposing **4** to laboratory light (2 days) (**FIG. 12A**); magnified view of the most intense peak (**FIG. 12B**). Note: the same results were observed after reaction of **4** with sodium ascorbate or glutathione.

FIGS. 13A & B show the RP-HPLC chromatogram monitored at 470 nm (**FIG. 13A**) and UV-vis spectrum (**FIG. 13B**) of conjugate **5** in water.

20 **FIG. 14** shows the high resolution ESI-MS showing an enhancement of the most intense peaks corresponding to **5**. Red boxes represent theoretical isotopic relative abundances.

FIG. 15 shows the formation of **6** (red frame) upon reduction (peak size increasing) or hydrolysis (peak size decreasing) of **4** (black frame) monitored by RP-HPLC.

25 **FIGS. 16A & B – FIG. 16A**: Comparison of the rate of hydrolysis for the known platinum(II)-texaphyrin conjugate **2** (cisTEX, red squares) compared to that of **4** at 37 C (blue rhombi) in phosphate buffer saline solution (pH = 7.5, 6 mM phosphate, 100 mM NaCl); **FIG. 16B**: Reduction rate of **4** in the dark at 37 C (blue rhombi) compared to (**4**) exposed to laboratory light at room temperature (red squares) in phosphate buffer saline (pH = 7.5, 6 mM phosphate, 100 mM NaCl). The designation 1 indicates the hydrolysis phase

(absence of light) while the designator 2 indicates the phase corresponding to subsequent light exposure.

FIGS. 17A-E show the RP-HPLC traces of cisplatin (FIG. 17A), **3** in the dark (FIG. 17B), **3** after being exposed 48 hours to ambient light (FIG. 17C), **4** after 48 hours light exposure (FIG. 17D), **4** after 1 hour reaction with sodium ascorbate (5 equiv.) FIG. 17E * Peak corresponding to sodium ascorbate.

FIG. 18 shows the ^1H NMR (D_2O PBS solution pH = 7.5, 300 K, 400 MHz) spectra of **3** recorded before and after exposure to laboratory light, showing the release of succinate anion (He#).

FIG. 19 shows the UV-visible spectra of **3** (in PBS solution, pH = 7.5, concentration = 1.6×10^{-4} M) before (red line) and after laboratory light exposure. The evolution observed (decrease in absorbance between 290 and 390 nm when Pt(IV) is reduced) is consistent with Ramos, *et al.*, 2011.

FIGS. 20A & B show the ESI-MS (negative mode, PBS solution) spectra of **3** before (FIG. 20A) and after 48h light exposure (FIG. 20B) showing the release of succinate anions after light exposure.

FIG. 21 shows the ^1H NMR (DMSO, 300 K, 400 MHz) spectra of **3** before letting sit (A) in the dark for 22 h (B) and (D) after being exposed for 48h to ambient light, showing the release of succinic acid (He) and formation of new species (red stars). The spectrum C corresponds to cisplatin in DMSO. Note: It is known that DMSO interacts with Pt(II) (Fischer, *et al.*, 2008), a finding that explains the NMR spectral profiles observed in (C) and (D). Support for this expected interaction was provided by subjecting this solution to ESI-MS analysis as described in FIG. 22

FIG. 22 shows the high resolution ESI-MS spectrum of **3** in $\text{DMSO}-d_6$ (solution used for NMR studies) after being exposed for 2 days to ambient light.

FIG. 23 shows the ^1H NMR spectra recorded in D_2O (pH = 7), 300 K, 400 MHz as obtained after exposure of the product obtained by reduction of **3** (either using laboratory light (filtered sunlight) for two days or sodium ascorbate (5 equiv.)) to 5' GMP for 2 additional days. As a reference, cisplatin was exposed to 2 equivalents of 5' GMP for 2 days; this forms the adduct $(5' \text{ GMP})_2\text{Pt(II)(NH}_3)_2$. * = impurity.

FIG. 24 shows the quantification by FAAS (Pt) and by nanodrop (DNA) of the number of Pt-DNA adducts formed after reaction of **4** with DNA in the dark (black circles) or exposed to laboratory light (black squares). Cisplatin (triangle) was used as a reference.

FIGS. 25A & B show the determination of the half maximal inhibitory concentrations (IC₅₀ in μ M, logarithmic scale) for the conjugates **4** (**FIG. 25A**) and **5** (**FIG. 25B**) against cancer cells from the wild type cell line, A2780.

FIGS. 26A & B show the determination of the half maximal inhibitory concentration (IC₅₀ in μ M, logarithmic scale) for the conjugates **4** (**FIG. 26A**) and **5** (**FIG. 26B**) against cancer cells from the cisplatin-resistant cell line, 2780CP.

FIG. 27 shows the general synthetic scheme to obtain either **OxaliPt(IV)-TEX** or **cisPt(IV)-TEX**.

FIG. 28 shows the general synthetic scheme to obtain dimeric structures of either **OxaliPt(IV)-TEX** or **cisPt(IV)-TEX**.

FIG. 29 shows the general synthetic scheme to obtain a heterodimeric structure containing both the platinum conjugating units **OxaliPt(IV)** and **cisPt(IV)** linked to the texaphyrin.

FIG. 30 shows the high-resolution ESI-MS spectrum of **OxaliPt(IV)-TEX** recorded from an aqueous sample.

FIG. 31 show the RP-HPLC chromatogram monitoring at 469 nm and UV-vis spectrum of conjugate **OxaliPt(IV)-TEX** studied in water.

FIG. 32 shows the HPLC trace of oxaliplatin (top), a platinum(IV) analogue of oxaliplatin (middle), and the platinum(IV) analogue of oxaliplatin in the presence of sodium ascorbate (bottom).

FIG. 33 shows the HPLC trace of a platinum(IV) analogue of oxaliplatin (top), and the platinum(IV) analogue of oxaliplatin in the presence of sodium ascorbate and the texaphyrin compound (bottom).

FIG. 34 shows cell viability as a function of concentration with the texaphyrin compound (MGd) (squares), the platinum(IV) analogue of oxaliplatin (triangle), and the platinum(IV) analogue of oxaliplatin with a texaphyrin compound (circles).

FIGS. 35A-35E show cell viability as a function of concentration with the texaphyrin
5 compound and a platinum(IV) analogue of oxaliplatin (circles) compared with the
platinum(IV) analogue alone (squares). A summary of the IC_{50} values for these combinations
is provided in Table 1. **FIG. 35A** shows the data for a platinum(IV) analogue wherein the
axial ligands are both hydroxide. **FIG. 35B** shows the data for a platinum(IV) analogue
wherein one of the axial ligands is hydroxide and the other is acetate. **FIG. 35C** shows the
10 data for a platinum(IV) analog wherein one of the axial ligands is hydroxide and the other is
succinate. **FIG. 35D** shows the data for a platinum(IV) analogue wherein the axial ligands
are both acetate. **FIG. 35E** shows the data for a platinum(IV) analogue wherein the axial
ligands are both ethanoate.

DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

The present disclosure describes new compounds (**FIG. 1**) which can be used to treat cancer and in particular platinum resistance cancer lines as well as new composition comprising a texaphyrin compound and a platinum(IV) drug.

5 The texaphyrin-platinum(IV) conjugates of the present disclosure display an increased stability toward hydrolysis and toward nucleophile such as 5'-guanosine monophosphate (5'-GMP), compared to the compounds approved by the FDA and earlier generations of platinum(II)-texaphyrin conjugates (**FIG. 2**). In some aspects, the new compounds are chemotherapeutic pro-drugs since the compounds are activated upon reduction by chemical
10 reducing agents (such as sodium ascorbate, glutathione) and also via irradiation to natural light. In some aspects, the new compounds can be used as chemotherapeutic agents in platinum resistant cancer cell lines as the conjugates of the present disclosure display increased activity in platinum resistant cancer cell lines compared to traditional platinum agents. In some embodiments, the metallated texaphyrin may also be used to allow detection
15 of the tumor or the location of the agents through imaging techniques such as MRI.

The present disclosure also describes methods of treating a cancer in a patient comprising administering a texaphyrin compound with a metal chemotherapeutic complex to the patient in a therapeutically effective amount. Without wishing to be bound by any theory, the texaphyrin compound localizes into a tumor cell and mediates the reduction of the metal
20 chemotherapeutic complex to form a cytotoxic species. In some aspects, the present disclosure relates to administering a texaphyrin compound with a platinum(IV) complex wherein the texaphyrin compound mediates the reduction of the platinum(IV) complex into a cytotoxic platinum(II) complex. In some aspects, these compositions can be administered wherein the texaphyrin compound is tethered to the platinum(IV) complex or wherein the
25 texaphyrin compound is not covalently linked to the platinum(IV) complex and is administered together or subsequently. In other embodiments, the texaphyrin compound and the platinum(IV) complex are administered with one or more additional therapeutic agents or modalities.

A. CHEMICAL DEFINITIONS

30 When used in the context of a chemical group: "hydrogen" means $-H$; "hydroxy" means $-OH$; "oxo" means $=O$; "carbonyl" means $-C(=O)-$; "carboxy" means $-C(=O)OH$

(also written as $-\text{COOH}$ or $-\text{CO}_2\text{H}$); “halo” means independently $-\text{F}$, $-\text{Cl}$, $-\text{Br}$ or $-\text{I}$; “amino” means $-\text{NH}_2$; “hydroxyamino” means $-\text{NHOH}$; “nitro” means $-\text{NO}_2$; imino means $=\text{NH}$; “cyano” means $-\text{CN}$; “isocyanate” means $-\text{N}=\text{C}=\text{O}$; “azido” means $-\text{N}_3$; in a monovalent context “phosphate” means $-\text{OP}(\text{O})(\text{OH})_2$ or a deprotonated form thereof; in a
 5 divalent context “phosphate” means $-\text{OP}(\text{O})(\text{OH})\text{O}-$ or a deprotonated form thereof; “mercapto” means $-\text{SH}$; and “thio” means $=\text{S}$; “sulfonyl” means $-\text{S}(\text{O})_2-$; and “sulfinyl” means $-\text{S}(\text{O})-$.

In the context of chemical formulas, the symbol “ $-$ ” means a single bond, “ $=$ ” means a double bond, and “ $\equiv$ ” means triple bond. The symbol “ $----$ ” represents an optional bond,
 10 which if present is either single or double. The symbol “ $\equiv$ ” represents a single bond or a

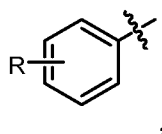
double bond. Thus, for example, the formula  includes , , , ,

and . And it is understood that no one such ring atom forms part of more than one

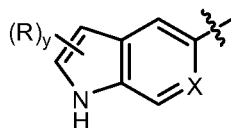
double bond. Furthermore, it is noted that the covalent bond symbol “ $-$ ”, when connecting one or two stereogenic atoms, does not indicate any preferred stereochemistry. Instead, it covers all stereoisomers as well as mixtures thereof. The symbol “ $\sim$ ”, when drawn
 15 perpendicularly across a bond (*e.g.*, $\text{---}\text{CH}_3$ for methyl) indicates a point of attachment of the group. It is noted that the point of attachment is typically only identified in this manner for larger groups in order to assist the reader in unambiguously identifying a point of attachment.

The symbol “ $\blacktriangleleft$ ” means a single bond where the group attached to the thick end of the wedge is “out of the page.” The symbol “ $\blacksquare$ ” means a single bond where the group attached to the thick end of the wedge is “into the page”. The symbol “ $\sim$ ” means a single bond where the geometry around a double bond (*e.g.*, either *E* or *Z*) is undefined. Both options, as well as combinations thereof are therefore intended. Any undefined valency on an atom of a structure shown in this application implicitly represents a hydrogen atom bonded to
 25 that atom. A bold dot on a carbon atom indicates that the hydrogen attached to that carbon is oriented out of the plane of the paper.

When a group “R” is depicted as a “floating group” on a ring system, for example, in the formula:



then R may replace any hydrogen atom attached to any of the ring atoms, including a depicted, implied, or expressly defined hydrogen, so long as a stable structure is formed. When a group “R” is depicted as a “floating group” on a fused ring system, as for example in the formula:



then R may replace any hydrogen attached to any of the ring atoms of either of the fused rings unless specified otherwise. Replaceable hydrogens include depicted hydrogens (*e.g.*, the hydrogen attached to the nitrogen in the formula above), implied hydrogens (*e.g.*, a hydrogen of the formula above that is not shown but understood to be present), expressly defined hydrogens, and optional hydrogens whose presence depends on the identity of a ring atom (*e.g.*, a hydrogen attached to group X, when X equals $-\text{CH}-$), so long as a stable structure is formed. In the example depicted, R may reside on either the 5-membered or the 6-membered ring of the fused ring system. In the formula above, the subscript letter “y” immediately following the group “R” enclosed in parentheses, represents a numeric variable. Unless specified otherwise, this variable can be 0, 1, 2, or any integer greater than 2, only limited by the maximum number of replaceable hydrogen atoms of the ring or ring system.

For the groups and classes below, the following parenthetical subscripts further define the group/class as follows: “(C_n)” defines the exact number (n) of carbon atoms in the group/class. “(C_{≤n})” defines the maximum number (n) of carbon atoms that can be in the group/class, with the minimum number as small as possible for the group in question, *e.g.*, it is understood that the minimum number of carbon atoms in the group “alkenyl_(C_{≤8})” or the class “alkene_(C_{≤8})” is two. For example, “alkoxy_(C_{≤10})” designates those alkoxy groups having from 1 to 10 carbon atoms. (C_n-n’) defines both the minimum (n) and maximum number (n’) of carbon atoms in the group. Similarly, “alkyl_(C₂₋₁₀)” designates those alkyl groups having from 2 to 10 carbon atoms.

The term “saturated” as used herein means the compound or group so modified has no carbon-carbon double and no carbon-carbon triple bonds, except as noted below. In the case of substituted versions of saturated groups, one or more carbon oxygen double bond or a carbon nitrogen double bond may be present. And when such a bond is present, then carbon-carbon double bonds that may occur as part of keto-enol tautomerism or imine/enamine tautomerism are not precluded.

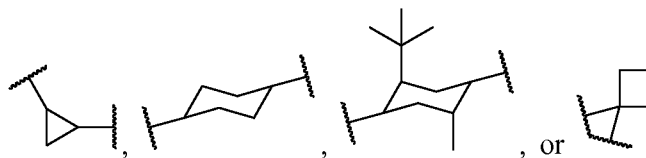
The term “aliphatic” when used without the “substituted” modifier signifies that the compound/group so modified is an acyclic or cyclic, but non-aromatic hydrocarbon compound or group. In aliphatic compounds/groups, the carbon atoms can be joined together in straight chains, branched chains, or non-aromatic rings (alicyclic). Aliphatic compounds/groups can be saturated, that is joined by single bonds (alkanes/alkyl), or unsaturated, with one or more double bonds (alkenes/alkenyl) or with one or more triple bonds (alkynes/alkynyl).

The term “alkyl” when used without the “substituted” modifier refers to a monovalent saturated aliphatic group with a carbon atom as the point of attachment, a linear or branched acyclic structure, and no atoms other than carbon and hydrogen. The groups $-\text{CH}_3$ (Me), $-\text{CH}_2\text{CH}_3$ (Et), $-\text{CH}_2\text{CH}_2\text{CH}_3$ (*n*-Pr or propyl), $-\text{CH}(\text{CH}_3)_2$ (*i*-Pr, *i*Pr or isopropyl), $-\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$ (*n*-Bu), $-\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_3$ (*sec*-butyl), $-\text{CH}_2\text{CH}(\text{CH}_3)_2$ (isobutyl), $-\text{C}(\text{CH}_3)_3$ (*tert*-butyl, *t*-butyl, *t*-Bu or *t*Bu), and $-\text{CH}_2\text{C}(\text{CH}_3)_3$ (*neo*-pentyl) are non-limiting examples of alkyl groups. The term “alkanediyl” when used without the “substituted” modifier refers to a divalent saturated aliphatic group, with one or two saturated carbon atom(s) as the point(s) of attachment, a linear or branched acyclic structure, no carbon-carbon double or triple bonds, and no atoms other than carbon and hydrogen. The groups, $-\text{CH}_2-$ (methylene), $-\text{CH}_2\text{CH}_2-$, $-\text{CH}_2\text{C}(\text{CH}_3)_2\text{CH}_2-$, and $-\text{CH}_2\text{CH}_2\text{CH}_2-$, are non-limiting examples of alkanediyl groups. The term “alkylidene” when used without the “substituted” modifier refers to the divalent group $=\text{CRR}'$ in which R and R' are independently hydrogen or alkyl. Non-limiting examples of alkylidene groups include: $=\text{CH}_2$, $=\text{CH}(\text{CH}_2\text{CH}_3)$, and $=\text{C}(\text{CH}_3)_2$. An “alkane” refers to the compound $\text{H}-\text{R}$, wherein R is alkyl as this term is defined above. When any of these terms is used with the “substituted” modifier one or more hydrogen atom has been independently replaced by $-\text{OH}$, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, $-\text{NH}_2$, $-\text{NO}_2$, $-\text{CO}_2\text{H}$, $-\text{CO}_2\text{CH}_3$, $-\text{CN}$, $-\text{SH}$, $-\text{OCH}_3$, $-\text{OCH}_2\text{CH}_3$, $-\text{C}(\text{O})\text{CH}_3$, $-\text{NHCH}_3$, $-\text{NHCH}_2\text{CH}_3$, $-\text{N}(\text{CH}_3)_2$, $-\text{C}(\text{O})\text{NH}_2$, $-\text{OC}(\text{O})\text{CH}_3$, or $-\text{S}(\text{O})_2\text{NH}_2$. The following groups are non-limiting examples of substituted alkyl groups: $-\text{CH}_2\text{OH}$, $-\text{CH}_2\text{Cl}$, $-\text{CF}_3$, $-\text{CH}_2\text{CN}$, $-\text{CH}_2\text{C}(\text{O})\text{OH}$, $-\text{CH}_2\text{C}(\text{O})\text{OCH}_3$, $-\text{CH}_2\text{C}(\text{O})\text{NH}_2$, $-\text{CH}_2\text{C}(\text{O})\text{CH}_3$, $-\text{CH}_2\text{OCH}_3$, $-\text{CH}_2\text{OC}(\text{O})\text{CH}_3$, $-\text{CH}_2\text{NH}_2$, $-\text{CH}_2\text{N}(\text{CH}_3)_2$, and $-\text{CH}_2\text{CH}_2\text{Cl}$. The term “haloalkyl” is a subset of substituted alkyl, in which one or more hydrogen atoms has been substituted with a halo group and no other atoms aside from carbon, hydrogen and halogen are present. The group, $-\text{CH}_2\text{Cl}$ is a non-limiting example of a haloalkyl. The term “fluoroalkyl” is a subset of substituted alkyl, in which one or more hydrogen has been substituted with a fluoro group and no other atoms

aside from carbon, hydrogen and fluorine are present. The groups, $-\text{CH}_2\text{F}$, $-\text{CF}_3$, and $-\text{CH}_2\text{CF}_3$ are non-limiting examples of fluoroalkyl groups.

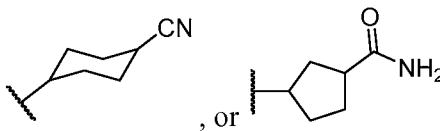
The term “cycloalkyl” when used without the “substituted” modifier refers to a monovalent saturated aliphatic group with a carbon atom as the point of attachment, a linear or branched cyclo or cyclic structure, no carbon-carbon double or triple bonds, and no atoms other than carbon and hydrogen. As used herein, the cycloalkyl group may contain one or more branching alkyl groups (carbon number limit permitting) attached to the ring system so long as the point of attachment is the ring system. Non-limiting examples of cycloalkyl groups include: $-\text{CH}(\text{CH}_2)_2$ (cyclopropyl), cyclobutyl, cyclopentyl, or cyclohexyl. The term “cycloalkanediyl” when used without the “substituted” modifier refers to a divalent saturated aliphatic group with one or two carbon atom as the point(s) of attachment, a linear or branched cyclo or cyclic structure, no carbon-carbon double or triple bonds, and no atoms

other than carbon and hydrogen.



are non-limiting examples of cycloalkanediyl groups. The term “cycloalkylidene” when used without the “substituted” modifier refers to the divalent group $=\text{CRR}'$ in which R and R' are taken together to form a cycloalkanediyl group with at least two carbons. Non-limiting examples of alkylidene groups include: $=\text{C}(\text{CH}_2)_2$ and $=\text{C}(\text{CH}_2)_5$. A “cycloalkane” refers to the compound $\text{H}-\text{R}$, wherein R is cycloalkyl as this term is defined above. When any of these terms is used with the “substituted” modifier one or more hydrogen atom has been independently replaced by $-\text{OH}$, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, $-\text{NH}_2$, $-\text{NO}_2$, $-\text{CO}_2\text{H}$, $-\text{CO}_2\text{CH}_3$, $-\text{CN}$, $-\text{SH}$, $-\text{OCH}_3$, $-\text{OCH}_2\text{CH}_3$, $-\text{C}(\text{O})\text{CH}_3$, $-\text{NHCH}_3$, $-\text{NHCH}_2\text{CH}_3$, $-\text{N}(\text{CH}_3)_2$, $-\text{C}(\text{O})\text{NH}_2$, $-\text{OC}(\text{O})\text{CH}_3$, or $-\text{S}(\text{O})_2\text{NH}_2$. The following groups are non-limiting examples of substituted

cycloalkyl groups: $-\text{C}(\text{OH})(\text{CH}_2)_2$,



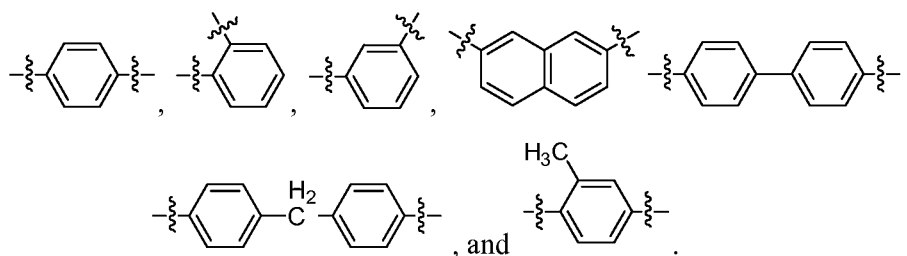
The term “alkenyl” when used without the “substituted” modifier refers to a monovalent unsaturated aliphatic group with a carbon atom as the point of attachment, a linear or branched, cyclo, cyclic or acyclic structure, at least one nonaromatic carbon-carbon double bond, no carbon-carbon triple bonds, and no atoms other than carbon and hydrogen. Non-limiting examples of alkenyl groups include: $-\text{CH}=\text{CH}_2$ (vinyl), $-\text{CH}=\text{CHCH}_3$, $-\text{CH}=\text{CHCH}_2\text{CH}_3$, $-\text{CH}_2\text{CH}=\text{CH}_2$ (allyl), $-\text{CH}_2\text{CH}=\text{CHCH}_3$, and $-\text{CH}=\text{CHCH}=\text{CH}_2$. The

term “alkenediyl” when used without the “substituted” modifier refers to a divalent unsaturated aliphatic group, with two carbon atoms as points of attachment, a linear or branched, cyclo, cyclic or acyclic structure, at least one nonaromatic carbon-carbon double bond, no carbon-carbon triple bonds, and no atoms other than carbon and hydrogen. The groups, $-\text{CH}=\text{CH}-$, $-\text{CH}=\text{C}(\text{CH}_3)\text{CH}_2-$, and $-\text{CH}=\text{CHCH}_2-$, are non-limiting examples of
5 alkenediyl groups. It is noted that while the alkenediyl group is aliphatic, once connected at both ends, this group is not precluded from forming part of an aromatic structure. The terms “alkene” and refer to a compound having the formula $\text{H}-\text{R}$, wherein R is alkenyl as this term is defined above. A “terminal alkene” refers to an alkene having just one carbon-carbon
10 double bond, wherein that bond forms a vinyl group at one end of the molecule. When any of these terms are used with the “substituted” modifier one or more hydrogen atom has been independently replaced by $-\text{OH}$, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, $-\text{NH}_2$, $-\text{NO}_2$, $-\text{CO}_2\text{H}$, $-\text{CO}_2\text{CH}_3$, $-\text{CN}$, $-\text{SH}$, $-\text{OCH}_3$, $-\text{OCH}_2\text{CH}_3$, $-\text{C}(\text{O})\text{CH}_3$, $-\text{NHCH}_3$, $-\text{NHCH}_2\text{CH}_3$, $-\text{N}(\text{CH}_3)_2$, $-\text{C}(\text{O})\text{NH}_2$, $-\text{OC}(\text{O})\text{CH}_3$, or $-\text{S}(\text{O})_2\text{NH}_2$. The groups, $-\text{CH}=\text{CHF}$, $-\text{CH}=\text{CHCl}$ and $-\text{CH}=\text{CHBr}$, are non-
15 limiting examples of substituted alkenyl groups.

The term “alkynyl” when used without the “substituted” modifier refers to a monovalent unsaturated aliphatic group with a carbon atom as the point of attachment, a linear or branched, acyclic structure, at least one carbon-carbon triple bond, and no atoms other than carbon and hydrogen. As used herein, the term alkynyl does not preclude the
20 presence of one or more non-aromatic carbon-carbon double bonds. The groups, $-\text{C}\equiv\text{CH}$, $-\text{C}\equiv\text{CCH}_3$, and $-\text{CH}_2\text{C}\equiv\text{CCH}_3$, are non-limiting examples of alkynyl groups. An “alkyne” refers to the compound $\text{H}-\text{R}$, wherein R is alkynyl. When any of these terms are used with the “substituted” modifier one or more hydrogen atom has been independently replaced by $-\text{OH}$, $-\text{F}$, $-\text{Cl}$, $-\text{Br}$, $-\text{I}$, $-\text{NH}_2$, $-\text{NO}_2$, $-\text{CO}_2\text{H}$, $-\text{CO}_2\text{CH}_3$, $-\text{CN}$, $-\text{SH}$, $-\text{OCH}_3$, $-\text{OCH}_2\text{CH}_3$,
25 $-\text{C}(\text{O})\text{CH}_3$, $-\text{NHCH}_3$, $-\text{NHCH}_2\text{CH}_3$, $-\text{N}(\text{CH}_3)_2$, $-\text{C}(\text{O})\text{NH}_2$, $-\text{OC}(\text{O})\text{CH}_3$, or $-\text{S}(\text{O})_2\text{NH}_2$.

The term “aryl” when used without the “substituted” modifier refers to a monovalent unsaturated aromatic group with an aromatic carbon atom as the point of attachment, said carbon atom forming part of a one or more six-membered aromatic ring structure, wherein the ring atoms are all carbon, and wherein the group consists of no atoms other than carbon
30 and hydrogen. If more than one ring is present, the rings may be fused or unfused. As used herein, the term does not preclude the presence of one or more alkyl or aralkyl groups (carbon number limitation permitting) attached to the first aromatic ring or any additional aromatic ring present. Non-limiting examples of aryl groups include phenyl (Ph), methylphenyl, (dimethyl)phenyl, $-\text{C}_6\text{H}_4\text{CH}_2\text{CH}_3$ (ethylphenyl), naphthyl, and a monovalent

group derived from biphenyl. The term “arenediyl” when used without the “substituted” modifier refers to a divalent aromatic group with two aromatic carbon atoms as points of attachment, said carbon atoms forming part of one or more six-membered aromatic ring structure(s) wherein the ring atoms are all carbon, and wherein the monovalent group consists of no atoms other than carbon and hydrogen. As used herein, the term does not preclude the presence of one or more alkyl, aryl or aralkyl groups (carbon number limitation permitting) attached to the first aromatic ring or any additional aromatic ring present. If more than one ring is present, the rings may be fused or unfused. Unfused rings may be connected via one or more of the following: a covalent bond, alkanediyl, or alkenediyl groups (carbon number limitation permitting). Non-limiting examples of arenediyl groups include:

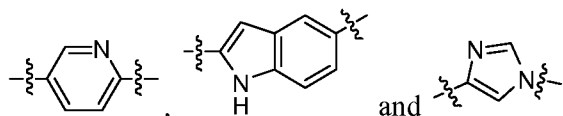


An “arene” refers to the compound H-R, wherein R is aryl as that term is defined above. Benzene and toluene are non-limiting examples of arenes. When any of these terms are used with the “substituted” modifier one or more hydrogen atom has been independently replaced by -OH, -F, -Cl, -Br, -I, -NH₂, -NO₂, -CO₂H, -CO₂CH₃, -CN, -SH, -OCH₃, -OCH₂CH₃, -C(O)CH₃, -NHCH₃, -NHCH₂CH₃, -N(CH₃)₂, -C(O)NH₂, -OC(O)CH₃, or -S(O)₂NH₂.

The term “aralkyl” when used without the “substituted” modifier refers to the monovalent group -alkanediyl-aryl, in which the terms alkanediyl and aryl are each used in a manner consistent with the definitions provided above. Non-limiting examples of aralkyls are: phenylmethyl (benzyl, Bn) and 2-phenyl-ethyl. When the term aralkyl is used with the “substituted” modifier one or more hydrogen atom from the alkanediyl and/or the aryl group has been independently replaced by -OH, -F, -Cl, -Br, -I, -NH₂, -NO₂, -CO₂H, -CO₂CH₃, -CN, -SH, -OCH₃, -OCH₂CH₃, -C(O)CH₃, -NHCH₃, -NHCH₂CH₃, -N(CH₃)₂, -C(O)NH₂, -OC(O)CH₃, or -S(O)₂NH₂. Non-limiting examples of substituted aralkyls are: (3-chlorophenyl)-methyl, and 2-chloro-2-phenyl-eth-1-yl.

The term “heteroaryl” when used without the “substituted” modifier refers to a monovalent aromatic group with an aromatic carbon atom or nitrogen atom as the point of attachment, said carbon atom or nitrogen atom forming part of one or more aromatic ring

structures wherein at least one of the ring atoms is nitrogen, oxygen or sulfur, and wherein the heteroaryl group consists of no atoms other than carbon, hydrogen, aromatic nitrogen, aromatic oxygen and aromatic sulfur. If more than one ring is present, the rings may be fused or unfused. As used herein, the term does not preclude the presence of one or more alkyl, aryl, and/or aralkyl groups (carbon number limitation permitting) attached to the aromatic ring or aromatic ring system. Non-limiting examples of heteroaryl groups include furanyl, imidazolyl, indolyl, indazolyl (Im), isoxazolyl, methylpyridinyl, oxazolyl, phenylpyridinyl, pyridinyl, pyrrolyl, pyrimidinyl, pyrazinyl, quinolyl, quinazolyl, quinoxalinyl, triazinyl, tetrazolyl, thiazolyl, thienyl, and triazolyl. The term “N-heteroaryl” refers to a heteroaryl group with a nitrogen atom as the point of attachment. The term “heteroarenediyl” when used without the “substituted” modifier refers to an divalent aromatic group, with two aromatic carbon atoms, two aromatic nitrogen atoms, or one aromatic carbon atom and one aromatic nitrogen atom as the two points of attachment, said atoms forming part of one or more aromatic ring structure(s) wherein at least one of the ring atoms is nitrogen, oxygen or sulfur, and wherein the divalent group consists of no atoms other than carbon, hydrogen, aromatic nitrogen, aromatic oxygen and aromatic sulfur. If more than one ring is present, the rings may be fused or unfused. Unfused rings may be connected via one or more of the following: a covalent bond, alkanediyl, or alkenediyl groups (carbon number limitation permitting). As used herein, the term does not preclude the presence of one or more alkyl, aryl, and/or aralkyl groups (carbon number limitation permitting) attached to the aromatic ring or aromatic ring system. Non-limiting examples of heteroarenediyl groups include:



A “heteroarene” refers to the compound H-R, wherein R is heteroaryl. Pyridine and quinoline are non-limiting examples of heteroarenes. When these terms are used with the “substituted” modifier one or more hydrogen atom has been independently replaced by -OH, -F, -Cl, -Br, -I, -NH₂, -NO₂, -CO₂H, -CO₂CH₃, -CN, -SH, -OCH₃, -OCH₂CH₃, -C(O)CH₃, -NHCH₃, -NHCH₂CH₃, -N(CH₃)₂, -C(O)NH₂, -OC(O)CH₃, or -S(O)₂NH₂.

The term “acyl” when used without the “substituted” modifier refers to the group -C(O)R, in which R is a hydrogen, alkyl, cycloalkyl, aryl, aralkyl or heteroaryl, as those terms are defined above. The groups, -CHO, -C(O)CH₃ (acetyl, Ac), -C(O)CH₂CH₃, -C(O)CH₂CH₂CH₃, -C(O)CH(CH₃)₂, -C(O)CH(CH₂)₂, -C(O)C₆H₅, -C(O)C₆H₄CH₃, -C(O)CH₂C₆H₅, -C(O)(imidazolyl) are non-limiting examples of acyl groups. A “thioacyl”

is defined in an analogous manner, except that the oxygen atom of the group $-C(O)R$ has been replaced with a sulfur atom, $-C(S)R$. The term “aldehyde” corresponds to an alkane, as defined above, wherein at least one of the hydrogen atoms has been replaced with a $-CHO$ group. When any of these terms are used with the “substituted” modifier one or more hydrogen atom (including a hydrogen atom directly attached the carbonyl or thiocarbonyl group, if any) has been independently replaced by $-OH$, $-F$, $-Cl$, $-Br$, $-I$, $-NH_2$, $-NO_2$, $-CO_2H$, $-CO_2CH_3$, $-CN$, $-SH$, $-OCH_3$, $-OCH_2CH_3$, $-C(O)CH_3$, $-NHCH_3$, $-NHCH_2CH_3$, $-N(CH_3)_2$, $-C(O)NH_2$, $-OC(O)CH_3$, or $-S(O)_2NH_2$. The groups, $-C(O)CH_2CF_3$, $-CO_2H$ (carboxyl), $-CO_2CH_3$ (methylcarboxyl), $-CO_2CH_2CH_3$, $-C(O)NH_2$ (carbamoyl), and $-CON(CH_3)_2$, are non-limiting examples of substituted acyl groups.

The term “alkoxy” when used without the “substituted” modifier refers to the group $-OR$, in which R is an alkyl, as that term is defined above. Non-limiting examples of alkoxy groups include: $-OCH_3$ (methoxy), $-OCH_2CH_3$ (ethoxy), $-OCH_2CH_2CH_3$, $-OCH(CH_3)_2$ (isopropoxy), and $-OC(CH_3)_3$ (*tert*-butoxy). The terms “cycloalkoxy”, “alkenyloxy”, “cycloalkenyloxy”, “alkynyloxy”, “aryloxy”, “aralkoxy”, “heteroaryloxy”, “heterocycloalkoxy”, and “acyloxy”, when used without the “substituted” modifier, refers to groups, defined as $-OR$, in which R is cycloalkyl, alkenyl, cycloalkenyl, alkynyl, aryl, aralkyl, heteroaryl, heterocycloalkyl, and acyl, respectively. The term “alkoxydiyl” refers to the divalent group $-O\text{-alkanediyl-}$, $-O\text{-alkanediyl-O-}$, or $\text{-alkanediyl-O-alkanediyl-}$. The terms “alkylthio”, “cycloalkylthio”, and “acylthio” when used without the “substituted” modifier refers to the group $-SR$, in which R is an alkyl, cycloalkyl, and acyl, respectively. The term “alcohol” corresponds to an alkane, as defined above, wherein at least one of the hydrogen atoms has been replaced with a hydroxy group. The term “ether” corresponds to an alkane, as defined above, wherein at least one of the hydrogen atoms has been replaced with an alkoxy or cycloalkoxy group. When any of these terms is used with the “substituted” modifier one or more hydrogen atom has been independently replaced by $-OH$, $-F$, $-Cl$, $-Br$, $-I$, $-NH_2$, $-NO_2$, $-CO_2H$, $-CO_2CH_3$, $-CN$, $-SH$, $-OCH_3$, $-OCH_2CH_3$, $-C(O)CH_3$, $-NHCH_3$, $-NHCH_2CH_3$, $-N(CH_3)_2$, $-C(O)NH_2$, $-OC(O)CH_3$, or $-S(O)_2NH_2$.

The term “alkylamino” when used without the “substituted” modifier refers to the group $-NHR$, in which R is an alkyl, as that term is defined above. Non-limiting examples of alkylamino groups include: $-NHCH_3$ and $-NHCH_2CH_3$. The term “dialkylamino” when used without the “substituted” modifier refers to the group $-NRR'$, in which R and R' can each independently be the same or different alkyl groups, or R and R' can be taken together to

represent an alkanediyl. The term “dicycloalkylamino” or “diarylamino” when used without the “substituted” modifier refers to the group $-NRR'$, in which R and R' can each independently be the same or different cycloalkyl or aryl groups, respectively. Non-limiting examples of dialkylamino groups include: $-N(CH_3)_2$, $-N(CH_3)(CH_2CH_3)$, and *N*-pyrrolidinyl.

5 The terms “alkoxyamino”, “cycloalkylamino”, “alkenylamino”, “cycloalkenylamino”, “alkynylamino”, “arylamino”, “aralkylamino”, “heteroarylamino”, “heterocycloalkylamino” and “alkylsulfonylamino” when used without the “substituted” modifier, refers to groups, defined as $-NHR$, in which R is alkoxy, cycloalkyl, alkenyl, cycloalkenyl, alkynyl, aryl, aralkyl, heteroaryl, heterocycloalkyl, and alkylsulfonyl, respectively. A non-limiting example of an arylamino group is $-NHC_6H_5$. The term “amido” (acylamino), when used without the “substituted” modifier, refers to the group $-NHR$, in which R is acyl, as that term is defined above. A non-limiting example of an amido group is $-NHC(O)CH_3$. The term “alkylamine” when used without the “substituted” modifier, refers to a group defined as defined as NH_2R , $NH(CH_3)R$, or $N(CH_3)_2R$ in which R is alkyl as that term is defined above.

10 Similarly, the terms “alkoxyamine”, “cycloalkylamine”, “alkenylamine”, “cycloalkenylamine”, “alkynylamine”, “arylamine”, “aralkylamine”, “heteroarylamine”, “heterocycloalkylamine” and “alkylsulfonylamine” when used without the “substituted” modifier, refers to groups, defined as NH_2R in which R is alkoxy, cycloalkyl, alkenyl, cycloalkenyl, alkynyl, aryl, aralkyl, heteroaryl, heterocycloalkyl, and alkylsulfonyl, respectively. Additionally, a dialkylamine or dicycloalkylamine is as those terms are defined above and the point of connectivity is a hydrogen atom. The term “alkylimino” when used without the “substituted” modifier refers to the divalent group $=NR$, in which R is an alkyl, as that term is defined above. The term “alkylaminodiyl” refers to the divalent group $-NH-alkanediyl-$, $-NH-alkanediyl-NH-$, or $-alkanediyl-NH-alkanediyl-$. When any of these terms is used with the “substituted” modifier one or more hydrogen atom has been independently replaced by $-OH$, $-F$, $-Cl$, $-Br$, $-I$, $-NH_2$, $-NO_2$, $-CO_2H$, $-CO_2CH_3$, $-CN$, $-SH$, $-OCH_3$, $-OCH_2CH_3$, $-C(O)CH_3$, $-NHCH_3$, $-NHCH_2CH_3$, $-N(CH_3)_2$, $-C(O)NH_2$, $-OC(O)CH_3$, or $-S(O)_2NH_2$. The groups $-NHC(O)OCH_3$ and $-NHC(O)NHCH_3$ are non-limiting examples of substituted amido groups.

25 The term “effective,” as that term is used in the specification and/or claims, means adequate to accomplish a desired, expected, or intended result. “Effective amount,” “Therapeutically effective amount” or “pharmaceutically effective amount” when used in the context of treating a patient or subject with a compound means that amount of the compound

which, when administered to a subject or patient for treating a disease, is sufficient to effect such treatment for the disease.

As used herein, the term “IC₅₀” refers to an inhibitory dose which is 50% of the maximum response obtained. This quantitative measure indicates how much of a particular drug or other substance (inhibitor) is needed to inhibit a given biological, biochemical or chemical process (or component of a process, i.e. an enzyme, cell, cell receptor or microorganism) by half.

As used herein, the term “ligand” references to a chemical group which coordinates to a metal center through a bond. The bond between the ligand and the metal center in some cases is either an ionic or a coordination bond. A ligand can be monovalent, divalent, trivalent or have a greater valency. In some cases, a ligand may be negatively charged. Some exemplary examples of ligands include, but are not limited to, halide (F⁻, Cl⁻, Br⁻, or I⁻), a carbonate (CO₃²⁻), bicarbonate (HCO₃⁻), hydroxide (OH⁻), perchlorate (ClO₄⁻), nitrate (NO₃⁻), sulfate (SO₄²⁻), acetate (CH₃CO₂⁻), trifluoroacetate (CF₃CO₂⁻), acetylacetonate (CH₃COCHCOCH₃⁻), trifluorosulfonate (CF₃SO₂⁻), or phosphate (PO₄³⁻). A ligand could also be a neutral species that contains a lone pair of electrons. Some examples of neutral ligands include but are not limited to aqua (H₂O) or ammonia (NH₃). Additionally, a neutral ligand can include groups such as an alkylamine or a dialkylamine.

As generally used herein “pharmaceutically acceptable” refers to those compounds, materials, compositions, and/or dosage forms which are, within the scope of sound medical judgment, suitable for use in contact with the tissues, organs, and/or bodily fluids of human beings and animals without excessive toxicity, irritation, allergic response, or other problems or complications commensurate with a reasonable benefit/risk ratio.

“Pharmaceutically acceptable salts” means salts of compounds of the present invention which are pharmaceutically acceptable, as defined above, and which possess the desired pharmacological activity. Such salts include acid addition salts formed with inorganic acids such as hydrochloric acid, hydrobromic acid, sulfuric acid, nitric acid, phosphoric acid, and the like; or with organic acids such as 1,2-ethanedisulfonic acid, 2-hydroxyethanesulfonic acid, 2-naphthalenesulfonic acid, 3-phenylpropionic acid, 4,4'-methylenebis(3-hydroxy-2-ene-1-carboxylic acid), 4-methylbicyclo[2.2.2]oct-2-ene-1-carboxylic acid, acetic acid, aliphatic mono- and dicarboxylic acids, aliphatic sulfuric acids, aromatic sulfuric acids, benzenesulfonic acid, benzoic acid, camphorsulfonic acid, carbonic acid, cinnamic acid, citric acid, cyclopentanepropionic acid, ethanesulfonic acid, fumaric acid, glucoheptonic acid, gluconic acid, glutamic acid, glycolic acid, heptanoic acid, hexanoic

acid, hydroxynaphthoic acid, lactic acid, laurylsulfuric acid, maleic acid, malic acid, malonic acid, mandelic acid, methanesulfonic acid, muconic acid, *o*-(4-hydroxybenzoyl)benzoic acid, oxalic acid, *p*-chlorobenzenesulfonic acid, phenyl-substituted alkanic acids, propionic acid, *p*-toluenesulfonic acid, pyruvic acid, salicylic acid, stearic acid, succinic acid, tartaric acid, tertiarybutylacetic acid, trimethylacetic acid, and the like. Pharmaceutically acceptable salts also include base addition salts which may be formed when acidic protons present are capable of reacting with inorganic or organic bases. Acceptable inorganic bases include sodium hydroxide, sodium carbonate, potassium hydroxide, aluminum hydroxide and calcium hydroxide. Acceptable organic bases include ethanolamine, diethanolamine, triethanolamine, tromethamine, *N*-methylglucamine and the like. It should be recognized that the particular anion or cation forming a part of any salt of this invention is not critical, so long as the salt, as a whole, is pharmacologically acceptable. Additional examples of pharmaceutically acceptable salts and their methods of preparation and use are presented in *Handbook of Pharmaceutical Salts: Properties, and Use* (P. H. Stahl & C. G. Wermuth eds., Verlag Helvetica Chimica Acta, 2002).

“Prevention” or “preventing” includes: (1) inhibiting the onset of a disease in a subject or patient which may be at risk and/or predisposed to the disease but does not yet experience or display any or all of the pathology or symptomatology of the disease, and/or (2) slowing the onset of the pathology or symptomatology of a disease in a subject or patient which may be at risk and/or predisposed to the disease but does not yet experience or display any or all of the pathology or symptomatology of the disease.

“Prodrug” means a compound that is convertible *in vivo* metabolically into an inhibitor according to the present invention. The prodrug itself may or may not also have activity with respect to a given target protein. For example, a compound comprising a hydroxy group may be administered as an ester that is converted by hydrolysis *in vivo* to the hydroxy compound. Suitable esters that may be converted *in vivo* into hydroxy compounds include acetates, citrates, lactates, phosphates, tartrates, malonates, oxalates, salicylates, propionates, succinates, fumarates, maleates, methylene-bis- β -hydroxynaphthoate, gentisates, isethionates, di-*p*-toluoyltartrates, methanesulfonates, ethanesulfonates, benzenesulfonates, *p*-toluenesulfonates, cyclohexylsulfamates, quinates, esters of amino acids, and the like. Similarly, a compound comprising an amine group may be administered as an amide that is converted by hydrolysis *in vivo* to the amine compound.

A “repeat unit” is the simplest structural entity of certain materials, for example, frameworks and/or polymers, whether organic, inorganic or metal-organic. In the case of a

polymer chain, repeat units are linked together successively along the chain, like the beads of a necklace. For example, in polyethylene, $[-CH_2CH_2-]_n$, the repeat unit is $-CH_2CH_2-$. The subscript “n” denotes the degree of polymerization, that is, the number of repeat units linked together. When the value for “n” is left undefined or where “n” is absent, it simply designates repetition of the formula within the brackets as well as the polymeric nature of the material. The concept of a repeat unit applies equally to where the connectivity between the repeat units extends three dimensionally, such as in metal organic frameworks, modified polymers, thermosetting polymers, etc.

In the context of this application, “selectively” means that greater than 50% of the activity of the compound is exhibited in the noted location. On the other hand, “preferentially” means that greater than 75% of the activity of the compound is exhibited in the noted location.

A “stereoisomer” or “optical isomer” is an isomer of a given compound in which the same atoms are bonded to the same other atoms, but where the configuration of those atoms in three dimensions differs. “Enantiomers” are stereoisomers of a given compound that are mirror images of each other, like left and right hands. “Diastereomers” are stereoisomers of a given compound that are not enantiomers. Chiral molecules contain a chiral center, also referred to as a stereocenter or stereogenic center, which is any point, though not necessarily an atom, in a molecule bearing groups such that an interchanging of any two groups leads to a stereoisomer. In organic compounds, the chiral center is typically a carbon, phosphorus or sulfur atom, though it is also possible for other atoms to be stereocenters in organic and inorganic compounds. A molecule can have multiple stereocenters, giving it many stereoisomers. In compounds whose stereoisomerism is due to tetrahedral stereogenic centers (e.g., tetrahedral carbon), the total number of hypothetically possible stereoisomers will not exceed 2^n , where n is the number of tetrahedral stereocenters. Molecules with symmetry frequently have fewer than the maximum possible number of stereoisomers. A 50:50 mixture of enantiomers is referred to as a racemic mixture. Alternatively, a mixture of enantiomers can be enantiomerically enriched so that one enantiomer is present in an amount greater than 50%. Typically, enantiomers and/or diastereomers can be resolved or separated using techniques known in the art. It is contemplated that that for any stereocenter or axis of chirality for which stereochemistry has not been defined, that for tetrahedral stereogenic centers the stereocenter or axis of chirality can be present in its *R* form, *S* form, or as a mixture of the *R* and *S* forms, including racemic and non-racemic mixtures. As used herein, the phrase “substantially free from other stereoisomers” means that the composition contains

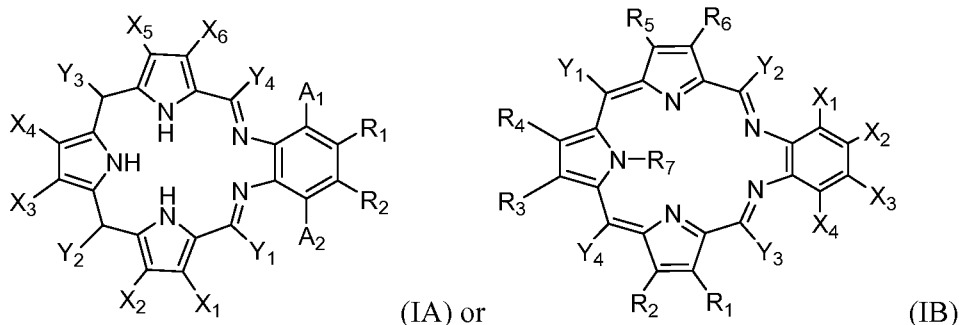
$\leq 15\%$, more preferably $\leq 10\%$, even more preferably $\leq 5\%$, or most preferably $\leq 1\%$ of another stereoisomer(s).

“Treatment” or “treating” includes (1) inhibiting a disease in a subject or patient experiencing or displaying the pathology or symptomatology of the disease (*e.g.*, arresting further development of the pathology and/or symptomatology), (2) ameliorating a disease in a subject or patient that is experiencing or displaying the pathology or symptomatology of the disease (*e.g.*, reversing the pathology and/or symptomatology), and/or (3) effecting any measurable decrease in a disease in a subject or patient that is experiencing or displaying the pathology or symptomatology of the disease.

The above definitions supersede any conflicting definition in any reference that is incorporated by reference herein. The fact that certain terms are defined, however, should not be considered as indicative that any term that is undefined is indefinite. Rather, all terms used are believed to describe the invention in terms such that one of ordinary skill can appreciate the scope and practice the present invention.

B. COMPOUNDS OF THE PRESENT INVENTION

In some aspects, the present invention relates to compounds of the formula:



wherein:

R_1 and R_2 are each independently selected from hydrogen, halo, hydroxy, amino,

mercapto, alkoxy_(C $\leq$ 12), substituted alkoxy_(C $\leq$ 12), or $\text{-(O-CH}_2\text{)}_n\text{-R}_3$, wherein n is 1-20 and R_3 is hydrogen, alkyl_(C $\leq$ 6), or substituted alkyl_(C $\leq$ 6), or a platinum(IV) chelating group;

A_1 and A_2 are each independently selected from hydrogen, halo, hydroxy, alkyl_(C $\leq$ 12),

substituted alkyl_(C $\leq$ 12), alkoxy_(C $\leq$ 12), substituted alkoxy_(C $\leq$ 12), or $\text{-(O-CH}_2\text{)}_n\text{-R}_3$,

wherein n is 1-20 and R₃ is hydrogen, alkyl_(C≤6), or substituted alkyl_(C≤6), or a platinum(IV) chelating group;

Y₁, Y₂, Y₃, and Y₄ are each independently selected from hydrogen, halo, alkyl_(C≤12), aryl_(C≤12), substituted alkyl_(C≤12), or substituted aryl_(C≤12);

5 X₁, X₂, X₃, X₄, X₅, and X₆ are each independently selected from hydrogen, hydroxy, halo, amino, carboxy, nitro, or cyano,

alkyl_(C≤12), alkenyl_(C≤12), alkynyl_(C≤12), aryl_(C≤12), aralkyl_(C≤12), acyl_(C≤12), amido_(C≤12), or a substituted version of any of these groups, or

a platinum(IV) chelating group;

10 R₇ is hydrogen,

alkyl_(C≤8), cycloalkyl_(C≤8), alkenyl_(C≤8), cycloalkenyl_(C≤8), alkynyl_(C≤8), alkoxy_(C≤8), or a substituted version of any of these groups, or

an amino protecting group;

provided that at least one of X₁, X₂, X₃, X₄, X₅, and X₆ is a platinum(IV) chelating group

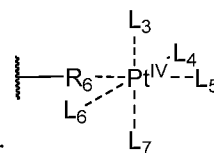
15

or an oxidized metal complex, a pharmaceutically acceptable salt, or tautomer thereof. As used herein, a platinum(IV) chelating group that may be used includes a complex of the formula: -A₃-X₇-A₄-R₄,

wherein:

20 A₃ and A₄ are each independently alkanediyl_(C≤12), alkenediyl_(C≤12), arenediyl_(C≤12), alkoxydiyl_(C≤12), alkylaminodiyl_(C≤12), or a substituted version of any of these groups,

X₇ is -O-, -S-, -NR₅-, -C(O)NR₅-, or -NR₅C(O)-, wherein R₅ is hydrogen, alkyl_(C≤6), or substituted alkyl_(C≤6), and



25

R₄ is amino, hydroxy, mercapto, carboxy, dicarboxy, or

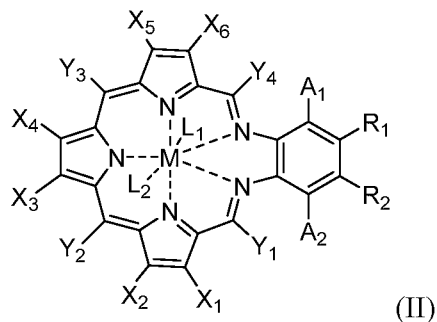
wherein:

R₆ is amino, hydroxy, mercapto, carboxy, or dicarboxy;

L₃, L₄, L₅, and L₆ are each ligands independently selected from aqua, ammonia, nitrate, sulfate, halide, hydroxide, phosphate, or glucose-6-phosphate,

5 alkylamine_(C≤12), cycloalkylamine_(C≤12), dialkylamine_(C≤18),
 dicycloalkylamine_(C≤18), arylamine_(C≤12), diarylamine_(C≤18),
 diaminoalkane_(C≤12), diaminocycloalkane_(C≤12), diaminoarene_(C≤12),
 heteroarene_(C≤12), alkylcarboxylate_(C≤12), alkyldicarboxylate_(C≤18),
 arylcarboxylate_(C≤12), aryldicarboxylate_(C≤18), or a substituted version of
 any of these groups.

Furthermore, an oxidized metal complex may have the formula:



wherein: R₁, R₂, A₁, A₂, Y₁, Y₂, Y₃, Y₄, X₁, X₂, X₃, X₄, X₅, and X₆ are as defined above;

10 M is a monovalent metal ion, a divalent metal ion, or a trivalent metal ion; and

 L₁ and L₂ are each absent or anionic ligands independently selected from fluoride, chloride, bromide, carbonate, hydroxide, perchlorate, nitrate, sulfate, trifluoromethylsulfonate, acetylacetonate, acetate, or trifluoroacetate;

15 provided that when M is a monovalent metal ion then L₁ and L₂ are absent, and when M is a divalent metal ion, then L₁ or L₂ is absent;

 or a pharmaceutically acceptable salt thereof.

20 The compounds provided by the present disclosure are shown, for example, above in the summary of the invention section and in the claims below. They may be made using the methods outlined in the Examples section. These methods can be further modified and optimized using the principles and techniques of organic chemistry as applied by a person skilled in the art. Such principles and techniques are taught, for example, in *March's Advanced Organic Chemistry: Reactions, Mechanisms, and Structure* (2007), which is incorporated by reference herein.

25 Compounds of the invention may contain one or more asymmetrically-substituted carbon or nitrogen atoms, and may be isolated in optically active or racemic form. Thus, all chiral, diastereomeric, racemic form, epimeric form, and all geometric isomeric forms of a chemical formula are intended, unless the specific stereochemistry or isomeric form is specifically indicated. In the context of this disclosure, metal complexes may exist in each of

their isomeric forms such that the ligands may be rearranged to form the other isomers. Compounds may occur as racemates and racemic mixtures, single enantiomers, diastereomeric mixtures and individual diastereomers. In some embodiments, a single diastereomer is obtained. The chiral centers of the compounds of the present invention can have the *S* or the *R* configuration. Additionally, stereoisomers of the metal center including the Pt(IV) cation arising from the various arrangements of the ligands around the metal ion are also contemplated.

Chemical formulas used to represent compounds of the invention will typically only show one of possibly several different tautomers. For example, many types of ketone groups are known to exist in equilibrium with corresponding enol groups. Similarly, many types of imine groups exist in equilibrium with enamine groups. Regardless of which tautomer is depicted for a given compound, and regardless of which one is most prevalent, all tautomers of a given chemical formula are intended.

Compounds of the invention may also have the advantage that they may be more efficacious than, be less toxic than, be longer acting than, be more potent than, produce fewer side effects than, be more easily absorbed than, and/or have a better pharmacokinetic profile (*e.g.*, higher oral bioavailability and/or lower clearance) than, and/or have other useful pharmacological, physical, or chemical properties over, compounds known in the prior art, whether for use in the indications stated herein or otherwise.

In addition, atoms making up the compounds of the present invention are intended to include all isotopic forms of such atoms. Isotopes, as used herein, include those atoms having the same atomic number but different mass numbers. By way of general example and without limitation, isotopes of hydrogen include tritium and deuterium, and isotopes of carbon include ^{13}C and ^{14}C . Additionally, the metal ions in the present invention can have different oxidation states unless otherwise noted. As used herein, the charge on the metal atom can be denoted either as a superscript such as Pt^{IV} or using parenthesis such as Pt(IV). These two forms are identical as would be recognized to a person of skill in the art. Even if one form is used in the application to describe the oxidation state in one place in the application, it is contemplated that the other form could be used in elsewhere in the application.

Compounds of the present invention may also exist in prodrug form. Since prodrugs are known to enhance numerous desirable qualities of pharmaceuticals (*e.g.*, solubility, bioavailability, manufacturing, *etc.*), the compounds employed in some methods of the invention may, if desired, be delivered in prodrug form. Thus, the invention contemplates

prodrugs of compounds of the present invention as well as methods of delivering prodrugs. Prodrugs of the compounds employed in the invention may be prepared by modifying functional groups present in the compound in such a way that the modifications are cleaved, either in routine manipulation or *in vivo*, to the parent compound. Accordingly, prodrugs include, for example, compounds described herein in which a hydroxy, amino, or carboxy group is bonded to any group that, when the prodrug is administered to a subject, cleaves to form a hydroxy, amino, or carboxylic acid, respectively.

It should be recognized that the particular anion or cation forming a part of any salt form of a compound provided herein is not critical, so long as the salt, as a whole, is pharmacologically acceptable. Additional examples of pharmaceutically acceptable salts and their methods of preparation and use are presented in *Handbook of Pharmaceutical Salts: Properties, and Use* (2002), which is incorporated herein by reference.

Those skilled in the art of organic chemistry will appreciate that many organic compounds can form complexes with solvents in which they are reacted or from which they are precipitated or crystallized. These complexes are known as “solvates.” For example, a complex with water is known as a “hydrate.” Solvates of the compounds provided herein are within the scope of the invention. It will also be appreciated by those skilled in organic chemistry that many organic compounds can exist in more than one crystalline form. For example, crystalline form may vary from solvate to solvate. Thus, all crystalline forms of the compounds provided herein or the pharmaceutically acceptable solvates thereof are within the scope of the present invention.

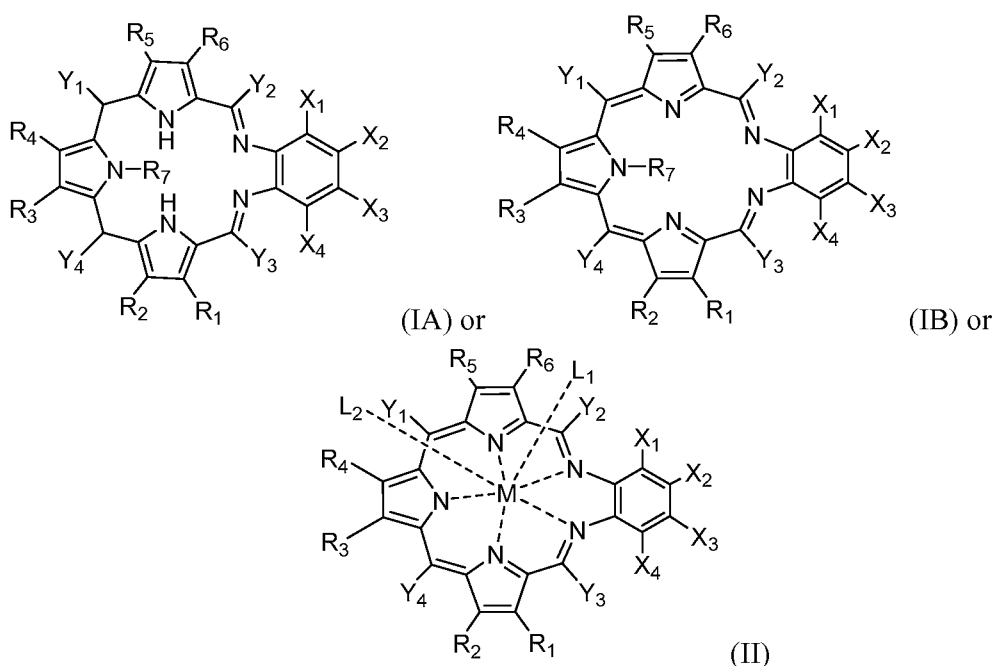
C. Metal Chemotherapeutic Complexes

In some aspects, the present disclosure provides methods and compositions which uses a metal chemotherapeutic complex. Some non-limiting examples of metal chemotherapeutic complexes which may be used include platinum(II), platinum(IV), osmium(II), titanium(IV), iridium(III), iron(II), copper(II), rhodium(III), ruthenium(II), cobalt(III), gallium(III), arsenic(III), molybdenum(VI), gold(I), gold(III), lanthanum(III), or tin(IV) (Romero-Canelon and Sadler, 2013). In some embodiments, these metal complexes may be administered in a higher oxidation state as a high oxidation metal containing chemotherapeutic complex to reduce side effects and/or improve other pharmacokinetic properties. In some embodiments, these compounds are oxidatively sensitive and thus when exposed to reducing agents *in vivo* will reduce to form a complex at a different oxidation state. In some embodiments, these compounds are show more cytotoxicity after exposure to

the reducing agent than the compound before reduction. In some aspects, these compounds are pro-drugs because they must be reduced *in situ* to form the cytotoxic species. In some embodiments, the present invention provides the use of one of these pro-drug metal chemotherapeutic complexes in conjunction with a texaphyrin compound which mediates the reduction to the cytotoxic form. In some embodiments, this process is selective for cancer cells, since the texaphyrin preferentially localizes to cancerous cells (U.S. Patent Nos. 5,599,923 and 5,599,928). In some embodiments, the metal chemotherapeutic complex is a high oxidation state gold, platinum, osmium, or ruthenium complex. For example, such high oxidation state metal chemotherapeutic complexes are taught by, U.S. Patent Nos. 4,265,823, 4,845,124, 4,870,208, 4,980,473, 5,072,011, 5,409,915, 5,624,919, 6,340,599, 6,774,254, 7,479,557, 7,655,697, 7,655,810, 8,193,175, 8,357,678, 8,481,496, 8,563,712, 8,653,132, 8,729,286, 8,748,484, 8,877,215, 8,828,984, and U.S. Patent Applications 2012/0164230, 2013/0303606, 2014/0221475, 2014/0274988, PCT International Applications WO9824424, WO2010027428, WO2012177935, WO2014165782, Chinese Application CN102058576, Chen *et al.*, 2013; Hall *et al.*, 2002; Hall *et al.*, 2003; Hall *et al.*, 2012; Nemirovski *et al.*, 2010; Novohradsky *et al.*, 2014; Shi *et al.*, 2012; Wexselblatt *et al.*, 2012; Wexselblatt *et al.*, 2015; Zhang *et al.*, 2012a; Zhang *et al.*, 2012b; Zhang *et al.*, 2013; Zheng *et al.*, 2015, Zhu *et al.*, 2014, which are all incorporated herein by reference. In some embodiments, the metal chemotherapeutic complex is a high oxidation state platinum complex. In one particular embodiment, the high oxidation state platinum complex is a platinum(IV) complex.

D. Texaphyrin Compounds

In some aspects, the present disclosure provides compositions and methods comprising a texaphyrin compound with or without a platinum chelating group directly bound to the macrocycle, wherein the texaphyrin is a macrocycle of the formula:



wherein:

Y₁-Y₄ are each independently selected from: hydrogen, amino, cyano, halo, hydroxy,
or hydroxyamino,

alkyl_(C≤12), cycloalkyl_(C≤12), alkenyl_(C≤12), cycloalkenyl_(C≤12), alkynyl_(C≤12), aryl_(C≤12),
aralkyl_(C≤12), heteroaryl_(C≤12), heterocycloalkyl_(C≤12), acyl_(C≤12), alkoxy_(C≤12),
acyloxy_(C≤12), aryloxy_(C≤12), heteroaryloxy_(C≤12), heterocycloalkoxy_(C≤12),
amido_(C≤12), alkylamino_(C≤12), dialkylamino_(C≤12), alkylthio_(C≤12), arylthio_(C≤12),
alkylsulfinyl_(C≤12), arylsulfinyl_(C≤12), alkylsulfonyl_(C≤12), arylsulfonyl_(C≤12), or a
substituted version of any of these groups; or

R₁-R₆ are each independently selected from: hydrogen, amino, cyano, halo, hydroxy,
hydroxyamino, or nitro,

alkyl_(C≤12), cycloalkyl_(C≤12), alkenyl_(C≤12), cycloalkenyl_(C≤12), alkynyl_(C≤12), aryl_(C≤12),
aralkyl_(C≤12), heteroaryl_(C≤12), heterocycloalkyl_(C≤12), acyl_(C≤12), alkoxy_(C≤12),
acyloxy_(C≤12), aryloxy_(C≤12), heteroaryloxy_(C≤12), heterocycloalkoxy_(C≤12),
amido_(C≤12), alkylamino_(C≤12), dialkylamino_(C≤12), or a substituted version of
any of these groups; or

a PEG moiety wherein the PEG moiety is of the formula: -(OCH₂CH₂)_nOR₈; wherein:

n is 1-20; and

R₈ is hydrogen, alkyl_(C≤8), or substituted alkyl_(C≤8); or

a platinum(IV) chelating group;

R₇ is hydrogen,

alkyl_(C≤8), cycloalkyl_(C≤8), alkenyl_(C≤8), cycloalkenyl_(C≤8), alkynyl_(C≤8), alkoxy_(C≤8), or a substituted version of any of these groups, or

an amino protecting group;

X₁-X₄ are each independently selected from: hydrogen, amino, cyano, halo, hydroxy, hydroxyamino, or nitro,

alkyl_(C≤12), cycloalkyl_(C≤12), alkenyl_(C≤12), cycloalkenyl_(C≤12), alkynyl_(C≤12), aryl_(C≤12), aralkyl_(C≤12), heteroaryl_(C≤12), heterocycloalkyl_(C≤12), acyl_(C≤12), alkoxy_(C≤12), acyloxy_(C≤12), aryloxy_(C≤12), heteroaryloxy_(C≤12), heterocycloalkoxy_(C≤12), amido_(C≤12), alkylamino_(C≤12), dialkylamino_(C≤12), or a substituted version of any of these groups; or

a PEG moiety wherein the PEG moiety is of the formula: $-(OCH_2CH_2)_nOR_8$; wherein:

n is 1-20; and

R₈ is hydrogen, alkyl_(C≤8), or substituted alkyl_(C≤8); or

a platinum(IV) chelating group;

L₁ and L₂ are each independently absent, a neutral ligand, or an anionic ligand; and

M is a metal ion;

provided that L₁ and L₂ are present or absent in a manner sufficient to balance the charge on the metal ion;

or a pharmaceutically acceptable salt or tautomer thereof.

Additional non-limiting examples of texaphyrins are taught by U.S. Patent Nos. 4,935,498, 5,252,270, 5,272,142, 5,292,414, 5,369,101, 5,432,171, 5,439,570, 5,504,205, 5,569,759, 5,583,220, 5,587,463, 5,591,422, 5,633,354, 5,776,925, 5,955,586, 5,994,535, 6,207,660, 7,112,671, and 8,410,263, which are all incorporated herein by reference. When the term, "texaphyrin compound" is used herein it can refer to a texaphyrin in both its oxidized and reduced forms, a metallotexaphyrin, or any of these groups. As would be known by a person of skill in the art, texaphyrins are known to undergo oxidation when a metal ion is bound. This phenomenon is described in U.S. Patent No. 5,504,205, Shimanovich, *et al.*, 2001 and Hannah, *et al.*, 2001, all of which are incorporated herein by reference. As this process is linked with the metalation of the texaphyrin compound, these compounds are referenced to herein as an oxidized metallated derivative of the reduced macrocycle formula.

In some aspects, the present disclosure provides compositions and methods of use of the metallated form of the texaphyrin compound. In some embodiments, the metal of the

metallated form is a transition metal. In some embodiments, the metal is a metal ion in the 2+ oxidation state or the 3+ oxidation state. In some embodiments, the metal is an actinide or lanthanide. In some embodiments, the metal is lutetium or gadolinium. In some embodiments, the metal atom is gadolinium. In some aspects, the texaphyrin compound is administered simultaneously with a reducing agent. In some embodiments, the reducing agent is a two electron donor. In some embodiments, the reducing agent is sodium ascorbate, thioredoxin reductase, a platinum(II) ion or complex, or a biological thiol, including but not limited to cysteine, homocysteine, or glutathione. A photoreduction may also be used in conjunction with the texaphyrin compound.

10 E. Hyperproliferative Diseases

While hyperproliferative diseases can be associated with any medical disorder that causes a cell to begin to reproduce uncontrollably, the prototypical example is cancer. One of the key elements of cancer is that the normal apoptotic cycle of the cell is interrupted and thus agents that lead to apoptosis of the cell are important therapeutic agents for treating these diseases. As such, the texaphyrin and platinum(IV) analogues and compositions described in this disclosure may be effective in treating cancers.

Cancer cells that may be treated with the compounds according to the embodiments include but are not limited to cells from the bladder, blood, bone, bone marrow, brain, breast, colon, esophagus, gastrointestinal, gum, head, kidney, liver, lung, nasopharynx, neck, ovary, prostate, skin, stomach, pancreas, testis, tongue, cervix, or uterus. In addition, the cancer may specifically be of the following histological type, though it is not limited to these: neoplasm, malignant; carcinoma; carcinoma, undifferentiated; giant and spindle cell carcinoma; small cell carcinoma; papillary carcinoma; squamous cell carcinoma; lymphoepithelial carcinoma; basal cell carcinoma; pilomatrix carcinoma; transitional cell carcinoma; papillary transitional cell carcinoma; adenocarcinoma; gastrinoma, malignant; cholangiocarcinoma; hepatocellular carcinoma; combined hepatocellular carcinoma and cholangiocarcinoma; trabecular adenocarcinoma; adenoid cystic carcinoma; adenocarcinoma in adenomatous polyp; adenocarcinoma, familial polyposis coli; solid carcinoma; carcinoid tumor, malignant; branchiolo-alveolar adenocarcinoma; papillary adenocarcinoma; chromophobe carcinoma; acidophil carcinoma; oxyphilic adenocarcinoma; basophil carcinoma; clear cell adenocarcinoma; granular cell carcinoma; follicular adenocarcinoma; papillary and follicular adenocarcinoma; nonencapsulating sclerosing carcinoma; adrenal cortical carcinoma; endometroid carcinoma; skin appendage carcinoma; apocrine

adenocarcinoma; sebaceous adenocarcinoma; ceruminous adenocarcinoma; mucoepidermoid carcinoma; cystadenocarcinoma; papillary cystadenocarcinoma; papillary serous cystadenocarcinoma; mucinous cystadenocarcinoma; mucinous adenocarcinoma; signet ring cell carcinoma; infiltrating duct carcinoma; medullary carcinoma; lobular carcinoma;

5 inflammatory carcinoma; paget's disease, mammary; acinar cell carcinoma; adenosquamous carcinoma; adenocarcinoma w/squamous metaplasia; thymoma, malignant; ovarian stromal tumor, malignant; thecoma, malignant; granulosa cell tumor, malignant; androblastoma, malignant; sertoli cell carcinoma; leydig cell tumor, malignant; lipid cell tumor, malignant; paraganglioma, malignant; extra-mammary paraganglioma, malignant; pheochromocytoma;

10 glomangiosarcoma; malignant melanoma; amelanotic melanoma; superficial spreading melanoma; malig melanoma in giant pigmented nevus; epithelioid cell melanoma; blue nevus, malignant; sarcoma; fibrosarcoma; fibrous histiocyoma, malignant; myxosarcoma; liposarcoma; leiomyosarcoma; rhabdomyosarcoma; embryonal rhabdomyosarcoma; alveolar rhabdomyosarcoma; stromal sarcoma; mixed tumor, malignant; mullerian mixed tumor;

15 nephroblastoma; hepatoblastoma; carcinosarcoma; mesenchymoma, malignant; brenner tumor, malignant; phyllodes tumor, malignant; synovial sarcoma; mesothelioma, malignant; dysgerminoma; embryonal carcinoma; teratoma, malignant; struma ovarii, malignant; choriocarcinoma; mesonephroma, malignant; hemangiosarcoma; hemangioendothelioma, malignant; kaposi's sarcoma; hemangiopericytoma, malignant; lymphangiosarcoma;

20 osteosarcoma; juxtacortical osteosarcoma; chondrosarcoma; chondroblastoma, malignant; mesenchymal chondrosarcoma; giant cell tumor of bone; ewing's sarcoma; odontogenic tumor, malignant; ameloblastic odontosarcoma; ameloblastoma, malignant; ameloblastic fibrosarcoma; pinealoma, malignant; chordoma; glioma, malignant; ependymoma; astrocytoma; protoplasmic astrocytoma; fibrillary astrocytoma; astroblastoma; glioblastoma;

25 oligodendroglioma; oligodendroblastoma; primitive neuroectodermal; cerebellar sarcoma; ganglioneuroblastoma; neuroblastoma; retinoblastoma; olfactory neurogenic tumor; meningioma, malignant; neurofibrosarcoma; neurilemmoma, malignant; granular cell tumor, malignant; malignant lymphoma; Hodgkin's disease; Hodgkin's; paraganuloma; malignant lymphoma, small lymphocytic; malignant lymphoma, large cell, diffuse; malignant

30 lymphoma, follicular; mycosis fungoides; other specified non-Hodgkin's lymphomas; malignant histiocytosis; multiple myeloma; mast cell sarcoma; immunoproliferative small intestinal disease; leukemia; lymphoid leukemia; plasma cell leukemia; erythroleukemia; lymphosarcoma cell leukemia; myeloid leukemia; basophilic leukemia; eosinophilic leukemia; monocytic leukemia; mast cell leukemia; megakaryoblastic leukemia; myeloid

sarcoma; and hairy cell leukemia. In certain aspects, the tumor may comprise an osteosarcoma, angiosarcoma, rhabdosarcoma, leiomyosarcoma, Ewing sarcoma, glioblastoma, neuroblastoma, or leukemia.

F. Pharmaceutical Formulations and Routes of Administration

5 For administration to a mammal in need of such treatment, the texaphyrin and platinum(IV) analogues and compositions conjugate of the present invention are ordinarily combined with one or more excipients appropriate to the indicated route of administration. The texaphyrin and platinum(IV) analogues and compositions of the present invention may be admixed with lactose, sucrose, starch powder, cellulose esters of alkanolic acids, cellulose
10 alkyl esters, talc, stearic acid, magnesium stearate, magnesium oxide, sodium and calcium salts of phosphoric and sulfuric acids, gelatin, acacia, sodium alginate, polyvinylpyrrolidone, and/or polyvinyl alcohol, and tableted or encapsulated for convenient administration. Alternatively, the conjugates may be dissolved in water, polyethylene glycol, propylene glycol, ethanol, corn oil, cottonseed oil, peanut oil, sesame oil, benzyl alcohol, sodium
15 chloride, and/or various buffers. Other excipients and modes of administration are well and widely known in the pharmaceutical art.

The pharmaceutical compositions useful in the present invention may be subjected to conventional pharmaceutical operations such as sterilization and/or may contain conventional pharmaceutical carriers and excipients such as preservatives, stabilizers, wetting agents,
20 emulsifiers, buffers, *etc.*

The texaphyrin and platinum(IV) analogues and compositions of the present invention may be administered by a variety of methods, *e.g.*, orally or by injection (*e.g.* subcutaneous, intravenous, intraperitoneal, *etc.*). Depending on the route of administration, the novel conjugates may be coated in a material to protect the compound from the action of acids and
25 other natural conditions which may inactivate the compound. They may also be administered by continuous perfusion/infusion of a disease or wound site.

To administer the therapeutic compound by other than parenteral administration, it may be necessary to coat the texaphyrin and platinum(IV) analogues and compositions of the present invention with, or co-administer the texaphyrin and platinum(IV) analogues and
30 compositions of the present invention with, a material to prevent its inactivation. For example, the therapeutic compound may be administered to a patient in an appropriate carrier, for example, liposomes, or a diluent. Pharmaceutically acceptable diluents include saline and aqueous buffer solutions. Liposomes include water-in-oil-in-water CGF emulsions

as well as conventional liposomes. Additionally, Trapasol®, Travasol®, cyclodextrin, and other drug carrier molecules may also be used in combination with the texaphyrin and platinum(IV) analogues and compositions of the present disclosure. It is contemplated that the compounds of the present disclosure may be formulated with a cyclodextrin as a drug carrier using an organic solvent such as dimethylacetamide with a polyethylene glycol and a poloxamer composition in an aqueous sugar solution. In some embodiments, the organic solvent is dimethylsulfoxide, dimethylformamide, dimethylacetamide, or other biologically compatible organic solvents. Additionally, the composition may be diluted with a polyethylene glycol polymer such as PEG100, PEG200, PEG250, PEG400, PEG500, PEG600, PEG750, PEG800, PEG900, PEG1000, PEG2000, PEG2500, PEG3000, or PEG4000. Additionally, the composition may further comprise one or more poloxamer composition wherein the poloxamer contains two hydrophilic polyoxyethylene groups and a hydrophobic polyoxypropylene or a substituted version of these groups. This mixture may be further diluted using an aqueous sugar solution such as 5% aqueous dextrose solution.

The texaphyrin and platinum(IV) analogues and compositions of the present invention may also be administered parenterally, intraperitoneally, intraspinally, or intracerebrally. Dispersions can be prepared in glycerol, liquid polyethylene glycols, and mixtures thereof and in oils. Under ordinary conditions of storage and use, these preparations may contain a preservative to prevent the growth of microorganisms.

Pharmaceutical compositions suitable for injectable use include sterile aqueous solutions (where water soluble) or dispersions and sterile powders for the extemporaneous preparation of sterile injectable solutions or dispersion are also envisioned. In all cases, the composition must be sterile and must be fluid to the extent that easy syringability exists. It must be stable under the conditions of manufacture and storage and must be preserved against the contaminating action of microorganisms such as bacteria and fungi. The carrier can be a solvent or dispersion medium containing, for example, water, ethanol, polyol (such as, glycerol, propylene glycol, and liquid polyethylene glycol, and the like), suitable mixtures thereof, and vegetable oils. The proper fluidity can be maintained, for example, by the use of a coating such as lecithin, by the maintenance of the required particle size in the case of dispersion and by the use of surfactants. Prevention of the action of microorganisms can be achieved by various antibacterial and antifungal agents, for example, parabens, chlorobutanol, phenol, ascorbic acid, thimerosal, and the like. In many cases, it will be preferable to include isotonic agents, for example, sugars, sodium chloride, or polyalcohols such as mannitol and sorbitol, in the composition. Prolonged absorption of the injectable

compositions can be brought about by including in the composition an agent which delays absorption, for example, aluminum monostearate or gelatin.

Sterile injectable solutions can be prepared by incorporating the texaphyrin and platinum(IV) analogues and compositions of the present invention in the required amount in
5 an appropriate solvent with one or a combination of ingredients enumerated above, as required, followed by filtered sterilization. Generally, dispersions are prepared by incorporating the therapeutic compound into a sterile carrier which contains a basic dispersion medium and the required other ingredients from those enumerated above. In the case of sterile powders for the preparation of sterile injectable solutions, the preferred
10 methods of preparation are vacuum drying and freeze-drying which yields a powder of the active ingredient (*i.e.*, the therapeutic compound) plus any additional desired ingredient from a previously sterile-filtered solution thereof.

The texaphyrin and platinum(IV) analogues and compositions of the present invention can be orally administered, for example, with an inert diluent or an assimilable edible carrier.
15 The therapeutic compound and other ingredients may also be enclosed in a hard or soft shell gelatin capsule, compressed into tablets, or incorporated directly into the subject's diet. For oral therapeutic administration, the conjugates may be incorporated with excipients and used in the form of ingestible tablets, buccal tablets, troches, capsules, elixirs, suspensions, syrups, wafers, and the like. The percentage of the therapeutic compound in the compositions and
20 preparations may, of course, be varied. The amount of the texaphyrin and platinum(IV) analogues and compositions of the present invention in such therapeutically useful compositions is such that a suitable dosage will be obtained.

It is especially advantageous to formulate parenteral compositions in dosage unit form for ease of administration and uniformity of dosage. Dosage unit form as used herein refers
25 to physically discrete units suited as unitary dosages for the subjects to be treated; each unit containing a predetermined quantity of the texaphyrin and platinum(IV) analogues and compositions of the present invention calculated to produce the desired therapeutic effect in association with the required pharmaceutical carrier. The specification for the dosage unit forms of the invention are dictated by and directly dependent on (a) the unique characteristics
30 of the texaphyrin and platinum(IV) analogues and compositions of the present invention and the particular therapeutic effect to be achieved, and (b) the limitations inherent in the art of compounding such a therapeutic compound for the treatment of a selected condition in a patient.

The therapeutic compound may also be administered topically to the skin, eye, or mucosa. Alternatively, if local delivery to the lungs is desired the therapeutic compound may be administered by inhalation in a dry-powder or aerosol formulation.

The texaphyrin and platinum(IV) analogues and compositions of the present invention describe in this disclosure are administered at a therapeutically effective dosage sufficient to treat a condition associated with a condition in a patient. For example, the efficacy of the texaphyrin and platinum(IV) analogues and compositions of the present invention can be evaluated in an animal model system that may be predictive of efficacy in treating the disease in humans, such as the model systems shown in the examples and drawings.

The actual dosage amount of the texaphyrin and platinum(IV) analogues and compositions of the present disclosure or composition comprising the conjugates of the present disclosure administered to a subject may be determined by physical and physiological factors such as age, sex, body weight, severity of condition, the type of disease being treated, previous or concurrent therapeutic interventions, idiopathy of the subject and on the route of administration. These factors may be determined by a skilled artisan. The practitioner responsible for administration will typically determine the concentration of active ingredient(s) in a composition and appropriate dose(s) for the individual subject. The dosage may be adjusted by the individual physician in the event of any complication.

An effective amount typically will vary from about 1 mg/kg to about 50 mg/kg, in one or more dose administrations daily, for one or several days (depending of course of the mode of administration and the factors discussed above). In some particular embodiments, the amount is less than 5,000 mg per day with a range of 10 mg to 4500 mg per day.

The effective amount may be less than 10 mg/kg/day, less than 50 mg/kg/day, less than 100 mg/kg/day, less than 250 mg/kg/day. It may alternatively be in the range of 1 mg/kg/day to 250 mg/kg/day.

In other non-limiting examples, a dose may also comprise from about 0.1 mg/kg/body weight, about 1 mg/kg/body weight, about 10 g/kg/body weight, about 50 g/kg/body weight, or more per administration, and any range derivable therein. In non-limiting examples of a derivable range from the numbers listed herein, a range of about 1 mg/kg/body weight to about 50 mg/kg/body weight, about 5 g/kg/body weight to about 10 g/kg/body weight, *etc.*, can be administered, based on the numbers described above.

In certain embodiments, a pharmaceutical composition of the present disclosure may comprise, for example, at least about 0.1% of a conjugate described in the present disclosure. In other embodiments, the compound of the present disclosure may comprise between about

0.25% to about 75% of the weight of the unit, or between about 25% to about 60%, or between about 1% to about 10%, for example, and any range derivable therein.

Single or multiple doses of the agents are contemplated. Desired time intervals for delivery of multiple doses can be determined by one of ordinary skill in the art employing no more than routine experimentation. As an example, subjects may be administered two doses daily at approximately 12 hour intervals. In some embodiments, the agents are administered once a day.

The compounds may be administered on a routine schedule. As used herein a routine schedule refers to a predetermined designated period of time. The routine schedule may encompass periods of time which are identical or which differ in length, as long as the schedule is predetermined. For instance, the routine schedule may involve administration twice a day, every day, every two days, every three days, every four days, every five days, every six days, a weekly basis, a monthly basis or any set number of days or weeks therebetween. Alternatively, the predetermined routine schedule may involve administration on a twice daily basis for the first week, followed by a daily basis for several months, *etc.* In other embodiments, the invention provides that the agent(s) may taken orally and that the timing of which is or is not dependent upon food intake. Thus, for example, the agents can be taken every morning and/or every evening, regardless of when the subject has eaten or will eat.

G. Combination Therapy

In some aspects, the present disclosure provides compositions of a texaphyrin compound and an high oxidation state metal chemotherapeutic agent such as a platinum(IV) complex. It is contemplated that these agents may be administered simultaneously. These compositions may be formulated as unit dose with both agents such that both agents are administered together. In other aspects, the texaphyrin compound may be administered before the high oxidation state metal chemotherapeutic agent by a time period from a few minutes to about one week. In some embodiments, the time period is from about 1 hour to about 24 hours. Thus, the time period may be from about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 27, 30, 33, 36, 42, or 48 hours, or any range derivable therein. In other embodiments, the high oxidation metal chemotherapeutic agent may be administered before the texaphyrin compound by a similar time period.

In addition to being used as a monotherapy, the texaphyrin and platinum(IV) analogues and compositions of the present invention may also find use in combination

therapies. Effective combination therapy may be achieved with a single composition or pharmacological formulation that includes both agents, or with two distinct compositions or formulations, administered at the same time, wherein one composition includes an texaphyrin and platinum(IV) analogues and compositions, and the other includes the second agent(s).

5 The other therapeutic modality may be administered before, concurrently with, or following administration of the texaphyrin and platinum(IV) analogues and compositions of the present invention. The therapy using the texaphyrin and platinum(IV) analogues and compositions of the present invention may precede or follow administration of the other agent(s) by intervals ranging from minutes to weeks. In embodiments where the other agent and the compounds or
10 compositions of the present disclosure are administered separately, one would generally ensure that a significant period of time did not expire between the time of each delivery, such that each agent would still be able to exert an advantageously combined effect. In such instances, it is contemplated that one would typically administer the texaphyrin and platinum(IV) analogues and compositions of the present invention and the other therapeutic
15 agent within about 12-24 hours of each other and, more preferably, within about 6-12 hours of each other, with a delay time of only about 12 hours being most preferred. In some situations, it may be desirable to extend the time period for treatment significantly, however, where several days (2, 3, 4, 5, 6 or 7) to several weeks (1, 2, 3, 4, 5, 6, 7 or 8) lapse between the respective administrations.

20 It also is conceivable that more than one administration of a texaphyrin-platinum(IV) conjugate or a composition of the texaphyrin compound and a high oxidation metal chemotherapeutic agent of the present disclosure, or the other agent will be desired. In this regard, various combinations may be employed. By way of illustration, where the compounds of the present disclosure are "A" and the other agent is "B", the following
25 permutations based on 3 and 4 total administrations are exemplary:

A/B/A B/A/B B/B/A A/A/B B/A/A A/B/B B/B/B/A B/B/A/B

A/A/B/B A/B/A/B A/B/B/A B/B/A/A B/A/B/A B/A/A/B B/B/B/A

A/A/A/B B/A/A/A A/B/A/A A/A/B/A A/B/B/B B/A/B/B B/B/A/B

Other combinations are likewise contemplated. Non-limiting examples of pharmacological
30 agents that may be used in the present invention include any pharmacological agent known to be of benefit in the treatment of a cancer or hyperproliferative disorder or disease. In some

embodiments, combinations of the texaphyrin-platinum(IV) conjugate or the composition of a texaphyrin compound and a high oxidation state metal chemotherapeutic agent of the present invention with a cancer targeting immunotherapy, radiotherapy, chemotherapy, or surgery are contemplated. Also contemplated is a combination of the texaphyrin-platinum(IV) conjugate the composition of a texaphyrin compound and a high oxidation state metal chemotherapeutic agent of the present disclosure with more than one of the above mentioned methods including more than one type of a specific therapy. In some embodiments, it is contemplated that the immunotherapy is a monoclonal antibody which targets HER2/neu such trastuzumab (Herceptin®), alemtuzumab (Campath®), bevacizumab (Avastin®), cetuximab (Eribitux®), and panitumumab (Vectibix®) or conjugated antibodies such as ibritumomab tiuxetan (Zevalin®), tositumomab (Bexxar®), brentuximab vedotin (Adcetris®), ado-trastuzumab emtansine (Kadcyla™), or denileukin dititox (Ontak®) as well as immune cell targeting antibodies such as ipilimumab (Yervoy®), tremelimumab, anti-PD-1, anti-4-1-BB, anti-GITR, anti-TIM3, anti-LAG-3, anti-TIGIT, anti-CTLA-4, or anti-LIGHT. Furthermore, in some embodiments, the texaphyrin-platinum(IV) conjugate the composition of a texaphyrin compound and a high oxidation state metal chemotherapeutic agent of the present disclosure are envisioned to be used in combination therapies with dendritic cell-based immunotherapies such as Sipuleucel-T (Provenge®) or adoptive T-cell immunotherapies.

Furthermore, it is contemplated that the methods described herein may be used in combination with a chemotherapeutic agent such as PR-171 (Kyprolis®), bortezomib (Velcade®), anthracyclines, taxanes, methotrexate, mitoxantrone, estramustine, doxorubicin, etoposide, vinblastine, vinorelbine, 5-fluorouracil, cisplatin, carboplatin, oxaliplatin, Pt(IV) complexes, topotecan, ifosfamide, cyclophosphamide, epirubicin, gemcitabine, vinorelbine, irinotecan, etoposide, vinblastine, pemetrexed, melphalan, capecitabine, oxaliplatin, BRAF inhibitors, and TGF-beta inhibitors. In some embodiments, the combination therapy is designed to target a cancer such as those listed above.

In some aspects, it is contemplated that the texaphyrin-platinum(IV) conjugate or the composition of a texaphyrin compound and a high oxidation state metal chemotherapeutic agent may be used in conjunction with radiation therapy. Radiotherapy, also called radiation therapy, is the treatment of cancer and other diseases with ionizing radiation. Ionizing radiation deposits energy that injures or destroys cells in the area being treated by damaging

their genetic material, making it impossible for these cells to continue to grow. Although radiation damages both cancer cells and normal cells, the latter are able to repair themselves and function properly.

Radiation therapy used according to the present invention may include, but is not limited to, the use of γ -rays, X-rays, and/or the directed delivery of radioisotopes to tumor cells. Other forms of DNA damaging factors are also contemplated such as microwaves and UV-irradiation. It is most likely that all of these factors induce a broad range of damage on DNA, on the precursors of DNA, on the replication and repair of DNA, and on the assembly and maintenance of chromosomes. Dosage ranges for X-rays range from daily doses of 50 to 200 roentgens for prolonged periods of time (3 to 4 weeks), to single doses of 2000 to 6000 roentgens. Dosage ranges for radioisotopes vary widely, and depend on the half-life of the isotope, the strength and type of radiation emitted, and the uptake by the neoplastic cells.

Additionally, it is contemplated texaphyrin-platinum(IV) conjugate the composition of a texaphyrin compound and a high oxidation state metal chemotherapeutic agent of the present invention are used in combination with sonodynamic therapy. The use of texaphyrins in sonodynamic therapy is described in U.S. Patent 6,207,660 incorporated herein by reference. A texaphyrin-platinum(IV) conjugate or the composition is administered before administration of the sonodynamic agent. The conjugate or composition may be administered as a single dose, or it may be administered as two or more doses separated by an interval of time. Parenteral administration is typical, including by intravenous and interarterial injection. Other common routes of administration can also be employed.

Ultrasound is generated by a focused array transducer driven by a power amplifier. The transducer can vary in diameter and spherical curvature to allow for variation of the focus of the ultrasonic output. Commercially available therapeutic ultrasound devices may be employed in the practice of the invention. The duration and wave frequency, including the type of wave employed may vary, and the preferred duration of treatment will vary from case to case within the judgment of the treating physician. Both progressive wave mode patterns and standing wave patterns have been successful in producing cavitation of diseased tissue. When using progressive waves, the second harmonic can advantageously be superimposed onto the fundamental wave.

Preferred sonodynamic agents employed in the present invention is ultrasound, particularly is low intensity, non-thermal ultrasound, i.e., ultrasound generated within the wavelengths of about 0.1 MHz and 5.0 MHz and at intensities between about 3.0 and 5.0 W/cm².

5 Furthermore, it is contemplated that the conjugates of the present invention can be used in combination with photodynamic therapy: By way of example, lutetium texaphyrin is administered in solution containing 2 mg/ml optionally in 5% mannitol, USP. Dosages of about 1.0 or 2.0 mg/kg to about 4.0 or 5.0 mg/kg, preferably 3.0 mg/kg may be employed, up to a maximum tolerated dose that was determined in one study to be 5.2 mg/kg. The
10 texaphyrin is administered by intravenous injection, followed by a waiting period of from as short a time as several minutes or about 3 hours to as long as about 72 or 96 hours (depending on the treatment being effected) to facilitate intracellular uptake and clearance from the plasma and extracellular matrix prior to the administration of photoirradiation.

The co-administration of a sedative (e.g., benzodiazapenes) and narcotic analgesic are
15 sometimes recommended prior to light treatment along with topical administration of Emla cream (lidocaine, 2.5% and prilocaine, 2.5%) under an occlusive dressing. Other intradermal, subcutaneous and topical anesthetics may also be employed as necessary to reduce discomfort. Subsequent treatments can be provided after approximately 21 days. The treating physician may choose to be particularly cautious in certain circumstances and advise that
20 certain patients avoid bright light for about one week following treatment.

When employing photodynamic therapy, a target area is treated with light at about 732±16.5 nm (full width half max) delivered by LED device or an equivalent light source (e.g., a Quantum Device Qbeam™ Q BMEDXM-728 Solid State Lighting System, which operates at 728 nm) at an intensity of 75 mW/cm² for a total light dose of 150 J/cm². The light
25 treatment takes approximately 33 minutes.

The optimum length of time following texaphyrin administration until light treatment can vary depending on the mode of administration, the form of administration, and the type of target tissue. Typically, the texaphyrin persists for a period of minutes to hours, depending on the texaphyrin, the formulation, the dose, the infusion rate, as well as the type of tissue
30 and tissue size.

After the photosensitizing texaphyrin has been administered, the tissue being treated is photoirradiated at a wavelength similar to the absorbance of the texaphyrin, usually either about 400-500 nm or about 700-800 nm, more preferably about 450-500 nm or about 710-760 nm, or most preferably about 450-500 nm or about 725-740 nm. The light source may be a laser, a light-emitting diode, or filtered light from, for example, a xenon lamp; and the light may be administered topically, endoscopically, or interstitially (via, e.g., a fiber optic probe). Preferably, the light is administered using a slit-lamp delivery system. The fluence and irradiance during the photoirradiating treatment can vary depending on type of tissue, depth of target tissue, and the amount of overlying fluid or blood. For example, a total light energy of about 100 J/cm² can be delivered at a power of 200 mW to 250 mW depending upon the target tissue.

One aspect of the present invention is that the compounds of the present invention can additionally be used to image the localization of the therapeutic agent. The texaphyrin core allows for the use of MRI to determine the location of the compound with the patient and determine the specific location and margin of the tumor to which it has localized. In some aspects, the ability to determine the location of the texaphyrin core may be advantageous for more or additional therapeutic methods such as surgery or radiation therapy.

H. EXAMPLES

The following examples are included to demonstrate preferred embodiments of the invention. It should be appreciated by those of skill in the art that the techniques disclosed in the examples which follow represent techniques discovered by the inventor to function well in the practice of the invention, and thus can be considered to constitute preferred modes for its practice. However, those of skill in the art should, in light of the present disclosure, appreciate that many changes can be made in the specific embodiments which are disclosed and still obtain a like or similar result without departing from the spirit and scope of the invention.

A. Example 1: General Methods and Materials

1. Materials

Starting materials were purchased from Fisher Scientific or Sigma Aldrich and used without further purification unless otherwise specified. Solvents were purified using a solvent

purifier system (Vacuum Atmospheres). Dichloromethane was freshly distilled after being dried over CaH_2 under argon. Reaction progress was monitored with Thin Layer Chromatography (TLC) (TLC silica gel 60 F254, Silicycle® UltraPure Silica gels). Texaphyrins and platinum (IV)-texaphyrin conjugates were purified on RP-tC18 SPE (Waters Sep-Pak, waters®) columns containing 10 g of C-18 using increasing gradient of acetonitrile in either 0.1 M ammonium acetate/1% acetic acid aqueous solution or 0.1 M potassium nitrate aqueous solution, depending on which anion (AcO^- or NO_3^-) was desired as ligands on the gadolinium(III) center. HPLC analyses were performed on a Shimadzu Analytical/Preparative HPLC system equipped with PDA detector and a C18 Acclaim™ 3 μm , 120 Å, 2.1×150 mm column (Thermo Scientific). An aqueous (0.1% acetic acid)/acetonitrile (0.1% acetic acid) gradient (30-99% acetonitrile over 20 minutes, 0.3 mL/min) was used for the analysis of all texaphyrin-containing compounds (detection at 470 and 740 nm). For analysis of 5'-GMP and $\text{Pt(II)(5'-GMP)}_2(\text{NH}_3)_2$, (0.1% acetic acid)/methanol (0.1% acetic acid) gradient (5-55% methanol over 20 minutes, 0.2 mL/min) was used and the detection was done at 254 nm. Mass spectrometric analyses were carried out in the University of Texas at Austin Mass Spectrometry Facility. Low-resolution and high-resolution electrospray mass spectrometric (ESI-MS) analyses were carried out using a Thermo Finnigan LTQ instrument and a Qq-FTICR (7 Telsa) instrument, respectively. Elemental analyses were performed by Atlantic Microlabs Inc. ^1H NMR spectra were recorded using a Varian 400 MHz instrument.

2. General procedure for EDC•HCl coupling

EDC•HCl (40 mg, 0.21 mmol) and N-hydroxysuccinimide NHS (24 mg, 0.21 mmol) were dissolved in HPLC submicron filtered grade water (4 mL). Platinum complex **3** (22 mg, 50 μmol) as a suspension in water (2 mL) was added to the mixture (termed “EDC•HCl + NHS”) and left stirring for 30 minutes. Precursor **1**^{ODMT}_{NH2} (60 mg, 42 μmol , RP-HLPC RT = 11.4 min) in CH_3CN (5 mL) was added dropwise to the previous solution and the reaction mixture was kept in the dark for 20 h at 40°C. The progress of the reaction was monitored by HPLC (a new peak is formed that is characterized by a RT = 9 min). KNO_3 (50 mL of a 0.1 M aqueous solution) was added and the resulting solution was loaded on a C18 column and subject to elution with increasing gradient of acetonitrile in 0.1 M aqueous KNO_3 . The isolated fraction was loaded on a new C18 column, desalted with water and eluted with pure methanol. The solvent was removed under vacuum to give the product **4** as a dark green

powder. (26.4 mg, 40%). For compound **5**, the same procedure was followed. Structures for these compounds can be found in **FIG. 4**.

3. Light exposure

For the light-induced release studies, aqueous solutions (of **3** or **4**) contained in glass vials were exposed to sunlight in the laboratory behind a window (Viracon®, GL-22), with the following transmittances properties: visible light = 38%, UV light (from 300 to 380 nm) = 12%. A low vapor pressure mercury lamp was also used. In this latter instance, compound **3** is reduced after 15 minutes exposure whereas conjugate **4** required a 15 hour exposure time to be similarly reduced.

4. Platinum-DNA binding

Salmon sperm DNA (1.125 mL of 500 µg DNA/mL in Tris-EDTA buffer) was incubated at 37 °C in the dark or exposed to light with platinum complexes (in solution in water; approximately 1 platinum/75 nucleotides as the final ratio). 200 µL aliquots were removed and added immediately to 40 µL of a 10 M aqueous ammonium acetate solution. DNA in samples was precipitated by adding 0.8 mL of absolute ethanol prechilled at -20°C. The samples were left in ice for 1 h and centrifuged at 14000 rpm for 4 minutes. The supernatant was removed carefully and small pellets were dissolved in 50 µL of Tris-EDTA buffer overnight at room temperature. Platinum content was determined by FAAS (model AA300/GTA-96; Varian Instruments, Victoria, Australia) using conditions described by Siddik, *et al.*, 1987 and Siddik and Newman, 1988, which are incorporated herein by reference. Samples were diluted with HCl when the initial Pt concentration was too high. DNA concentrations were determined using a Nanodrop ND-1000 spectrophotometer.

5. Cell culture

The A2780 line was established from a patient's biopsy prior to initiation of any chemotherapeutic regimen (Godwin, *et al.*, 1992). The resistant cell line, 2780CP, used in this study, was established from A2780 cells, as described by Siddik, *et al.*, 1998. The two cell lines have wild-type p53 genotype and/or function. Cells were grown in RPMI containing 10% fetal calf serum and antibiotics (100 µg/mL streptomycin and 100 U/mL penicillin).

6. Viability tests

The proliferation of exponential phase cultures of A2780 and 2780CP cells was assessed by tetrazolium dye reduction (Mosmann, 1983, which is incorporated herein by reference). In brief, tumor cells were seeded in 96-well microliter plates at 700 (A2780) and 1000 (2780CP) cells/well, respectively, and allowed to adhere overnight in RPMI 1640 medium supplemented with 2 mM L-glutamine, 10% heat inactivated fetal bovine serum, antibiotics (200 U/cm³ penicillin and 200 µg/cm³ streptomycin). After 24h, drug was added. After a total incubation time of 6 days at 37°C, 50 µL of a stock solution at 3 mg/ml of the tetrazolium dye, 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT, Sigma Chemical) were added to each well, the plates incubated at 37°C for 4 hours, whereupon the medium was removed, the formazan product dissolved in DMSO (50-100 µL) and absorbance values at 570 nm was measured using a microplate reader (Molecular Devices, Sunnyvale, CA). Absorbance values were corrected for background and then normalized to wells containing untreated cells to allow plate-to-plate comparisons. The growth inhibition data were fitted to a sigmoidal dose-response curve to generate IC₅₀, which is the drug concentration inhibiting cell growth by 50%. The IC₅₀ is presented as mean ± standard deviation.

Example 2: Chemistry of Texaphyrin Platinum Conjugates

The asymmetric platinum(IV) complex **3**, a derivative of cisplatin originally reported by Lippard, (Feazell, *et al.* 2007; Xiao, *et al.* 2011; Xiao, *et al.* 2012; Dhar *et al.* 2009), was chosen as the platinum precursor for conjugates **4** and **5**. This precursor has the advantage that it contains a difunctional succinic acid moiety that can both serve as the axial ligand for the Pt(IV) center and allow facile conjugation to an amino-functionalized texaphyrin core. Moreover, the presence of an electron-donating hydroxy ligand in the other axial position of complex **3** was expected to make conjugates derived from it more stable than analogues containing carboxylato or halo ligands about the Pt(IV) center, which are known to undergo rapid hydrolysis under biologically relevant conditions (Wexselblatt, *et al.* 2013).

The synthesis of conjugates **4** and **5** is shown in Scheme 2. Briefly, the mono- and bis-amine derivatives of MGd **1** (Wei, *et al.* 2005) were subjected to carbodiimide coupling conditions in the presence of the Pt(IV)-containing precursor **3**; after purification, this gave conjugates **4** and **5** in yields of 40% and 20%, respectively.

Conjugate **4** is highly soluble in water. Its stability towards hydrolysis could thus be evaluated using RP-HPLC. This was done by monitoring the decrease in the absorption intensity at 470 nm (Abs_{470}), a peak corresponding to the starting material **4** (**FIG. 6**). On the basis of these studies, which were carried out in aqueous media at 310 K while minimizing exposure to light, it was concluded that conjugate **4** possesses greater hydrolytic stability ($t_{1/2}$ > 3 days) than the first generation platinum(II) conjugate, cisTEX (**2**) ($t_{1/2}$ = 12 h) when tested under the same conditions. Without being bound by theory, this greater kinetic stability can be attributed to the relative inertness of the platinum(IV) complex present in conjugate **4**.

Studies were undertaken to investigate the photosensitivity of the Pt(IV) moiety within conjugate **4**. Without being bound by theory, Pt(IV) complexes are hypothesized to lose both axial ligands upon reduction (Wexselblatt and Gibson, 2012; Wexselblatt, *et al.*, 2012; Sinisi, *et al.* 2010; Nemirovski, *et al.*, 2010). In the case of **4**, loss of both axial ligands (i.e., the hydroxyl ligand and the texaphyrin-bearing succinate) would give rise to texaphyrin **6** and cisplatin. After exposure to glass-filtered daylight (see Example 4.1), the starting material is transformed ($t_{1/2}$ = 5 h, ca. 100% after 48 h) to a new compound that on the basis of mass spectrometric and RP-HPLC analyses corresponds to what would be expected for the succinic acid-functionalized texaphyrin **6** (**FIG. 6**). This daughter compound (**6**) was independently synthesized, allowing for direct co-injection studies.

Texaphyrin **6** was also obtained when the Pt(IV) conjugate **4** was subject to reduction using the known biological reductants, sodium ascorbate (NaAsc) and glutathione (GSH). The other reduction product, namely cisplatin, was identified using RP-HPLC after being separated from **6** on a C18 RP HPLC column (**FIG. 17**).

In an effort to understand further the chemistry of Pt(IV) as it bears on conjugates **4** and **5**, 1H NMR spectroscopy was used to probe the effect of light on the texaphyrin-free Pt(IV) complex **3**. The choice of **3**, rather than **4** or **5**, was dictated by the paramagnetic nature of these latter species. The spectrum of **3** was recorded in D_2O and is characterized by two triplets at 2.58 and 2.38 ppm corresponding to the four asymmetric methylene protons present in the axially coordinated succinate. In the dark, no change in the spectrum was observed, even after one week. This finding is in line with the comparatively high hydrolytic stability of **4** noted above. In contrast, when precursor **3** was exposed to glass-filtered daylight for 2 days, the two triplets originally present in the spectrum were seen to coalesce into a singlet at 2.39 ppm. This final spectrum corresponds to that of the free succinate anion

in water. It was also possible to detect the released succinate anion by ESI-MS analysis (**FIG. 20**). Taken in concert, these findings suggest that compound **3** is similar to **4** in that exposure to ambient light induces release of the axial succinate ligand. Without being bound by theory, the observation supports the conclusion that the presence of the texaphyrin localizing group is not necessary to trigger axial ligand release.

An analogous ^1H NMR spectral experiment using **3** in DMSO allowed the peaks corresponding to the coordinated NH_3 protons to be monitored. After exposure of **3** to ambient light for 2 days, the initial signals at 5.8 ppm decrease in intensity, while new peaks between 4 and 5.3 ppm appear that are characteristic of a Pt(II) species. These new peaks are similar to those observed when cisplatin is solubilized in DMSO (**FIG. 21**). Analysis of this solution by ESI-MS reveals signals corresponding to $[\text{Pt(II)(NH}_3)_2(\text{Cl})(\text{DMSO})]^+$ (**FIG. 22**).

Guanosine 5'-monophosphate (5'-GMP) was used as a trapping agent for Pt(II). In the dark, no change was observed in the ^1H -NMR spectrum (and RP-HPLC chromatogram) of **3** even after incubating for one-week in the presence of 5'-GMP. Nor were changes in the spectrum of 5'-GMP observed. The lack of change can be taken as evidence that this Pt(IV) complex does not bind to 5'-GMP. In contrast, after exposure to light for 2 days, a new peak is observed at 8.6 ppm (**FIG. 5**, triangle). This peak appears at high frequency, as is typical for the H^8 resonance of 5'-GMP in complexes where a diamagnetic cation is coordinated to N^7 of 5'-GMP (Berners-Price, *et al.* 1994; Berners-Price, *et al.* 1993). This new signal was comparable to the signal obtained when sodium ascorbate was added to a mixture of **3** + 5'-GMP or when cisplatin was added to 5'-GMP (**FIG. 5C**).

The solutions used for the NMR spectral studies were also analyzed by RP-HPLC. As can be seen by inspection of the upper part of **FIG. 5**, a new peak appeared after exposing a mixture **3** + 5'-GMP to ambient light for 2 days. This peak has the same retention time (10.9 min) as does the complex formed between cisplatin and 5'-GMP. This leads us to suggest that the same 5'-GMP - Pt(II), complex, namely the known adduct $(5'\text{-GMP})_2\text{-Pt(II)-}(\text{NH}_3)_2$, (Choi, *et al.*, 1998; Van der Veer, *et al.* 1986; Roat, *et al.* 1993; Choi, *et al.* 1999; Zöllner, *et al.* 2001) is formed upon light-induced reduction of **3**.

The influence of light on the interaction between **4** and DNA was also investigated (Shi, *et al.* 2012). It was observed that when **4** is exposed to ambient light, 8.5 ± 1.1 times

more DNA-Pt adducts are formed (average of 2 independent studies) than when **4** is kept in the dark (see **FIG. 6C**).

The anti-proliferative effects of conjugates **4** and **5** were assessed with platinum sensitive human ovarian A2780 cells and the isogenic cisplatin resistant 2780CP cell line. These experiments were carried out in the dark at 37 °C for conjugate **4**. Colorimetric cell proliferation assay results (Table 1) lead us to conclude that these new platinum(IV) conjugates are more efficient in inhibiting cancer cell growth in both cell lines than the first generation conjugate cisTEX (**2**). This enhancement in efficacy is fully consistent with the suggestion that the greater hydrolytic stability of **4** and **5** compared to **2** serves to increase the effective concentration of Pt(II) at locales where it is most effective. The potency of conjugate **5** is roughly equal to that of conjugate **4** on a per platinum basis.

Table 1. Half maximal inhibitory concentrations (IC₅₀) (micromolar) determined for the Pt(IV)-TEX conjugates **4** and **5**, and the texaphyrin-free platinum(IV) precursor complex **3**. Also given are data for the platinum(II) complexes cisplatin and cisTEX (**2**).

Compounds	IC ₅₀ 2780CP	IC ₅₀ A2780	Resistance factor ^[b]
Cisplatin ^[a]	7.3 (0.2)	0.33 (0.02)	18.25
2 ^[a]	17.0 (1.5)	1.63 (0.20)	10.42
3	26.88 (2.04)	6.31 (0.38)	4.26
4	10.66 (0.63)	1.28 (0.12)	8.32
5	4.55 (0.29)	0.67 (0.06)	6.79

[a] See Arambula, *et al.*, 2012. [b] Resistance factor = IC₅₀(2780CP)/IC₅₀(A2780)

Example 3: Synthesis of Texaphyrin Platinum Complexes

1. Platinum complexes

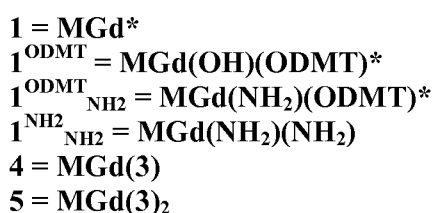
Cis-cis-trans-Pt(IV)(Cl)₂(NH₃)₂(OH)₂ (oxoplatin): Cisplatin (100 mg, 0.33 mmol) was dissolved in 1.5 mL of deionized water. H₂O₂ (4 mL; 30% in water) was added drop-wise and the mixture was heated at 60°C overnight in the dark. The solution was then cooled to room temperature and placed in a refrigerator for 1 h. A light yellow powder (or crystals under

conditions of very slow cooling overnight) is obtained. The solid was collected by filtration using 0.8 μ M isoporeTM membrane filters (Millipore), rinsed with cold water and dried under vacuum. The product (60 mg, 54%) was characterized by ESI-MS and IR spectroscopy and the data correspond to those reported in Kuroda, *et al.*, 1983, which is incorporated herein by reference.

ESI-MS: positive mode: 300 $[M-Cl]^{+}$ and 356.9 $[M+Na^{+}]$; FTIR: 3460 and 540 cm^{-1} (O-H and Pt-OH bond stretching).

Cis-cis-trans-Pt(IV)(Cl)₂(NH₃)₂(OH)(OOC-CH₂-COOH) (3): Oxoplatin (60 mg, 0.18 mmol) was dissolved in dry DMSO (5 mL) and succinic anhydride (18 mg, 0.18 mmol) was added. The reaction mixture was stirred under N₂ in the dark overnight. The solution containing some insoluble material was filtered a first time using a PTFE membrane filter, which was then washed with cold acetone. To the filtrate was added a further aliquot of cold acetone ($V_{total} = 500$ mL). The filtrate was then left in an ice cold bath in the dark for 2 h. A very thin suspension formed. This was collected by filtration using another PTFE membrane filter, washed with cold acetone and dried under vacuum. The product (54 mg, 69%) was characterized by ESI-MS (high resolution), ¹H NMR spectroscopy, IR spectroscopy, and elemental analysis. The characterization data correspond to those reported in Johnstone, *et al.*, 2013, which is incorporated herein by reference: ESI-MS: Positive mode: 416.97 $[M-OH]^{+}$, 434.98 $[M+H^{+}]^{+}$, 456.97 $[M+Na^{+}]^{+}$; Negative mode: 432.97 $[M-H^{+}]^{-}$, 468.94 $[M+Cl]^{-}$; ¹H-NMR (DMSO-*d*₆, 300 K, 400 MHz): 2.3 ppm (4H, m, -CH₂), 5.8 ppm (6H, m, NH₃). Note: In D₂O, the NH₃ signals are not visible. However, the signals from the coordinated succinic acid moiety are better differentiated than in DMSO-*d*₆ (two triplets each integrating for 2H at 2.38 and 2.58 ppm). Elemental analysis: Calcd for C₄H₁₂Cl₂N₂O₅Pt: C 11.07, H 2.79, Cl 16.33, N 6.45; found: C 11.83, H 2.88, Cl 15.62, N 6.35.; and FT-IR: 3460, 1700, 1640, 540 cm^{-1} . Note: IR absorption features corresponding to the presumed O-H bond stretching mode (3460 cm^{-1}) are maximal for oxoplatin, intermediate for complex **3**, and absent for cisplatin. The same order is observed for the Pt-OH bond stretching features (540 cm^{-1}). For complex **3**, peaks at 1640 and 1700 cm^{-1} , characteristic of coordinated and free carboxylic acid groups, respectively, are observed.

2. Texaphyrins:



6 = MGd(succinic acid)

* known compounds whose synthesis are already published (Wei, *et al.*, 2005)

1^{NH2}_{NH2}: To a round bottom flask containing triphenylphosphine (685 mg, 2.6 mmol) was added phthalimide (384.5 mg, 2.6 mmol) and **1** (500 mg, 0.287 mmol) in one batch, both of which starting materials were previously dried overnight under vacuum. To this mixture was added 100 mL of freshly distilled CH₂Cl₂ (dried over CaH₂). The resulting green solution was cooled over ice for about 15 minutes under N₂. Following this, diisopropylazocarboxylate (514 μ L, 2.6 mmol) was added drop-wise. The reaction mixture was kept over ice for 2-3 hours and allowed to warm slowly to ambient temperature. The solvent was removed under reduced pressure. To the resulting residue, was added 30 mL of methanol, 10 mL of acetonitrile (to increase the solubility) and 27 mL of methylamine (40% in water). After 7 hours of stirring at ambient temperature, N₂ was bubbled through the reaction mixture to remove excess methylamine. The volatiles were then removed under reduced pressure and the resulting solids were resuspended in 20 mL of acetonitrile and 80-100 mL of an aqueous 0.1 M ammonium acetate/1% acetic acid solution. The resulting solution was loaded on a C-18 column and purified by chromatography using an increasing gradient of acetonitrile/0.1 M aqueous ammonium acetate + 1% acetic acid while monitoring by HPLC (RT = 6.9 min). The product was loaded on a new C-18 column, desalted by rinsing with HPLC grade submicron filtered water, eluting with methanol, and drying under reduced pressure. This gave a dark green powder (140 mg, 24%). Notes: The published protocol for **1^{ODMT}_{NH2}** (Wei, *et al.*, 2005, which is incorporated herein by reference) recommends extracting the products with chloroform after deprotection by methylamine. However, in the case of **1^{NH2}_{NH2}** this protocol is not effective because the product remains in the aqueous layer. Therefore, the crude material was loaded immediately onto the C18 column. Before being coupled with **3**, **1^{NH2}_{NH2}** was solubilized in a mixture of acetonitrile and 0.1 M aqueous KNO₃ in order to exchange the acetate ligands for nitrate. The resulting solution was loaded on a new C18 column and as described above, desalted with water, eluted off the column using methanol, and then dried under reduced pressure.

3. Conjugates TEX-Pt(IV):

4_{NO3} = MGd(OH)(3): EDC•HCl (40 mg, 0.21 mmol) and N-hydroxysuccinimide NHS (24 mg, 0.21 mmol) were dissolved in HPLC submicron filtered grade water (4 mL). Complex **3** (22 mg, 50 μ mol) as a suspension in water (2 mL) was added to the mixture (termed "EDC•HCl + NHS") and left stirring for 30 minutes. Precursor **1^{ODMT}_{NH2}** (60 mg, 42

μ mol, HPLC RT = 11.4 min) in CH₃CN (5 mL) was added drop-wise to the previous solution and the reaction mixture was kept in the dark for 20 h at 40°C. The progress of the reaction was monitored by HPLC (a new peak is formed that is characterized by a RT = 9 min). Following this period, KNO₃ (50 mL of a 0.1 M aqueous solution) was added and the resulting solution was loaded onto a C18 column and subject to elution with increasing gradient of acetonitrile in 0.1 M aqueous KNO₃. The isolated fraction was loaded onto a new C18 column, desalted with water and eluted with pure methanol. The solvent was removed under vacuum to give the product as a dark green powder (26.4 mg, 40%). The non-platinated compound, **MGd(OH)(NH₂)** (the DMT group was deprotected by HCl), is isolated during the purification. This latter species was used in another coupling reaction. Note: During this coupling, a trace of **6** (ca. 5%; RT = 9.99 min) is formed, as inferred from the HPLC analysis. Sometimes it proved difficult to drive the reaction to completion. However, this is not problematic since the non-platinated species **1^{OH}_{NH2}** (the DMT group was removed by HCl) is relatively easy to separate using a C18 column. Once isolated, the product was analyzed by high resolution ESI-MS; as shown in **FIGS. 5, 6A & B, and 7A & B**. Elemental analysis: Calcd for C₅₂H₇₇Cl₂GdN₁₀O₁₉Pt: C 39.79, H 4.95, Cl 4.52, N 8.92; found: C 39.07, H 4.97, Cl 4.17, N 8.90.

(6) MGd(OH)(succinic acid): This compound can be obtained by either reducing the platinum(IV) center within the conjugate **4** (light, sodium ascorbate or glutathione) or from the reaction between **1^{ODMT}_{NH2}** and succinic acid. In this latter instance, **1^{ODMT}_{NH2}** (20 mg, 13.7 μ mol) in acetonitrile (50 mL) was added slowly and drop-wise into a solution containing succinic acid (1.6 g, 13.7 mmol), EDC•HCl (2.6 g, 13.7 mmol) and NHS (1.53 g, 13.7 mmol) in HPLC submicron filtered grade water (150 mL). The reaction was stirred overnight under N₂. The reaction progress was checked by TLC (silica gel plates; 80/20 CH₂Cl₂/MeOH, eluent) with Rf **1^{ODMT}_{NH2}** = 0 and Rf **6^{ODMT}** = 0.57. The solution was loaded on a C18 column and the product was purified using an increasing gradient of acetonitrile in an aqueous solution of 0.1 M ammonium acetate + 1% acetic acid. The protected intermediate (**6^{ODMT}**) was desalted using submicron filtered HPLC grade water, eluted with methanol and dried under reduced pressure. To deprotect the DMT group, **6^{ODMT}** was dissolved in 2 mL of dichloromethane and 1.5 mL of acetic acid were added. The solution was stirred for 3 h and checked by TLC (silica gel plates; 80/20 CH₂Cl₂/MeOH, eluent). The rf of **6** = 0.34. The product was purified on a C18 column as above (yield: 6.6 mg, 40%). Characterization is shown in **FIGS. 10, 11A-C, and 12A & B**.

5 $5_{\text{NO}_3} = \text{MGd}(\mathbf{3})_2$: EDC•HCl (14.5 mg, 76 μmol) and N-hydroxysuccinimide NHS (8.74 mg, 0.21 mmol) were dissolved in submicron filtered HPLC grade water (8 mL). Complex **3** (33 mg, 76 μmol) as a suspension in water (2 mL) was added to the “EDC•HCl + NHS” solution and left stirring for 30 minutes. Precursor **1**^{NH₂} (34.5 mg, 30 μmol , RT = 6.9 min) in CH₃CN (5 mL) was added drop-wise to the previous solution and the reaction mixture was kept in the dark for 20 hours. The progress of the reaction was checked by HPLC. Two new peaks appear at RT = 7.7 and 8.7 min as the reaction is allowed to run. The first peak (7.7 min) is the mono-platinated compound **MGd(3)(NH₂)** and the second one (8.7 min) is the desired bis-platinated product (**5**). After 20 h, EDC•HCl and NHS (76 μmol of each) were added in water. After 3 days, there is still a trace of starting material (2%). The mono- and bisplatinated compounds are likewise present in similar quantities (as inferred from HPLC analysis). The solution was diluted with 0.1 M aqueous KNO₃ and loaded onto a C18 column. The two conjugates were purified and isolated using an increasing gradient of acetonitrile in 0.1 M aqueous KNO₃. Fractions were monitored by HPLC, desalted using a new C18 column and submicron filtered HPLC grade water, eluted with methanol and dried under reduced pressure. This gave **5** as dark green powder. The yield was 12 mg (20%). Characterization is shown in **FIGS. 13A & B and 14**.

Example 4: Stability and Biological Studies of Texaphyrin Platinum Complexes

1. Hydrolysis and light-induced reduction of **4**

20 For the hydrolysis studies, reactions were carried in the dark by following the changes in the spectral features as a function of time in aqueous media. For the light-induced release studies, solutions of **3** or **4** contained in glass vials were exposed to sunlight in the laboratory behind a double-paned window (Viracon[®], VE1-85), filtering off about 75% of the UV light. The same experiments were also carried out using a fluorescent tube Hg 25W (light source in chemical fume hood).

25 In order to identify the reduced platinum complex, the solution was loaded onto a C18 column to separate the platinum complex from the texaphyrin moiety. The green fraction was found to contain the succinic-functionalized texaphyrin **6**, as identified by RP-HPLC and HR ESI-MS analysis (**FIGS. 9A & B and 10**). The first fraction collected, containing the platinum complex, revealed a peak eluting at 3 min analogous to those observed for cisplatin and for **3** after being reduced (see **FIG. 17A-E**).

2. Photo-reactivity of 3:

The photo-reactivity of compound 3 is shown in FIGS. 18-22.

3. Interaction between 5'-GMP and the photo-induced reduction product of 3:

5 The NMR spectra shown in FIG. 23 shows the sequestration of 3 and 5'-GMP.

4. Platinum-DNA interactions:

Salmon sperm DNA (1.125 mL of 500 μ g DNA/mL in Tris-EDTA buffer) was incubated at 37 °C in the dark or exposed to light with platinum complexes (in solution in water; approximately 1 platinum/75 nucleotides as the final ratio) in the absence or presence of glutathione (GSH; solution in 20 mM EDTA). 200 μ L aliquots were removed and added immediately to 40 μ L of a 10 M aqueous ammonium acetate solution. DNA in samples was precipitated by adding 0.8 mL of absolute ethanol prechilled at -20 °C. The samples were left in an ice bath for 1 h and centrifuged at 14000 rpm for 4 minutes. The supernatant was removed carefully and small pellets obtained in this way were dissolved in 50 μ L of TRIS-EDTA buffer overnight at room temperature. Platinum content was determined by FAAS (model AA300/GTA-96; Varian Instruments, Victoria, Australia) using conditions described previously (Siddik, *et al.*, 1987; Siddik and Newman, 1988) Samples were diluted with HCl when the initial Pt concentration was too high. DNA concentrations were determined using a Nanodrop ND-1000 spectrophotometer. Results can be seen in FIG. 24.

20 5. *In vitro* tests:

The proliferation of exponential phase cultures of A2780 and 2780CP cells was assessed by tetrazolium dye reduction (Mosmann, 1983, which is incorporated herein by reference). In brief, tumor cells were seeded in 96-well microliter plates at 500 (A2780) and 1000 (2780CP) cells/well, respectively, and allowed to adhere overnight in RPMI 1640 medium supplemented with 2 mM L-glutamine, 10% heat inactivated fetal bovine serum, and antibiotics (200 U/cm³ penicillin and 200 μ g/cm³ streptomycin). After 4 days, the tetrazolium dye, 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT, Sigma Chemical) was added to each well, the plates incubated at 37°C for 4 hours, whereupon the medium was removed, the formazan product dissolved in DMSO (50-100 μ L) and absorbance values at 560-650 nm were measured using a microplate reader (Molecular Devices, Sunnyvale, CA). Absorbance values were corrected for background and then normalized to wells containing untreated cells to allow plate-to-plate comparisons. The growth inhibition data were fitted to a sigmoidal dose-response

curve to generate IC_{50} , which is the drug concentration inhibiting cell growth by 50%. The IC_{50} is presented as mean $\pm$ standard deviation. The IC_{50} values are shown in **FIGS. 19-20**.

Example 5: Formation of OxaliPt(IV)-Tex and Hetero-bis Platinum(IV) Conjugates

1. Synthesis of platinum (IV) complex, derivate from oxaliplatin

The platinum(IV) complex used for the synthesis of oxaliPt(IV)-TEX (**FIG. 27**) (with L_{ax} = acetate, L_{equa1} = oxalate and L_{equa2} = R, R-diaminocyclohexane) was synthesized following the published protocols (Hambley *et al.*, 2013; Keppler *et al.*, 2014). The only difference is that the final compound was purified by silica gel chromatography using an increasing gradient of methanol in dichloromethane (from 5 to 60%). The purified complex was characterized by TLC (R_f = 0.17 in methanol:dichloromethane 3:7), by 1H NMR (**FIG. 33**) and by HR-ESI MS (**FIG. 32**).

2. Synthesis of OxaliPt(IV)-Tex conjugate

Analogues of compounds **4** that contain the oxaliplatin platinum core were prepared using the method described in **FIGS. 27-29**.

EDC•HCl (17 mg, 89 μ mol) and N-hydroxysuccinimide NHS (12 mg, 107 μ mol) were dissolved in HPLC submicron filtered grade water (5 mL). A Pt(IV) complex derived from oxaliplatin (**FIG. 27**) (23 mg, 40 μ mol) in water (5 mL) was added to the mixture (termed “EDC•HCl + NHS”) and left stirring for 30 minutes. A solution of precursor $1^{ODMT}_{NH_2}$ (50 mg, 33 μ mol, HPLC RT = 11.4 min) in CH_3CN (5 mL) containing diisopropylamine (9 μ L, 64.2 μ mol) was added drop-wise to the previous solution and the reaction mixture was kept in the dark for 20 h. The progress of the reaction was monitored by HPLC (a new peak is formed that is characterized by a RT = 13 min). Following this period, aqueous HCl 0.5 N (2 mL, 1 mmol) was added to remove the DMT protecting group. After one hour (reaction monitored by HPLC), 50 mL of an aqueous solution containing 0.1% of acetic acid was added to the reaction mixture and the solution was loaded on a C18 column. The elution was done using an increasing gradient of acetonitrile in water (containing 0.1% acetic acid). The isolated fraction corresponding to the desired compound (**FIG. 31**) was loaded onto a new C18 column, desalted with water and eluted with pure methanol. The solvent was removed under vacuum to give the product as a dark green powder (36 mg,

64%). The product with axial acetate ligands was analyzed by high resolution ESI-MS; as shown in **FIG. 30**. Elemental Analysis: Calculated: C = 46.55%, H = 5.50%, and N = 6.58%; Found: C = 45.55%, H = 5.79%, and N = 6.59%. Similar compounds with axial hydroxide and chloride ligands were prepared similarly.

5 **Example 6: General Methods and Materials for Texaphyrin and High Oxidation State Metal Chemotherapeutic Complexes**

1. HPLC Monitoring of Pt(IV) Reduction Catalyzed by Motexafin Gadolinium (MGd)

10 Pt(IV) complex and sodium ascorbate were dissolved in PBS buffer (pH = 7) and incubated at 37 °C, in absence or presence of MGd. At a given time, an aliquot (20 µL) was analyzed by RP-HPLC (C18 column, increasing gradient of acetonitrile in water, both solvents contain 0.1% acetic acid).

2. Antiproliferative Activities Determined Using 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) Assays

15 A2780 cancer cells were incubated (37 °C, 5% CO₂ atmosphere, dark) in 96-wells plates at a concentration of 600 cells/well, in a culture medium containing 10% fetal bovine serum and supplemented with penicillin and streptomycin. After 15 h, drugs (Pt(IV), MGd, MGd+Pt(IV)) were added to cells (gradient of concentration, from 0 to 200 µM, 3-fold dilutions) and plates were incubated for five more days using the above conditions. After five
20 days, MTT dye was added in each well (0.15 mg/well) and plates were left for 4 hours in the incubator. Then, supernatant was carefully removed and 50 µL of DMSO were added to dissolve MTT purple formazan crystals. The absorbance was read at 570 nm using a plate reader.

25 **Example 7: HPLC Monitoring of the Pt(IV) Reduction Catalyzed by Motexafin Gadolinium (MGd)**

 In absence of motexafin gadolinium (MGd), no change was noticed on the HPLC trace. On this basis, it was concluded that the starting material Pt(IV) does not react with sodium ascorbate (1 molar equiv. / 2 equiv. electrons), even after several hours (FIG. 32). In presence of MGd (0.5 equiv.), a new peak was observed after only 10 minutes. The peak
30 area represents about 67% and the retention time matches perfectly with the one of oxaliplatin (Pt(II)) (FIG. 33). This provides evidence that MGd is essential for Pt(IV)

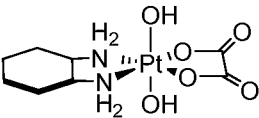
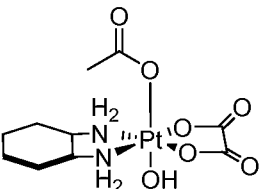
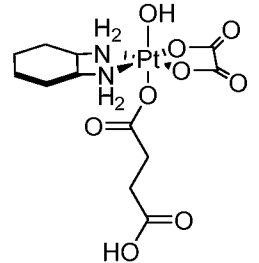
reduction acting as a redox mediator to allow the electron transfer from sodium ascorbate to Pt(IV). This reduction goes to completion in about 25 min under these conditions. This experiment was repeated with a variety of different Pt(IV) complexes.

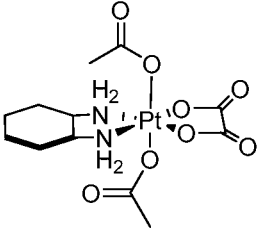
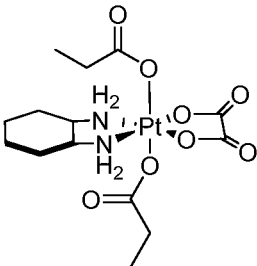
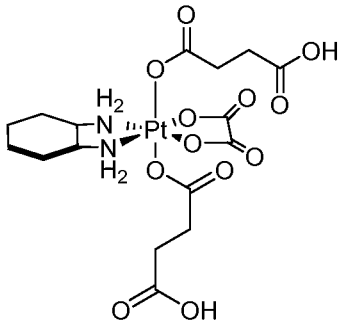
Example 8: Antiproliferative Activities Determined Using 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) Assays

The growth inhibitions observed for both MGd ($IC_{50} = 78 \mu M$) and Pt(IV) ($IC_{50} = 40 \mu M$) are much lower than the one observed when MGd is combined with Pt(IV) ($IC_{50} = 6.5 \mu M$) (see **FIG. 34**). This observation is taken as evidence that a synergistic effect takes place and is in agreement with the results observed in the HPLC experiments (described in Example 7).

Similar growth inhibition studies were carried out using a variety of different Pt(IV) complexes in combination with MGd (See **FIG. 35A-E**). A summary of the IC_{50} observed is shown in Table 1.

Table 1: IC_{50} of Different Pt(IV) Complexes in the Presence of MGd

Pt(IV) Complex	IC_{50} without MGd (μM)	IC_{50} with MGd (μM)
	22.3 ± 2.8	9.26 ± 1.61
	6.15 ± 0.69	4.12 ± 0.14
	5.81 ± 0.92	3.28 ± 0.53

Pt(IV) Complex	IC ₅₀ without MGd (μM)	IC ₅₀ with MGd (μM)
	4.10 ± 0.13	3.42 ± 0.04
	2.30 ± 0.12	2.12 ± 0.13
	34 ± 5.6	7 ± 0.6

All of the compositions and methods disclosed and claimed herein can be made and executed without undue experimentation in light of the present disclosure. While the compositions and methods of this invention have been described in terms of certain embodiments, it will be apparent to those of skill in the art that variations may be applied to the compositions and methods and in the steps or in the sequence of steps of the methods described herein without departing from the concept, spirit and scope of the invention. More specifically, it will be apparent that certain agents which are both chemically and physiologically related may be substituted for the agents described herein while the same or similar results would be achieved. All such similar substitutes and modifications apparent to those skilled in the art are deemed to be within the spirit, scope and concept of the invention as defined by the appended claims.

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The following references, to the extent that they provide exemplary procedural or other details supplementary to those set forth herein, are specifically incorporated herein by reference.

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U.S. Patent No. 4,845,124
U.S. Patent No. 4,870,208
U.S. Patent No. 4,935,498
U.S. Patent No. 4,980,473
U.S. Patent No. 5,072,011
U.S. Patent No. 5,252,270
U.S. Patent No. 5,272,142
U.S. Patent No. 5,292,414
U.S. Patent No. 5,369,101
U.S. Patent No. 5,409,915
U.S. Patent No. 5,432,171
U.S. Patent No. 5,439,570
U.S. Patent No. 5,504,205
U.S. Patent No. 5,533,354
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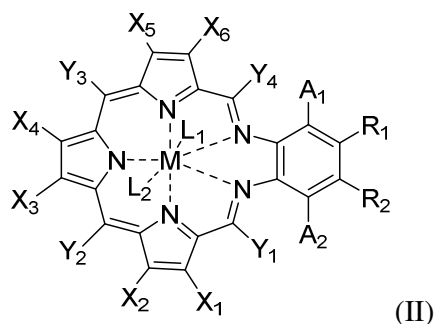
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CLAIMS

What is claimed is:

1. A compound of the formula:



wherein:

R_1 and R_2 are each independently selected from hydrogen, halo, hydroxy, amino, mercapto, alkoxy_{C≤12}, substituted alkoxy_{C≤12}, or $\left(\text{OCH}_2\text{CH}_2 \right)_n \text{OR}_3$, wherein n is 1-20 and R_3 is hydrogen, alkyl_{C≤6}, or substituted alkyl_{C≤6}, or a platinum(IV) chelating group;

A_1 and A_2 are each independently selected from hydrogen, halo, hydroxy, alkyl_{C≤12}, substituted alkyl_{C≤12}, alkoxy_{C≤12}, substituted alkoxy_{C≤12}, or $\left(\text{OCH}_2\text{CH}_2 \right)_n \text{OR}_3$, wherein n is 1-20 and R_3 is hydrogen, alkyl_{C≤6}, or substituted alkyl_{C≤6}, or a platinum(IV) chelating group;

Y_1 , Y_2 , Y_3 , and Y_4 are each independently selected from hydrogen, halo, alkyl_{C≤12}, aryl_{C≤12}, substituted alkyl_{C≤12}, or substituted aryl_{C≤12};

X_1 , X_2 , X_3 , X_4 , X_5 , and X_6 are each independently selected from hydrogen, hydroxy, halo, amino, carboxy, nitro, or cyano,

alkyl_{C≤12}, alkenyl_{C≤12}, alkynyl_{C≤12}, aryl_{C≤12}, aralkyl_{C≤12}, acyl_{C≤12}, amido_{C≤12}, or a substituted version of any of these groups, or

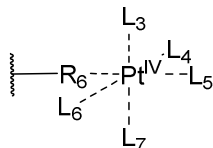
a platinum(IV) chelating group;

provided that at least one of X_1 , X_2 , X_3 , X_4 , X_5 , and X_6 is a platinum(IV) chelating group;

wherein the platinum(IV) chelating group is further defined as:

$-\text{A}_3-\text{X}_7-\text{A}_4-\text{R}_4$, wherein A_3 and A_4 are each independently alkanediyl_{C≤12}, alkenediyl_{C≤12}, arenediyl_{C≤12}, alkoxydiyl_{C≤12},

alkylaminodiyl_{C≤12}, or a substituted version of any of these groups, X₇ is -O-, -S-, -NR₅-, -C(O)NR₅-, or -NR₅C(O)-, wherein R₅ is hydrogen, alkyl_{C≤6}, or substituted alkyl_{C≤6}, and R₄ is



wherein:

R₆ is amino, hydroxy, mercapto, carboxy, or dicarboxy;

L₃-L₇ are each ligands independently selected from aqua, ammonia, nitrate, sulfate, halide, hydroxide, phosphate, or glucose-6-phosphate,

alkylamine_{C≤12}, cycloalkylamine_{C≤12}, dialkylamine_{C≤18}, dicycloalkylamine_{C≤18}, arylamine_{C≤12}, diarylamine_{C≤18}, diaminoalkane_{C≤12}, diaminocycloalkane_{C≤12}, diaminoarene_{C≤12}, heteroarene_{C≤12}, alkylcarboxylate_{C≤12}, alkylidicarboxylate_{C≤18}, arylcarboxylate_{C≤12}, arylidicarboxylate_{C≤18}, or a substituted version of any of these groups

provided that R₆ and L₃-L₇ are appropriately charged to obtain a neutral platinum(IV) chelating group;

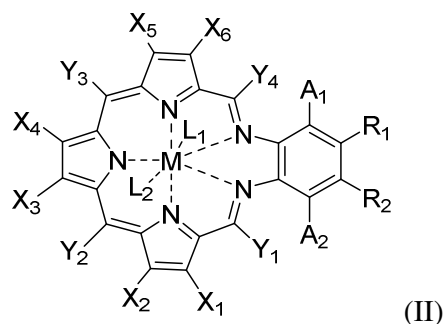
M is a monovalent metal ion, a divalent metal ion, or a trivalent metal ion; and

L₁ and L₂ are each absent or anionic ligands independently selected from fluoride, chloride, bromide, carbonate, hydroxide, perchlorate, nitrate, sulfate, trifluoromethylsulfonate, acetylacetonate, acetate, or trifluoroacetate;

provided that when M is a monovalent metal ion then L₁ and L₂ are absent, and when M is a divalent metal ion, then L₁ or L₂ is absent;

or a pharmaceutically acceptable salt, or tautomer thereof.

2. The compound of claim 1, wherein the formula is further defined as:



wherein:

R_1 and R_2 are each independently selected from hydrogen, halo, hydroxy, amino, mercapto, alkoxy_{C≤12}, substituted alkoxy_{C≤12}, or $\text{---}(\text{OCH}_2\text{CH}_2)_n\text{OR}_3$, wherein n is 1-20 and R_3 is hydrogen, alkyl_{C≤6}, or substituted alkyl_{C≤6};

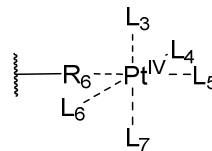
A_1 and A_2 are each independently selected from hydrogen, halo, hydroxy, alkyl_(C≤12), substituted alkyl_{C≤12}, alkoxy_{C≤12}, substituted alkoxy_{C≤12}, or $\text{---}(\text{OCH}_2\text{CH}_2)_n\text{OR}_3$, wherein n is 1-20 and R_3 is hydrogen, alkyl_{C≤6}, or substituted alkyl_{C≤6};

Y_1 , Y_2 , Y_3 , and Y_4 are each independently selected from hydrogen, halo, alkyl_{C≤12}, or substituted alkyl_{C≤12};

X_1 , X_2 , X_3 , X_4 , X_5 , and X_6 are each independently selected from hydrogen, hydroxy, halo, amino, carboxy, nitro, or cyano,

alkyl_{C≤12}, alkenyl_{C≤12}, aryl_{C≤12}, or a substituted version of any of these groups, or

a platinum(IV) chelating group of the formula: $\text{---}A_3\text{---}X_7\text{---}A_4\text{---}R_4$, wherein A_3 and A_4 are each independently alkanediyl_{C≤12}, alkoxydiyl_{C≤12}, alkylaminodiyl_{C≤12}, or a substituted version of any of these groups, X_7 is $\text{---}NR_5\text{---}$, $\text{---}C(O)NR_5\text{---}$, or $\text{---}NR_5C(O)\text{---}$, wherein R_5 is hydrogen,



alkyl_{C≤12}, or substituted alkyl_{C≤12}, and R_4 is

wherein:

R_6 is amino, hydroxy, mercapto, carboxy, or dicarboxy;

L_3 - L_7 are each ligands independently selected from aqua, ammonia, halide, or hydroxide,

diaminoalkane_{C≤12}, diaminocycloalkane_{C≤12}, diaminoarene_{C≤12},
alkyldicarboxylate_{C≤18}, aryldicarboxylate_{C≤18}, or a
substituted version of any of these groups;

provided that R₆ and L₃-L₇ are appropriately charged to obtain
a neutral platinum(IV) chelating group;

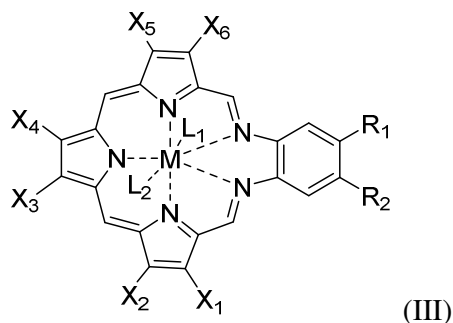
provided that at least one of X₁, X₂, X₃, X₄, X₅, and X₆ is a platinum(IV)
chelating group;

M is a trivalent lanthanide metal ion; and

L₁ and L₂ are each anionic ligands independently selected from fluoride,
chloride, bromide, perchlorate, nitrate, sulfate,
trifluoromethylsulfonate, acetate, or trifluoroacetate;

or a pharmaceutically acceptable salt, or tautomer thereof.

3. The compound of either claim 1 or claim 2, wherein the formula is further defined
as:



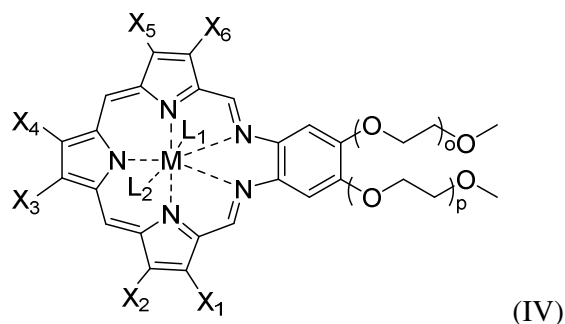
wherein:

R₁ and R₂ are each independently selected from hydroxy, alkoxy_{C≤12},

substituted alkoxy_{C≤12}, or $\text{-(O-CH}_2\text{)}_n\text{-R}_3$ wherein n is 1-20 and R₃ is
hydrogen, alkyl_{C≤6}, or substituted alkyl_{C≤6};

or a pharmaceutically acceptable salt, or tautomer thereof.

4. The compound according to any one of claims 1-3, wherein the formula is further
defined as:



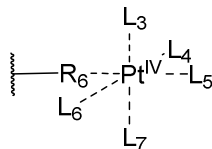
wherein:

o and p are each independently 1, 2, 3, 4, 5, or 6;

X₁, X₂, X₃, X₄, X₅, and X₆ are each independently selected from hydrogen, hydroxy, or halo,

alkyl_{C≤12} or substituted alkyl_{C≤12}, or

a platinum chelating group of the formula: -A₃-X₇-A₄-R₄, wherein A₃ and A₄ are each independently alkanediyl_{C≤12}, alkoxydiyl_{C≤12}, or a substituted version of any of these groups, X₇ is -C(O)NR₅-, or -NR₅C(O)-, wherein R₅ is hydrogen, alkyl_(C≤12), or substituted



alkyl_(C≤12), and R₄ is

wherein:

R₆ is carboxy or dicarboxy;

L₃, L₄, L₅, and L₆ are each ligands independently selected from aqua, ammonia, halide, or hydroxide,

diaminoalkane_{C≤12}, diaminocycloalkane_{C≤12}, alkyl dicarboxylate_{C≤18}, or a substituted version of any of these groups;

provided that R₆ and L₃-L₇ are appropriately charged to obtain a neutral platinum(IV) chelating group;

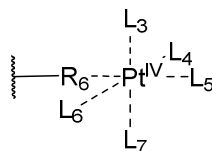
provided that at least one of X₁, X₂, X₃, X₄, X₅, and X₆ is a platinum(IV) chelating group;

M is a trivalent lanthanide metal ion; and

L₁ and L₂ are each anionic ligands independently selected from nitrate, acetate, or trifluoroacetate;

or a pharmaceutically acceptable salt, or tautomer thereof.

5. The compound of claim 4, wherein o is 2, 3, or 4.
6. The compound of claim 5, wherein o is 3.
7. The compound according to any one of claims 4-6, wherein p is 2, 3, or 4.
8. The compound of claim 7, wherein p is 3.
9. The compound according to any one of claims 1-8, wherein X_1 is $\text{alkyl}_{C\leq 12}$ or substituted $\text{alkyl}_{C\leq 12}$.
10. The compound of claim 9, wherein X_1 is methyl.
11. The compound according to any one of claims 1-10, wherein X_2 is a platinum(IV) chelating group of the formula: $-A_3-X_7-A_4-R_4$, wherein A_3 and A_4 are each independently $\text{alkanediyl}_{C\leq 12}$, $\text{alkoxydiyl}_{C\leq 12}$, or a substituted version of any of these groups, X_7 is $-\text{C}(\text{O})\text{NR}_5-$ or $-\text{NR}_5\text{C}(\text{O})-$, wherein R_5 is hydrogen, $\text{alkyl}_{C\leq 12}$,



or substituted $\text{alkyl}_{C\leq 12}$, and R_4 is

wherein:

R_6 is carboxy or dicarboxy;

L_3 , L_4 , L_5 , and L_6 are each ligands independently selected from aqua, ammonia, halide, or hydroxide,

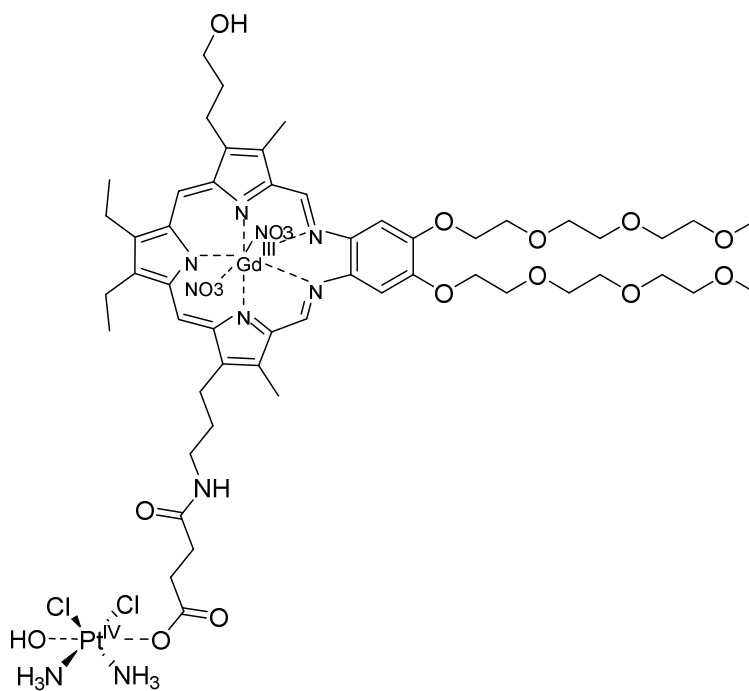
$\text{diaminoalkane}_{C\leq 12}$, $\text{diaminocycloalkane}_{C\leq 12}$, $\text{alkyldicarboxylate}_{C\leq 18}$, or a substituted version of any of these groups.

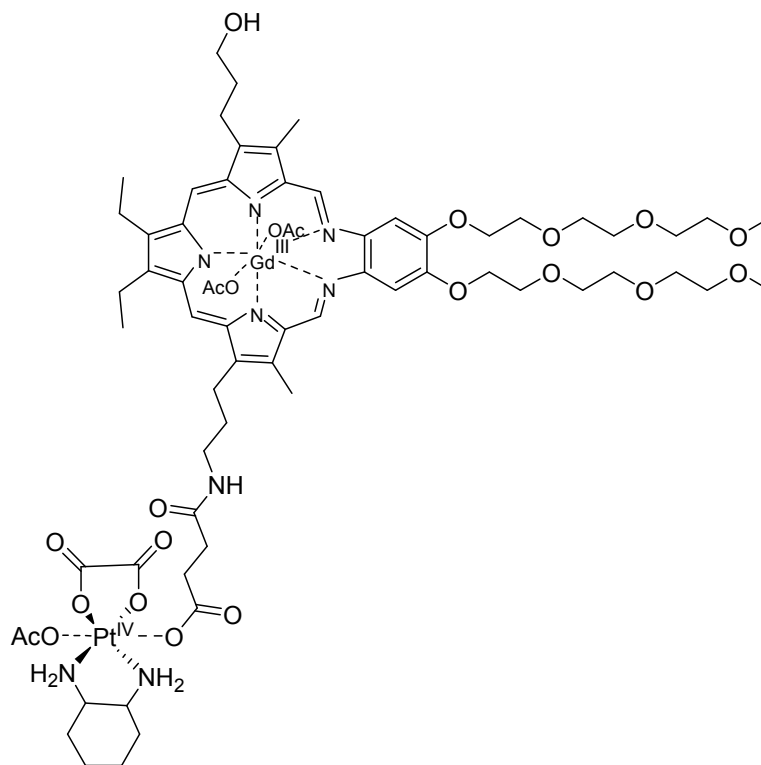
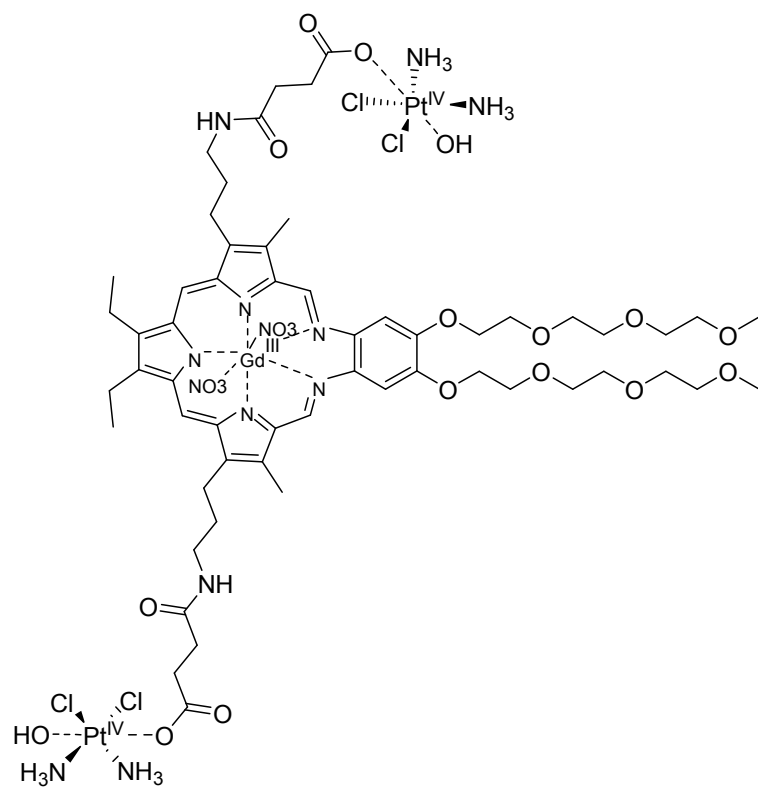
12. The compound of claim 11, wherein A_3 is $\text{alkanediyl}_{C\leq 12}$ or substituted $\text{alkanediyl}_{C\leq 12}$.
13. The compound of claim 12, wherein A_3 is $\text{alkanediyl}_{C\leq 8}$.
14. The compound of claim 13, wherein A_3 is $-\text{CH}_2\text{CH}_2\text{CH}_2-$.

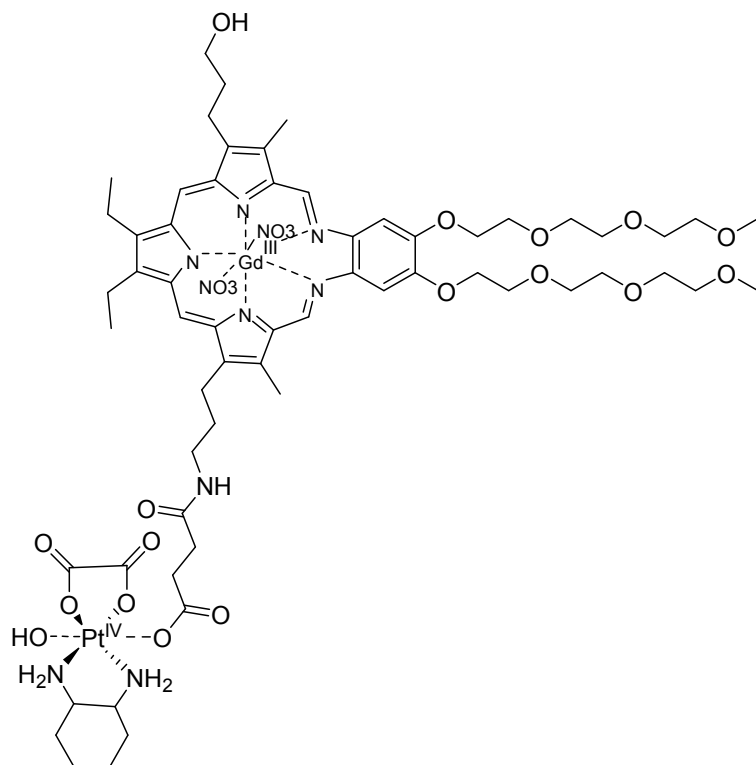
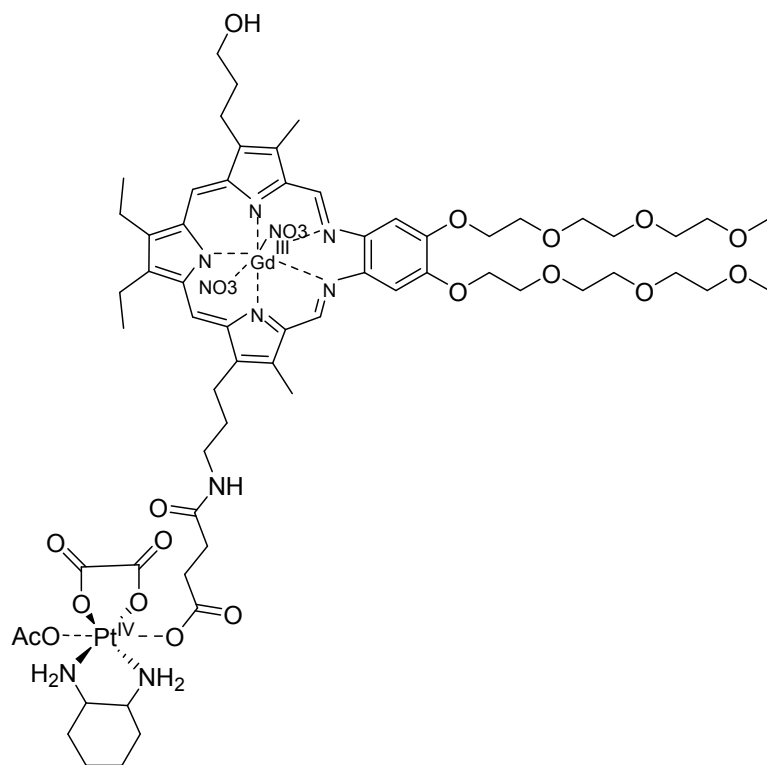
15. The compound according to any one of claims 1-14, wherein X_7 is $-\text{C}(\text{O})\text{NH}-$ or $-\text{NHC}(\text{O})-$.
16. The compound of claim 15, wherein X_7 is $-\text{NHC}(\text{O})-$.
17. The compound according to any one of claims 11-16, wherein A_4 is alkanediyl $_{\text{C}\leq 12}$ or substituted alkanediyl $_{\text{C}\leq 12}$.
18. The compound of claim 17, wherein A_4 is alkanediyl $_{\text{C}\leq 8}$.
19. The compound of claim 18, wherein A_4 is $-\text{CH}_2\text{CH}_2-$.
20. The compound according to any one of claims 11 to 19, wherein R_6 is carboxy.
21. The compound according to any one of claims 11 to 20, wherein L_3 is halide.
22. The compound of claim 21, wherein L_3 is chloride.
23. The compound according to any one of claims 11-22, wherein L_4 is hydroxide.
24. The compound according to any one of claims 11-23, wherein L_5 is amino.
25. The compound according to any one of claims 11-24, wherein L_6 is halide.
26. The compound of claim 25, wherein L_6 is chloride.
27. The compound according to any one of claims 11 to 20, wherein L_3 and L_6 are taken together and are alkylidicarboxylate $_{\text{C}\leq 18}$.
28. The compound of claim 27, wherein L_3 and L_6 are $^-\text{O}_2\text{CCO}_2^-$.
29. The compound according to any one of claims 11-28, wherein L_7 is amino.
30. The compound according to any one of claims 11-23 and 25-28, wherein L_5 and L_7 are taken together and are diaminocycloalkane $_{\text{C}\leq 12}$.
31. The compound of claim 30, wherein L_5 and L_7 are each the amino group of 1,2-diaminocyclohexane.
32. The compound according to any one of claims 1-31, wherein X_3 is alkyl $_{\text{C}\leq 12}$ or substituted alkyl $_{\text{C}\leq 12}$.
33. The compound of claim 32, wherein X_3 is alkyl $_{\text{C}\leq 8}$.

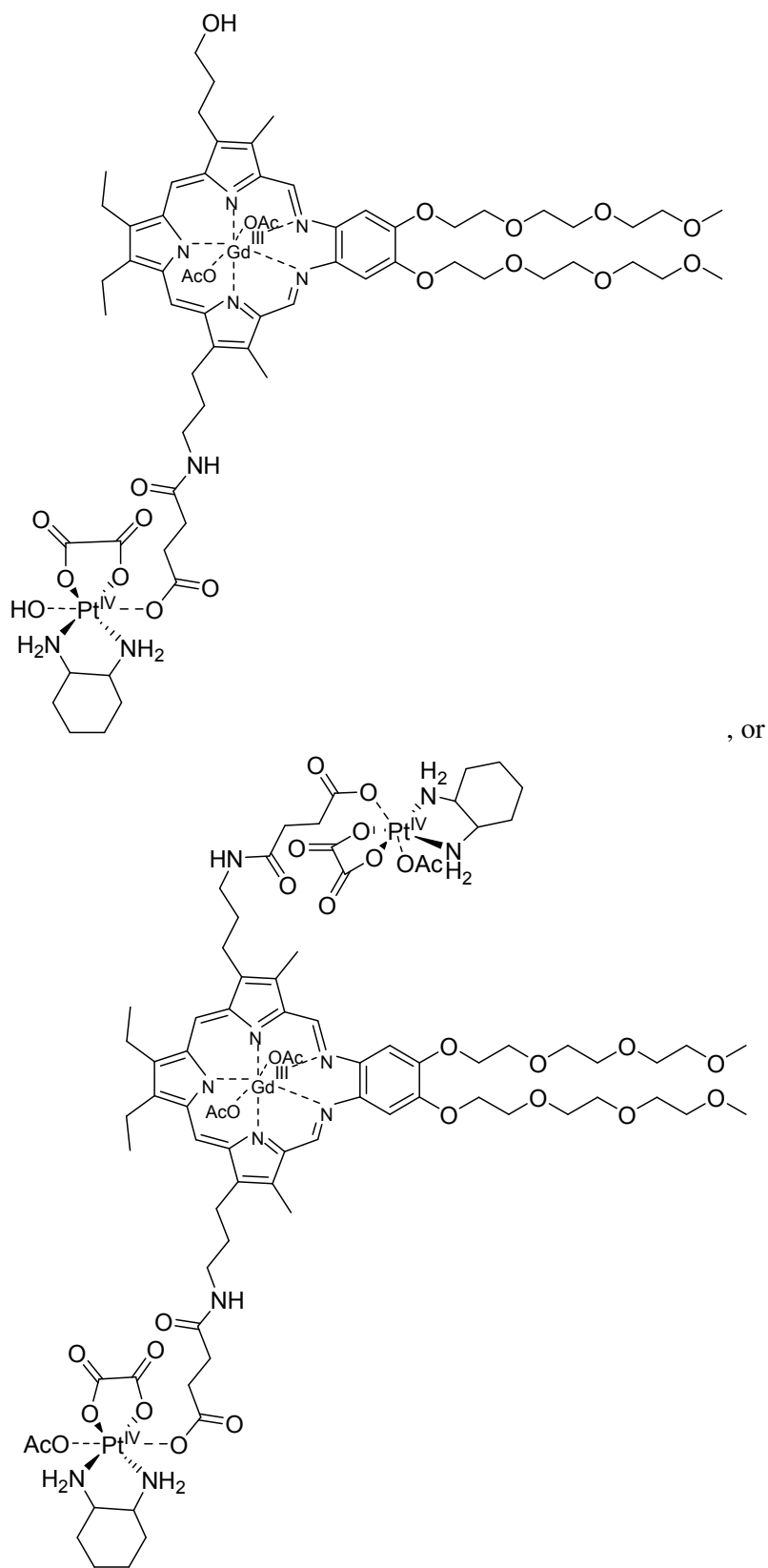
34. The compound of claim 33, wherein X_3 is ethyl.
35. The compound according to any one of claims 1-34, wherein X_4 is $\text{alkyl}_{C\leq 12}$ or substituted $\text{alkyl}_{C\leq 12}$.
36. The compound of claim 35, wherein X_4 is $\text{alkyl}_{C\leq 8}$.
37. The compound of claim 36, wherein X_4 is ethyl.
38. The compound according to any one of claims 1-37, wherein X_5 is $\text{alkyl}_{C\leq 12}$ or substituted $\text{alkyl}_{C\leq 12}$.
39. The compound of claim 38, wherein X_5 is substituted $\text{alkyl}_{C\leq 8}$.
40. The compound of claim 39, wherein X_5 is $-\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$.
41. The compound according to any one of claims 1-37, wherein X_5 is a platinum(IV) chelating group.
42. The compound according to any one of claims 1-41, wherein X_6 is $\text{alkyl}_{C\leq 12}$ or substituted $\text{alkyl}_{C\leq 12}$.
43. The compound of claim 42, wherein X_6 is $\text{alkyl}_{C\leq 8}$.
44. The compound of claim 43, wherein X_6 is methyl.
45. The compound according to any one of claims 1-44, wherein M is gadolinium.
46. The compound of claim 45, wherein M is Gd(III).
47. The compound according to any one of claims 1-46, wherein L_1 is acetate or nitrate.
48. The compound according to any one of claims 1-47, wherein L_2 is acetate or nitrate.

49. The compound of claim 1 further defined as:







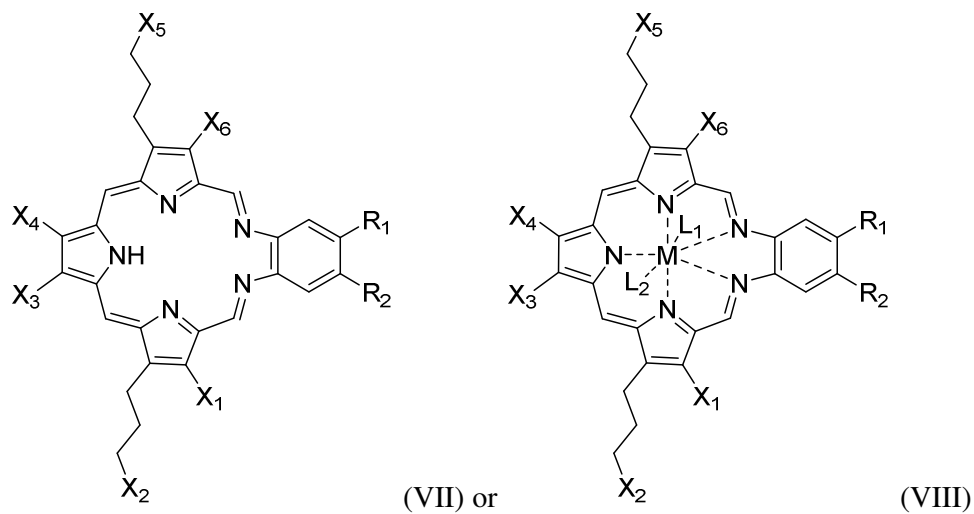


or a pharmaceutically acceptable salt, or tautomer thereof.

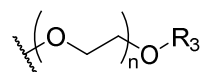
50. A pharmaceutical composition comprising:
- (A) a pharmaceutically acceptable carrier; and
 - (B) a compound according to any one of claims 1-49.
51. The pharmaceutical composition according to claim 50, wherein the pharmaceutical composition is formulated to be administered: orally, intraadiposally, intraarterially, intraarticularly, intracranially, intradermally, intralesionally, intramuscularly, intranasally, intraocularly, intrapericardially, intraperitoneally, intrapleurally, intraprostatically, intrarectally, intrathecally, intratracheally, intratumorally, intraumbilically, intravaginally, intravenously, intravesicularly, intravitreally, liposomally, locally, mucosally, parenterally, rectally, subconjunctivally, subcutaneously, sublingually, topically, transbuccally, transdermally, vaginally, in crèmes, in lipid compositions, via a catheter, via a lavage, via continuous infusion, via infusion, via inhalation, via injection, via local delivery, or via localized perfusion.
52. The pharmaceutical composition of claim 51, wherein the pharmaceutical composition is formulated to be administered orally or intravenously.
53. The pharmaceutical composition according to any one of claims 50-52, wherein the composition is formulated as a unit dose.
54. Use of a compound or pharmaceutical composition according to claims 1 to 53 in the manufacture of a medicament for treating cancer in a patient.
55. The use of claim 54, wherein the cancer is a carcinoma, sarcoma, lymphoma, leukemia, melanoma, mesothelioma, multiple myeloma, or seminoma.
56. The use of claim 54, wherein the cancer is of the bladder, blood, bone, brain, breast, central nervous system, cervix, colon, endometrium, esophagus, gall bladder, genitalia, genitourinary tract, head, kidney, larynx, liver, lung, muscle tissue, neck, oral or nasal mucosa, ovary, pancreas, prostate, skin, spleen, small intestine, large intestine, stomach, testicle, or thyroid.
57. The use of claim 56, wherein the cancer is ovarian cancer, testicular cancer, or bladder cancer.
58. The use of claim 57, wherein the ovarian cancer is ovarian carcinoma.
59. The use of claim 56, wherein the cancer is colon cancer or colorectal cancer.
60. The use according to any one of claims 54-59, wherein the cancer is resistant to a metal chemotherapeutic.

61. The use of claim 60, wherein the cancer is resistant to a platinum chemotherapeutic.
62. The use of claim 61, wherein the cancer is resistant to cisplatin, carboplatin, or oxaliplatin.
63. The use according to any one of claims 54-62, wherein the use comprises a compound or composition according to any one of claims 1-53 to be administered.
64. The use of claim 63, wherein the compound localizes to a tumor before the reduction of the platinum(IV) chelating group.
65. The use according to any one of claims 54-64, wherein the compound of formula II is to be administered once.
66. The use according to any one of claims 54-64, wherein the compound of formula II is to be administered two or more times.
67. The use according to any one of claims 54-66, wherein the use further comprises a reducing agent to be administered.
68. The use according to any one of claims 54-67, wherein the use is to be administered in conjunction with a second therapy.
69. The use of claim 68, wherein the second therapy is a second chemotherapeutic drug, surgery, radiotherapy, photodynamic therapy, sonodynamic therapy, cryotherapy, or immunotherapy.
70. The use of claim 69, wherein the second chemotherapeutic drug is bleomycin, doxorubicin, taxol, taxotere, etoposide, 4-OH cyclophosphamide, or 5-fluorouracil.
71. The use of claim 69, wherein the second chemotherapeutic drug is cisplatin, carboplatin, oxaliplatin, or a Pt(IV) complex.

72. A method of preparing a platinum-texaphyrin complex of the formula:



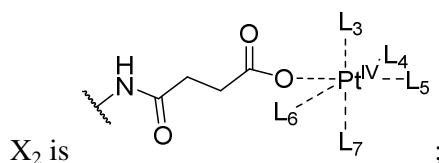
R_1 and R_2 are each independently selected from hydrogen, halo, hydroxy, amino, mercapto, alkoxy_{C≤12}, substituted alkoxy_{C≤12}, or



wherein n is 1-8 and R_3 is hydrogen, alkyl_{C≤6}, or substituted alkyl_{C≤6};

X_1 , X_3 , X_4 , and X_6 are each independently selected from hydrogen, hydroxy, halo, amino, carboxy, nitro, or cyano,

alkyl_{C≤12}, alkenyl_{C≤12}, alkynyl_{C≤12}, aryl_{C≤12}, aralkyl_{C≤12}, acyl_{C≤12}, amido_{C≤12}, or a substituted version of any of these groups,



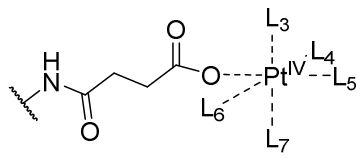
wherein:

L_3 , L_4 , L_5 , L_6 , and L_7 are each ligands independently selected from aqua, ammonia, nitrate, sulfate, halide, hydroxide, phosphate, or glucose-6-phosphate,

alkylamine_{C≤12}, cycloalkylamine_{C≤12}, dialkylamine_{C≤18}, dicycloalkylamine_{C≤18}, arylamine_{C≤12}, diarylamine_{C≤18}, diaminoalkane_{C≤12}, diaminocycloalkane_{C≤12}, diaminoarene_{C≤12}, heteroarene_{C≤12}, alkylcarboxylate_{C≤12}, alkylidicarboxylate_{C≤18}, arylcarboxylate_{C≤12},

aryldicarboxylate_{C≤18}, or a substituted version of any of these groups;

X₅ are each independently selected from amino, hydroxy, alkoxy_{C≤12}, substituted alkoxy_{C≤12}, aralkoxy_{C≤24}, or substituted aralkoxy_{C≤24}, or

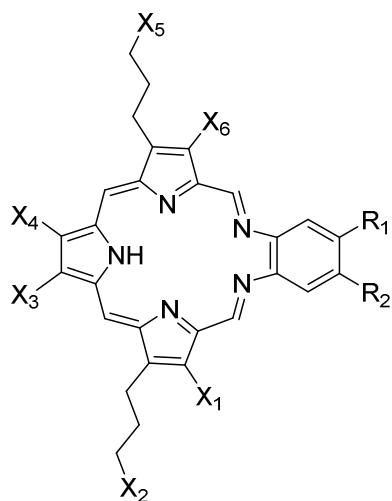


M is a metal ion; and

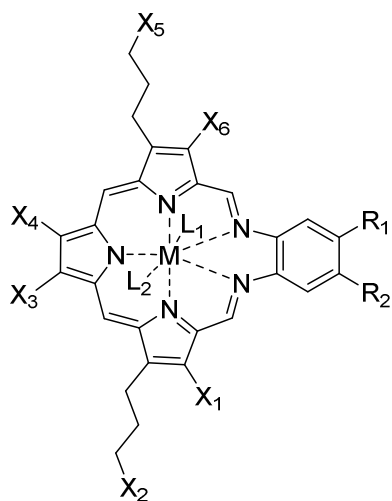
L₁ and L₂ are each anionic ligands independently selected from fluoride, chloride, bromide, carbonate, hydroxide, perchlorate, nitrate, sulfate, trifluoromethylsulfonate, acetylacetonate, acetate, or trifluoroacetate;

provided that L₁ and L₂ are present or absent as necessary to balance the charge on M;

comprising reacting a compound of the formula



(IX) or



(X)

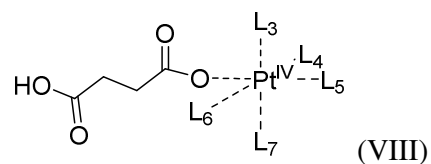
wherein:

X₂ is amino;

X₅ is amino, hydroxy, alkoxy_{C≤12}, substituted alkoxy_{C≤12}, aralkoxy_{C≤24}, or substituted aralkoxy_{C≤24}; and

R₁, R₂, X₁, X₃, X₄, and X₆ are as defined above;

with a compound of the formula:



in a solvent and in the presence of an activating agent.

73. The method of claim 72, wherein the solvent is an aqueous organic mixture.
74. The method of claim 73, wherein the solvent is a water and acetonitrile mixture.
75. The method according to any one of claims 72-74, wherein the activating agent is N-hydroxysuccinimide, 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide (EDC), dicyclohexylcarbodiimide (DCC), diisopropylcarbodiimide (DIC), PyBOP, BOP, HOBT, or N,N'-carbonyldiimidazole (CDI).
76. The method of claim 75, wherein the activating agent is a N-hydroxysuccinimide and 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide.