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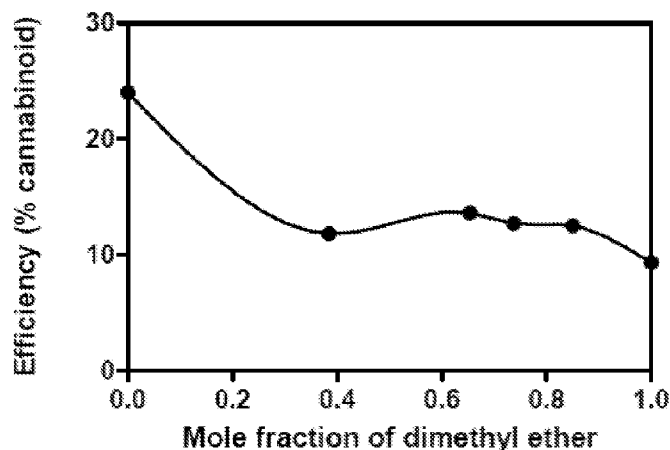
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(54) Title: SYSTEMS AND METHODS FOR EXTRACTION OF NATURAL PRODUCTS

FIG. 1

Extraction Efficiency of Mixtures of R22/DME



(57) Abstract: Described herein, *inter alia*, are processes, methods, and compositions useful for the extraction of natural products from source materials.



SYSTEMS AND METHODS FOR EXTRACTION OF NATURAL PRODUCTS

CROSS-REFERENCES TO RELATED APPLICATIONS

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[0001] This application claims the benefit of U.S. Provisional Application No. 62/431,351, filed December 7, 2016, and U.S. Utility Application No. 15/469,311, filed on March 24, 2017, both of which are incorporated herein by reference in their entirety and for all purposes.

BACKGROUND OF THE INVENTION

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[0002] A major problem in pharmaceutical chemistry relates to extraction of useful substances from plants or animals where such useful substances are employed for the formulation of a pharmaceutical or a nutraceutical. Various processes exist for the extraction of natural products from plant, animal, fungi, bacteria, or virus, but each of these processes suffer from one or more deficiencies. There is an unmet need for a new methodology which can safely and selectively extract desired medicinally or nutritionally valuable components from natural materials. Disclosed herein, *inter alia*, are solutions to these and other problems in the art.

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BRIEF SUMMARY OF THE INVENTION

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[0003] In an aspect is provided a method of extracting a natural organic compound from a natural material, the method including contacting the natural material with an extraction fluid thereby extracting the natural organic compound from the natural material into the extraction fluid to form an extracted fluid solution. The extraction fluid includes a fluorophilic compound and a hydrofluorocarbon.

[0004] In an aspect is provided a fluid including chlorodifluoromethane and dimethyl ether.

BRIEF DESCRIPTION OF THE DRAWINGS

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[0005] FIG. 1. Graph depicting the efficiency of mixtures of chlorodifluoromethane (R22) and dimethyl ether (DME) to extract total cannabinoids in a single 30-minute extraction at 26 °C.

[0006] FIG. 2. Graph demonstrating that the efficiency of pure materials (chlorodifluoromethane (R22), dimethyl ether (DME), and other materials (e.g., refrigerants)) to extract cannabinoids in a single 30-minute procedure at 26 °C can be determined.

DETAILED DESCRIPTION OF THE INVENTION

5 I. Definitions

[0007] The abbreviations used herein have their conventional meaning within the chemical and biological arts. The chemical structures and formulae set forth herein are constructed according to the standard rules of chemical valency known in the chemical arts.

[0008] Where substituent groups are specified by their conventional chemical formulae,
10 written from left to right, they equally encompass the chemically identical substituents that would result from writing the structure from right to left, e.g., $-\text{CH}_2\text{O}-$ is equivalent to $-\text{OCH}_2-$.

[0009] The term “alkyl,” by itself or as part of another substituent, means, unless otherwise stated, a straight (i.e., unbranched) or branched carbon chain (or carbon), or combination thereof, which may be fully saturated, mono- or polyunsaturated and can include mono-, di- and
15 multivalent radicals, having the number of carbon atoms designated (i.e., $\text{C}_1\text{-C}_{10}$ means one to ten carbons). Alkyl is an uncyclized chain. Examples of saturated hydrocarbon radicals include, but are not limited to, groups such as methyl, ethyl, n-propyl, isopropyl, n-butyl, t-butyl, isobutyl, sec-butyl, homologs and isomers of, for example, n-pentyl, n-hexyl, n-heptyl, n-octyl, and the like. An unsaturated alkyl group is one having one or more double bonds or triple bonds.
20 Examples of unsaturated alkyl groups include, but are not limited to, vinyl, 2-propenyl, crotyl, 2-isopentenyl, 2-(butadienyl), 2,4-pentadienyl, 3-(1,4-pentadienyl), ethynyl, 1- and 3-propynyl, 3-butynyl, and the higher homologs and isomers. An alkoxy is an alkyl attached to the remainder of the molecule via an oxygen linker ($-\text{O}-$). An alkyl moiety may be an alkenyl moiety. An alkyl moiety may be an alkynyl moiety. An alkyl moiety may be fully saturated. An alkenyl may
25 include more than one double bond and/or one or more triple bonds in addition to the one or more double bonds. An alkynyl may include more than one triple bond and/or one or more double bonds in addition to the one or more triple bonds.

[0010] The term “alkylene,” by itself or as part of another substituent, means, unless otherwise stated, a divalent radical derived from an alkyl, as exemplified, but not limited by,

-CH₂CH₂CH₂CH₂-. Typically, an alkyl (or alkylene) group will have from 1 to 24 carbon atoms, with those groups having 10 or fewer carbon atoms being preferred herein. A “lower alkyl” or “lower alkylene” is a shorter chain alkyl or alkylene group, generally having eight or fewer carbon atoms. The term “alkenylene,” by itself or as part of another substituent, means, unless otherwise stated, a divalent radical derived from an alkene.

[0011] The term “heteroalkyl,” by itself or in combination with another term, means, unless otherwise stated, a stable straight or branched chain, or combinations thereof, including at least one carbon atom and at least one heteroatom (e.g., O, N, P, Si, and S), and wherein the nitrogen and sulfur atoms may optionally be oxidized, and the nitrogen heteroatom may optionally be quaternized. The heteroatom(s) (e.g., N, S, Si, or P) may be placed at any interior position of the heteroalkyl group or at the position at which the alkyl group is attached to the remainder of the molecule. Heteroalkyl is an uncyclized chain. Examples include, but are not limited to: -CH₂-CH₂-O-CH₃, -CH₂-CH₂-NH-CH₃, -CH₂-CH₂-N(CH₃)-CH₃, -CH₂-S-CH₂-CH₃, -CH₂-CH₂-S(O)-CH₃, -CH₂-CH₂-S(O)₂-CH₃, -CH=CH-O-CH₃, -Si(CH₃)₃, -CH₂-CH=N-OCH₃, -CH=CH-N(CH₃)-CH₃, -O-CH₃, -O-CH₂-CH₃, and -CN. Up to two or three heteroatoms may be consecutive, such as, for example, -CH₂-NH-OCH₃ and -CH₂-O-Si(CH₃)₃. A heteroalkyl moiety may include one heteroatom (e.g., O, N, S, Si, or P). A heteroalkyl moiety may include two optionally different heteroatoms (e.g., O, N, S, Si, or P). A heteroalkyl moiety may include three optionally different heteroatoms (e.g., O, N, S, Si, or P). A heteroalkyl moiety may include four optionally different heteroatoms (e.g., O, N, S, Si, or P). A heteroalkyl moiety may include five optionally different heteroatoms (e.g., O, N, S, Si, or P). A heteroalkyl moiety may include up to 8 optionally different heteroatoms (e.g., O, N, S, Si, or P). The term “heteroalkenyl,” by itself or in combination with another term, means, unless otherwise stated, a heteroalkyl including at least one double bond. A heteroalkenyl may optionally include more than one double bond and/or one or more triple bonds in addition to the one or more double bonds. The term “heteroalkynyl,” by itself or in combination with another term, means, unless otherwise stated, a heteroalkyl including at least one triple bond. A heteroalkynyl may optionally include more than one triple bond and/or one or more double bonds in addition to the one or more triple bonds.

[0012] Similarly, the term “heteroalkylene,” by itself or as part of another substituent, means, unless otherwise stated, a divalent radical derived from heteroalkyl, as exemplified, but not limited by, $-\text{CH}_2-\text{CH}_2-\text{S}-\text{CH}_2-\text{CH}_2-$ and $-\text{CH}_2-\text{S}-\text{CH}_2-\text{CH}_2-\text{NH}-\text{CH}_2-$. For heteroalkylene groups, heteroatoms can also occupy either or both of the chain termini (e.g., alkyleneoxy,

5 alkylenedioxy, alkyleneamino, alkylenediamino, and the like). Still further, for alkylene and heteroalkylene linking groups, no orientation of the linking group is implied by the direction in which the formula of the linking group is written. For example, the formula $-\text{C}(\text{O})_2\text{R}'$ represents both $-\text{C}(\text{O})_2\text{R}'$ and $-\text{R}'\text{C}(\text{O})_2-$. As described above, heteroalkyl groups, as used herein, include those groups that are attached to the remainder of the molecule through a heteroatom, such as -
10 $\text{C}(\text{O})\text{R}'$, $-\text{C}(\text{O})\text{NR}'$, $-\text{NR}'\text{R}''$, $-\text{OR}'$, $-\text{SR}'$, and/or $-\text{SO}_2\text{R}'$. Where “heteroalkyl” is recited, followed by recitations of specific heteroalkyl groups, such as $-\text{NR}'\text{R}''$ or the like, it will be understood that the terms heteroalkyl and $-\text{NR}'\text{R}''$ are not redundant or mutually exclusive. Rather, the specific heteroalkyl groups are recited to add clarity. Thus, the term “heteroalkyl” should not be interpreted herein as excluding specific heteroalkyl groups, such as $-\text{NR}'\text{R}''$ or the like.

15 [0013] The terms “cycloalkyl” and “heterocycloalkyl,” by themselves or in combination with other terms, mean, unless otherwise stated, cyclic versions of “alkyl” and “heteroalkyl,” respectively. Cycloalkyl and heterocycloalkyl are not aromatic. Additionally, for heterocycloalkyl, a heteroatom can occupy the position at which the heterocycle is attached to the remainder of the molecule. Examples of cycloalkyl include, but are not limited to,
20 cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, 1-cyclohexenyl, 3-cyclohexenyl, cycloheptyl, and the like. Examples of heterocycloalkyl include, but are not limited to, 1-(1,2,5,6-tetrahydropyridyl), 1-piperidinyl, 2-piperidinyl, 3-piperidinyl, 4-morpholinyl, 3-morpholinyl, tetrahydrofuran-2-yl, tetrahydrofuran-3-yl, tetrahydrothien-2-yl, tetrahydrothien-3-yl, 1-piperazinyl, 2-piperazinyl, and the like. A “cycloalkylene” and a “heterocycloalkylene,” alone or
25 as part of another substituent, means a divalent radical derived from a cycloalkyl and heterocycloalkyl, respectively.

[0014] The terms “halo” or “halogen,” by themselves or as part of another substituent, mean, unless otherwise stated, a fluorine, chlorine, bromine, or iodine atom. Additionally, terms such as “haloalkyl” are meant to include monohaloalkyl and polyhaloalkyl. For example, the term

“halo(C₁-C₄)alkyl” includes, but is not limited to, fluoromethyl, difluoromethyl, trifluoromethyl, 2,2,2-trifluoroethyl, 4-chlorobutyl, 3-bromopropyl, and the like.

[0015] The term “acyl” means, unless otherwise stated, -C(O)R where R is a substituted or unsubstituted alkyl, substituted or unsubstituted cycloalkyl, substituted or unsubstituted heteroalkyl, substituted or unsubstituted heterocycloalkyl, substituted or unsubstituted aryl, or substituted or unsubstituted heteroaryl.

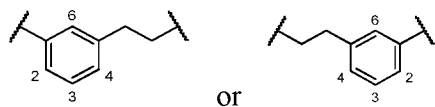
[0016] The term “aryl” means, unless otherwise stated, a polyunsaturated, aromatic, hydrocarbon substituent, which can be a single ring or multiple rings (preferably from 1 to 3 rings) that are fused together (i.e., a fused ring aryl) or linked covalently. A fused ring aryl refers to multiple rings fused together wherein at least one of the fused rings is an aryl ring. The term “heteroaryl” refers to aryl groups (or rings) that contain at least one heteroatom such as N, O, or S, wherein the nitrogen and sulfur atoms are optionally oxidized, and the nitrogen atom(s) are optionally quaternized. Thus, the term “heteroaryl” includes fused ring heteroaryl groups (i.e., multiple rings fused together wherein at least one of the fused rings is a heteroaromatic ring). A 5,6-fused ring heteroarylene refers to two rings fused together, wherein one ring has 5 members and the other ring has 6 members, and wherein at least one ring is a heteroaryl ring. Likewise, a 6,6-fused ring heteroarylene refers to two rings fused together, wherein one ring has 6 members and the other ring has 6 members, and wherein at least one ring is a heteroaryl ring. And a 6,5-fused ring heteroarylene refers to two rings fused together, wherein one ring has 6 members and the other ring has 5 members, and wherein at least one ring is a heteroaryl ring. A heteroaryl group can be attached to the remainder of the molecule through a carbon or heteroatom. Non-limiting examples of aryl and heteroaryl groups include phenyl, naphthyl, pyrrolyl, pyrazolyl, pyridazinyl, triazinyl, pyrimidinyl, imidazolyl, pyrazinyl, purinyl, oxazolyl, isoxazolyl, thiazolyl, furyl, thienyl, pyridyl, pyrimidyl, benzothiazolyl, benzoxazolyl, benzimidazolyl, benzofuran, isobenzofuranyl, indolyl, isoindolyl, benzothiophenyl, isoquinolyl, quinoxalinyl, quinolyl, 1-naphthyl, 2-naphthyl, 4-biphenyl, 1-pyrrolyl, 2-pyrrolyl, 3-pyrrolyl, 3-pyrazolyl, 2-imidazolyl, 4-imidazolyl, pyrazinyl, 2-oxazolyl, 4-oxazolyl, 2-phenyl-4-oxazolyl, 5-oxazolyl, 3-isoxazolyl, 4-isoxazolyl, 5-isoxazolyl, 2-thiazolyl, 4-thiazolyl, 5-thiazolyl, 2-furyl, 3-furyl, 2-thienyl, 3-thienyl, 2-pyridyl, 3-pyridyl, 4-pyridyl, 2-pyrimidyl, 4-pyrimidyl, 5-benzothiazolyl, purinyl, 2-benzimidazolyl, 5-indolyl, 1-isoquinolyl, 5-isoquinolyl, 2-quinoxalinyl, 5-quinoxalinyl, 3-

quinolyl, and 6-quinolyl. Substituents for each of the above noted aryl and heteroaryl ring systems are selected from the group of acceptable substituents described below. An “arylene” and a “heteroarylene,” alone or as part of another substituent, mean a divalent radical derived from an aryl and heteroaryl, respectively. A heteroaryl group substituent may be -O- bonded to a ring heteroatom nitrogen.

[0017] Spirocyclic rings are two or more rings wherein adjacent rings are attached through a single atom. The individual rings within spirocyclic rings may be identical or different. Individual rings in spirocyclic rings may be substituted or unsubstituted and may have different substituents from other individual rings within a set of spirocyclic rings. Possible substituents for individual rings within spirocyclic rings are the possible substituents for the same ring when not part of spirocyclic rings (e.g. substituents for cycloalkyl or heterocycloalkyl rings). Spirocyclic rings may be substituted or unsubstituted cycloalkyl, substituted or unsubstituted cycloalkylene, substituted or unsubstituted heterocycloalkyl or substituted or unsubstituted heterocycloalkylene and individual rings within a spirocyclic ring group may be any of the immediately previous list, including having all rings of one type (e.g. all rings being substituted heterocycloalkylene wherein each ring may be the same or different substituted heterocycloalkylene). When referring to a spirocyclic ring system, heterocyclic spirocyclic rings means a spirocyclic rings wherein at least one ring is a heterocyclic ring and wherein each ring may be a different ring. When referring to a spirocyclic ring system, substituted spirocyclic rings means that at least one ring is substituted and each substituent may optionally be different.

[0018] The term “oxo,” as used herein, means an oxygen that is double bonded to a carbon atom.

[0019] The term “alkylarylene” as an arylene moiety covalently bonded to an alkylene moiety (also referred to herein as an alkylene linker). In embodiments, the alkylarylene group has the formula:



[0020] An alkylarylene moiety may be substituted (e.g. with a substituent group) on the alkylene moiety or the arylene linker (e.g. at carbons 2, 3, 4, or 6) with halogen, oxo, -N₃, -CF₃, -CCl₃, -CBr₃, -Cl₃, -CN, -CHO, -OH, -NH₂, -COOH, -CONH₂, -NO₂, -SH, -SO₂CH₃, -SO₃H, -OSO₃H, -SO₂NH₂, -NHNH₂, -ONH₂, -NHC(O)NHNH₂, substituted or unsubstituted C₁-C₅ alkyl or substituted or unsubstituted 2 to 5 membered heteroalkyl). In embodiments, the alkylarylene is unsubstituted.

[0021] Each of the above terms (e.g., “alkyl,” “heteroalkyl,” “cycloalkyl,” “heterocycloalkyl,” “aryl,” and “heteroaryl”) includes both substituted and unsubstituted forms of the indicated radical. Preferred substituents for each type of radical are provided below.

[0022] Substituents for the alkyl and heteroalkyl radicals (including those groups often referred to as alkylene, alkenyl, heteroalkylene, heteroalkenyl, alkynyl, cycloalkyl, heterocycloalkyl, cycloalkenyl, and heterocycloalkenyl) can be one or more of a variety of groups selected from, but not limited to, -OR', =O, =NR', =N-OR', -NR'R'', -SR', -halogen, -SiR'R''R''', -OC(O)R', -C(O)R', -CO₂R', -CONR'R'', -OC(O)NR'R'', -NR''C(O)R', -NR'-C(O)NR''R''', -NR''C(O)₂R', -NR-C(NR'R''R''')=NR''', -NR-C(NR'R'')=NR'', -S(O)R', -S(O)₂R', -S(O)₂NR'R'', -NRSO₂R', -NR'NR''R''', -ONR'R'', -NR'C(O)NR''NR''R''', -CN, -NO₂, -NR'SO₂R'', -NR'C(O)R'', -NR'C(O)-OR'', -NR'OR'', in a number ranging from zero to (2m'+1), where m' is the total number of carbon atoms in such radical. R, R', R'', R''', and R'''' each preferably independently refer to hydrogen, substituted or unsubstituted heteroalkyl, substituted or unsubstituted cycloalkyl, substituted or unsubstituted heterocycloalkyl, substituted or unsubstituted aryl (e.g., aryl substituted with 1-3 halogens), substituted or unsubstituted heteroaryl, substituted or unsubstituted alkyl, alkoxy, or thioalkoxy groups, or arylalkyl groups. When a compound described herein includes more than one R group, for example, each of the R groups is independently selected as are each R', R'', R''', and R'''' group when more than one of these groups is present. When R' and R'' are attached to the same nitrogen atom, they can be combined with the nitrogen atom to form a 4-, 5-, 6-, or 7-membered ring. For example, -NR'R'' includes, but is not limited to, 1-pyrrolidinyl and 4-morpholinyl. From the above discussion of substituents, one of skill in the art will understand that the term “alkyl” is meant to include groups including carbon atoms bound to groups other than hydrogen groups, such as haloalkyl (e.g., -CF₃ and -CH₂CF₃) and acyl (e.g., -C(O)CH₃, -C(O)CF₃, -C(O)CH₂OCH₃, and the like).

[0023] Similar to the substituents described for the alkyl radical, substituents for the aryl and heteroaryl groups are varied and are selected from, for example: -OR', -NR'R'', -SR', -halogen, -SiR'R''R''', -OC(O)R', -C(O)R', -CO₂R', -CONR'R'', -OC(O)NR'R'', -NR''C(O)R', -NR'-C(O)NR''R''', -NR''C(O)₂R', -NR-C(NR'R''R''')=NR''', -NR-C(NR'R'')=NR''', -S(O)R', -S(O)₂R', -S(O)₂NR'R'', -NRSO₂R', -NR'NR''R''', -ONR'R'', -NR'C(O)NR''NR''R''', -CN, -NO₂, -R', -N₃, -CH(Ph)₂, fluoro(C₁-C₄)alkoxy, and fluoro(C₁-C₄)alkyl, -NR'SO₂R', -NR'C(O)R'', -NR'C(O)-OR'', -NR'OR'', in a number ranging from zero to the total number of open valences on the aromatic ring system; and where R', R'', R''', and R'''' are preferably independently selected from hydrogen, substituted or unsubstituted alkyl, substituted or unsubstituted heteroalkyl, substituted or unsubstituted cycloalkyl, substituted or unsubstituted heterocycloalkyl, substituted or unsubstituted aryl, and substituted or unsubstituted heteroaryl. When a compound described herein includes more than one R group, for example, each of the R groups is independently selected as are each R', R'', R''', and R'''' groups when more than one of these groups is present.

[0024] Substituents for rings (e.g. cycloalkyl, heterocycloalkyl, aryl, heteroaryl, cycloalkylene, heterocycloalkylene, arylene, or heteroarylene) may be depicted as substituents on the ring rather than on a specific atom of a ring (commonly referred to as a floating substituent). In such a case, the substituent may be attached to any of the ring atoms (obeying the rules of chemical valency) and in the case of fused rings or spirocyclic rings, a substituent depicted as associated with one member of the fused rings or spirocyclic rings (a floating substituent on a single ring), may be a substituent on any of the fused rings or spirocyclic rings (a floating substituent on multiple rings). When a substituent is attached to a ring, but not a specific atom (a floating substituent), and a subscript for the substituent is an integer greater than one, the multiple substituents may be on the same atom, same ring, different atoms, different fused rings, different spirocyclic rings, and each substituent may optionally be different. Where a point of attachment of a ring to the remainder of a molecule is not limited to a single atom (a floating substituent), the attachment point may be any atom of the ring and in the case of a fused ring or spirocyclic ring, any atom of any of the fused rings or spirocyclic rings while obeying the rules of chemical valency. Where a ring, fused rings, or spirocyclic rings contain one or more ring heteroatoms and the ring, fused rings, or spirocyclic rings are shown with one more floating substituents (including, but not limited to, points of attachment to the remainder of the molecule), the floating substituents may be bonded to the heteroatoms. Where the ring heteroatoms are shown bound to one or more

hydrogens (e.g. a ring nitrogen with two bonds to ring atoms and a third bond to a hydrogen) in the structure or formula with the floating substituent, when the heteroatom is bonded to the floating substituent, the substituent will be understood to replace the hydrogen, while obeying the rules of chemical valency.

5 [0025] Two or more substituents may optionally be joined to form aryl, heteroaryl, cycloalkyl, or heterocycloalkyl groups. Such so-called ring-forming substituents are typically, though not necessarily, found attached to a cyclic base structure. In one embodiment, the ring-forming substituents are attached to adjacent members of the base structure. For example, two ring-forming substituents attached to adjacent members of a cyclic base structure create a fused ring
10 structure. In another embodiment, the ring-forming substituents are attached to a single member of the base structure. For example, two ring-forming substituents attached to a single member of a cyclic base structure create a spirocyclic structure. In yet another embodiment, the ring-forming substituents are attached to non-adjacent members of the base structure.

[0026] Two of the substituents on adjacent atoms of the aryl or heteroaryl ring may optionally
15 form a ring of the formula $-T-C(O)-(CRR')_q-U-$, wherein T and U are independently $-NR-$, $-O-$, $-CRR'-$, or a single bond, and q is an integer of from 0 to 3. Alternatively, two of the substituents on adjacent atoms of the aryl or heteroaryl ring may optionally be replaced with a substituent of the formula $-A-(CH_2)_r-B-$, wherein A and B are independently $-CRR'-$, $-O-$, $-NR-$, $-S-$, $-S(O)-$, $-S(O)_2-$, $-S(O)_2NR'-$, or a single bond, and r is an integer of from 1 to 4. One of the single bonds
20 of the new ring so formed may optionally be replaced with a double bond. Alternatively, two of the substituents on adjacent atoms of the aryl or heteroaryl ring may optionally be replaced with a substituent of the formula $-(CRR')_s-X'-(C''R''R''')_d-$, where s and d are independently integers of from 0 to 3, and X' is $-O-$, $-NR'-$, $-S-$, $-S(O)-$, $-S(O)_2-$, or $-S(O)_2NR'-$. The substituents R, R', R'', and R''' are preferably independently selected from hydrogen, substituted or unsubstituted
25 alkyl, substituted or unsubstituted heteroalkyl, substituted or unsubstituted cycloalkyl, substituted or unsubstituted heterocycloalkyl, substituted or unsubstituted aryl, and substituted or unsubstituted heteroaryl.

[0027] As used herein, the terms “heteroatom” or “ring heteroatom” are meant to include oxygen (O), nitrogen (N), sulfur (S), phosphorus (P), and silicon (Si).

[0028] A “substituent group,” as used herein, means a group selected from the following moieties:

(A) oxo, halogen, -CF₃, -CN, -OH, -NH₂, -COOH, -CONH₂, -NO₂, -SH, -SO₃H, -SO₄H, -SO₂NH₂, -NHNH₂, -ONH₂, -NHC=(O)NHNH₂, -NHC=(O)NH₂, -NHSO₂H, -NHC=(O)H, -NHC(O)-OH, -NHOH, -OCF₃, -OCHF₂, unsubstituted alkyl, unsubstituted heteroalkyl, unsubstituted cycloalkyl, unsubstituted heterocycloalkyl, unsubstituted aryl, unsubstituted heteroaryl, and

(B) alkyl, heteroalkyl, cycloalkyl, heterocycloalkyl, aryl, heteroaryl, substituted with at least one substituent selected from:

(i) oxo, halogen, -CF₃, -CN, -OH, -NH₂, -COOH, -CONH₂, -NO₂, -SH, -SO₃H, -SO₄H, -SO₂NH₂, -NHNH₂, -ONH₂, -NHC=(O)NHNH₂, -NHC=(O)NH₂, -NHSO₂H, -NHC=(O)H, -NHC(O)-OH, -NHOH, -OCF₃, -OCHF₂, unsubstituted alkyl, unsubstituted heteroalkyl, unsubstituted cycloalkyl, unsubstituted heterocycloalkyl, unsubstituted aryl, unsubstituted heteroaryl, and

(ii) alkyl, heteroalkyl, cycloalkyl, heterocycloalkyl, aryl, heteroaryl, substituted with at least one substituent selected from:

(a) oxo, halogen, -CF₃, -CN, -OH, -NH₂, -COOH, -CONH₂, -NO₂, -SH, -SO₃H, -SO₄H, -SO₂NH₂, -NHNH₂, -ONH₂, -NHC=(O)NHNH₂, -NHC=(O)NH₂, -NHSO₂H, -NHC=(O)H, -NHC(O)-OH, -NHOH, -OCF₃, -OCHF₂, unsubstituted alkyl, unsubstituted heteroalkyl, unsubstituted cycloalkyl, unsubstituted heterocycloalkyl, unsubstituted aryl, unsubstituted heteroaryl, and

(b) alkyl, heteroalkyl, cycloalkyl, heterocycloalkyl, aryl, heteroaryl, substituted with at least one substituent selected from: oxo, halogen, -CF₃, -CN, -OH, -NH₂, -COOH, -CONH₂, -NO₂, -SH, -SO₃H, -SO₄H, -SO₂NH₂, -NHNH₂, -ONH₂, -NHC=(O)NHNH₂, -NHC=(O)NH₂, -NHSO₂H, -NHC=(O)H, -NHC(O)-OH, -NHOH, -OCF₃, -OCHF₂, unsubstituted alkyl, unsubstituted heteroalkyl, unsubstituted cycloalkyl, unsubstituted heterocycloalkyl, unsubstituted aryl, unsubstituted heteroaryl.

[0029] A “size-limited substituent” or “size-limited substituent group,” as used herein, means a group selected from all of the substituents described above for a “substituent group,” wherein each substituted or unsubstituted alkyl is a substituted or unsubstituted C₁-C₂₀ alkyl, each substituted or unsubstituted heteroalkyl is a substituted or unsubstituted 2 to 20 membered

heteroalkyl, each substituted or unsubstituted cycloalkyl is a substituted or unsubstituted C₃-C₈ cycloalkyl, each substituted or unsubstituted heterocycloalkyl is a substituted or unsubstituted 3 to 8 membered heterocycloalkyl, each substituted or unsubstituted aryl is a substituted or unsubstituted C₆-C₁₀ aryl, and each substituted or unsubstituted heteroaryl is a substituted or unsubstituted 5 to 10 membered heteroaryl.

[0030] A “lower substituent” or “lower substituent group,” as used herein, means a group selected from all of the substituents described above for a “substituent group,” wherein each substituted or unsubstituted alkyl is a substituted or unsubstituted C₁-C₈ alkyl, each substituted or unsubstituted heteroalkyl is a substituted or unsubstituted 2 to 8 membered heteroalkyl, each substituted or unsubstituted cycloalkyl is a substituted or unsubstituted C₃-C₇ cycloalkyl, each substituted or unsubstituted heterocycloalkyl is a substituted or unsubstituted 3 to 7 membered heterocycloalkyl, each substituted or unsubstituted aryl is a substituted or unsubstituted C₆-C₁₀ aryl, and each substituted or unsubstituted heteroaryl is a substituted or unsubstituted 5 to 9 membered heteroaryl.

[0031] In some embodiments, each substituted group described in the compounds herein is substituted with at least one substituent group. More specifically, in some embodiments, each substituted alkyl, substituted heteroalkyl, substituted cycloalkyl, substituted heterocycloalkyl, substituted aryl, substituted heteroaryl, substituted alkylene, substituted heteroalkylene, substituted cycloalkylene, substituted heterocycloalkylene, substituted arylene, and/or substituted heteroarylene described in the compounds herein are substituted with at least one substituent group. In other embodiments, at least one or all of these groups are substituted with at least one size-limited substituent group. In other embodiments, at least one or all of these groups are substituted with at least one lower substituent group.

[0032] In other embodiments of the compounds herein, each substituted or unsubstituted alkyl may be a substituted or unsubstituted C₁-C₂₀ alkyl, each substituted or unsubstituted heteroalkyl is a substituted or unsubstituted 2 to 20 membered heteroalkyl, each substituted or unsubstituted cycloalkyl is a substituted or unsubstituted C₃-C₈ cycloalkyl, each substituted or unsubstituted heterocycloalkyl is a substituted or unsubstituted 3 to 8 membered heterocycloalkyl, each substituted or unsubstituted aryl is a substituted or unsubstituted C₆-C₁₀ aryl, and/or each substituted or unsubstituted heteroaryl is a substituted or unsubstituted 5 to 10 membered

heteroaryl. In some embodiments of the compounds herein, each substituted or unsubstituted alkylene is a substituted or unsubstituted C₁-C₂₀ alkylene, each substituted or unsubstituted heteroalkylene is a substituted or unsubstituted 2 to 20 membered heteroalkylene, each substituted or unsubstituted cycloalkylene is a substituted or unsubstituted C₃-C₈ cycloalkylene, each substituted or unsubstituted heterocycloalkylene is a substituted or unsubstituted 3 to 8 membered heterocycloalkylene, each substituted or unsubstituted arylene is a substituted or unsubstituted C₆-C₁₀ arylene, and/or each substituted or unsubstituted heteroarylene is a substituted or unsubstituted 5 to 10 membered heteroarylene.

[0033] In some embodiments, each substituted or unsubstituted alkyl is a substituted or unsubstituted C₁-C₈ alkyl, each substituted or unsubstituted heteroalkyl is a substituted or unsubstituted 2 to 8 membered heteroalkyl, each substituted or unsubstituted cycloalkyl is a substituted or unsubstituted C₃-C₇ cycloalkyl, each substituted or unsubstituted heterocycloalkyl is a substituted or unsubstituted 3 to 7 membered heterocycloalkyl, each substituted or unsubstituted aryl is a substituted or unsubstituted C₆-C₁₀ aryl, and/or each substituted or unsubstituted heteroaryl is a substituted or unsubstituted 5 to 9 membered heteroaryl. In some embodiments, each substituted or unsubstituted alkylene is a substituted or unsubstituted C₁-C₈ alkylene, each substituted or unsubstituted heteroalkylene is a substituted or unsubstituted 2 to 8 membered heteroalkylene, each substituted or unsubstituted cycloalkylene is a substituted or unsubstituted C₃-C₇ cycloalkylene, each substituted or unsubstituted heterocycloalkylene is a substituted or unsubstituted 3 to 7 membered heterocycloalkylene, each substituted or unsubstituted arylene is a substituted or unsubstituted C₆-C₁₀ arylene, and/or each substituted or unsubstituted heteroarylene is a substituted or unsubstituted 5 to 9 membered heteroarylene. In some embodiments, the compound is a chemical species set forth in the Examples section, figures, or tables below.

[0034] In embodiments, a substituted or unsubstituted moiety (e.g., substituted or unsubstituted alkyl, substituted or unsubstituted heteroalkyl, substituted or unsubstituted cycloalkyl, substituted or unsubstituted heterocycloalkyl, substituted or unsubstituted aryl, substituted or unsubstituted heteroaryl, substituted or unsubstituted alkylene, substituted or unsubstituted heteroalkylene, substituted or unsubstituted cycloalkylene, substituted or unsubstituted heterocycloalkylene, substituted or unsubstituted arylene, and/or substituted or unsubstituted heteroarylene) is

unsubstituted (e.g., is an unsubstituted alkyl, unsubstituted heteroalkyl, unsubstituted cycloalkyl, unsubstituted heterocycloalkyl, unsubstituted aryl, unsubstituted heteroaryl, unsubstituted alkylene, unsubstituted heteroalkylene, unsubstituted cycloalkylene, unsubstituted heterocycloalkylene, unsubstituted arylene, and/or unsubstituted heteroarylene, respectively). In

embodiments, a substituted or unsubstituted moiety (e.g., substituted or unsubstituted alkyl, substituted or unsubstituted heteroalkyl, substituted or unsubstituted cycloalkyl, substituted or unsubstituted heterocycloalkyl, substituted or unsubstituted aryl, substituted or unsubstituted heteroaryl, substituted or unsubstituted alkylene, substituted or unsubstituted heteroalkylene, substituted or unsubstituted cycloalkylene, substituted or unsubstituted heterocycloalkylene, substituted or unsubstituted arylene, and/or substituted or unsubstituted heteroarylene) is substituted (e.g., is a substituted alkyl, substituted heteroalkyl, substituted cycloalkyl, substituted heterocycloalkyl, substituted aryl, substituted heteroaryl, substituted alkylene, substituted heteroalkylene, substituted cycloalkylene, substituted heterocycloalkylene, substituted arylene, and/or substituted heteroarylene, respectively).

[0035] In embodiments, a substituted moiety (e.g., substituted alkyl, substituted heteroalkyl, substituted cycloalkyl, substituted heterocycloalkyl, substituted aryl, substituted heteroaryl, substituted alkylene, substituted heteroalkylene, substituted cycloalkylene, substituted heterocycloalkylene, substituted arylene, and/or substituted heteroarylene) is substituted with at least one substituent group, wherein if the substituted moiety is substituted with a plurality of substituent groups, each substituent group may optionally be different. In embodiments, if the substituted moiety is substituted with a plurality of substituent groups, each substituent group is different.

[0036] In embodiments, a substituted moiety (e.g., substituted alkyl, substituted heteroalkyl, substituted cycloalkyl, substituted heterocycloalkyl, substituted aryl, substituted heteroaryl, substituted alkylene, substituted heteroalkylene, substituted cycloalkylene, substituted heterocycloalkylene, substituted arylene, and/or substituted heteroarylene) is substituted with at least one size-limited substituent group, wherein if the substituted moiety is substituted with a plurality of size-limited substituent groups, each size-limited substituent group may optionally be different. In embodiments, if the substituted moiety is substituted with a plurality of size-limited substituent groups, each size-limited substituent group is different.

[0037] In embodiments, a substituted moiety (e.g., substituted alkyl, substituted heteroalkyl, substituted cycloalkyl, substituted heterocycloalkyl, substituted aryl, substituted heteroaryl, substituted alkylene, substituted heteroalkylene, substituted cycloalkylene, substituted heterocycloalkylene, substituted arylene, and/or substituted heteroarylene) is substituted with at least one lower substituent group, wherein if the substituted moiety is substituted with a plurality of lower substituent groups, each lower substituent group may optionally be different. In embodiments, if the substituted moiety is substituted with a plurality of lower substituent groups, each lower substituent group is different.

[0038] In embodiments, a substituted moiety (e.g., substituted alkyl, substituted heteroalkyl, substituted cycloalkyl, substituted heterocycloalkyl, substituted aryl, substituted heteroaryl, substituted alkylene, substituted heteroalkylene, substituted cycloalkylene, substituted heterocycloalkylene, substituted arylene, and/or substituted heteroarylene) is substituted with at least one substituent group, size-limited substituent group, or lower substituent group; wherein if the substituted moiety is substituted with a plurality of groups selected from substituent groups, size-limited substituent groups, and lower substituent groups; each substituent group, size-limited substituent group, and/or lower substituent group may optionally be different. In embodiments, if the substituted moiety is substituted with a plurality of groups selected from substituent groups, size-limited substituent groups, and lower substituent groups; each substituent group, size-limited substituent group, and/or lower substituent group is different.

[0039] Certain compounds of the present invention possess asymmetric carbon atoms (optical or chiral centers) or double bonds; the enantiomers, racemates, diastereomers, tautomers, geometric isomers, stereoisometric forms that may be defined, in terms of absolute stereochemistry, as (R)- or (S)- or, as (D)- or (L)- for amino acids, and individual isomers are encompassed within the scope of the present invention. The compounds of the present invention do not include those that are known in art to be too unstable to synthesize and/or isolate. The present invention is meant to include compounds in racemic and optically pure forms. Optically active (R)- and (S)-, or (D)- and (L)-isomers may be prepared using chiral synthons or chiral reagents, or resolved using conventional techniques. When the compounds described herein contain olefinic bonds or other centers of geometric asymmetry, and unless specified otherwise, it is intended that the compounds include both E and Z geometric isomers.

[0040] As used herein, the term “isomers” refers to compounds having the same number and kind of atoms, and hence the same molecular weight, but differing in respect to the structural arrangement or configuration of the atoms.

[0041] The term “tautomer,” as used herein, refers to one of two or more structural isomers which exist in equilibrium and which are readily converted from one isomeric form to another. It will be apparent to one skilled in the art that certain compounds of this invention may exist in tautomeric forms, all such tautomeric forms of the compounds being within the scope of the invention.

[0042] Unless otherwise stated, structures depicted herein are also meant to include all stereochemical forms of the structure; i.e., the R and S configurations for each asymmetric center. Therefore, single stereochemical isomers as well as enantiomeric and diastereomeric mixtures of the present compounds are within the scope of the invention.

[0043] Unless otherwise stated, structures depicted herein are also meant to include compounds which differ only in the presence of one or more isotopically enriched atoms. For example, compounds having the present structures except for the replacement of a hydrogen by a deuterium or tritium, or the replacement of a carbon by ^{13}C - or ^{14}C -enriched carbon are within the scope of this invention.

[0044] The compounds of the present invention may also contain unnatural proportions of atomic isotopes at one or more of the atoms that constitute such compounds. For example, the compounds may be radiolabeled with radioactive isotopes, such as for example tritium (^3H), iodine-125 (^{125}I), or carbon-14 (^{14}C). All isotopic variations of the compounds of the present invention, whether radioactive or not, are encompassed within the scope of the present invention.

[0045] It should be noted that throughout the application that alternatives are written in Markush groups, for example, each amino acid position that contains more than one possible amino acid. It is specifically contemplated that each member of the Markush group should be considered separately, thereby comprising another embodiment, and the Markush group is not to be read as a single unit.

[0046] “Analog,” or “analogue” is used in accordance with its plain ordinary meaning within Chemistry and Biology and refers to a chemical compound that is structurally similar to another

compound (i.e., a so-called “reference” compound) but differs in composition, e.g., in the replacement of one atom by an atom of a different element, or in the presence of a particular functional group, or the replacement of one functional group by another functional group, or the absolute stereochemistry of one or more chiral centers of the reference compound. Accordingly,
5 an analog is a compound that is similar or comparable in function and appearance but not in structure or origin to a reference compound.

[0047] The terms “a” or “an,” as used in herein means one or more. In addition, the phrase “substituted with a[n],” as used herein, means the specified group may be substituted with one or more of any or all of the named substituents. For example, where a group, such as an alkyl or
10 heteroaryl group, is “substituted with an unsubstituted C₁-C₂₀ alkyl, or unsubstituted 2 to 20 membered heteroalkyl,” the group may contain one or more unsubstituted C₁-C₂₀ alkyls, and/or one or more unsubstituted 2 to 20 membered heteroalkyls.

[0048] As used herein, the term "about" means a range of values including the specified value, which a person of ordinary skill in the art would consider reasonably similar to the specified
15 value. In embodiments, the term "about" means within a standard deviation using measurements generally acceptable in the art. In embodiments, about means a range extending to +/- 10% of the specified value. In embodiments, about means the specified value.

[0049] Moreover, where a moiety is substituted with an R substituent, the group may be referred to as “R-substituted.” Where a moiety is R-substituted, the moiety is substituted with at
20 least one R substituent and each R substituent is optionally different. Where a particular R group is present in the description of a chemical genus (such as Formula (I)), a Roman alphabetic symbol may be used to distinguish each appearance of that particular R group. For example, where multiple R¹³ substituents are present, each R¹³ substituent may be distinguished as R^{13A}, R^{13B}, R^{13C}, R^{13D}, etc., wherein each of R^{13A}, R^{13B}, R^{13C}, R^{13D}, etc. is defined within the scope of
25 the definition of R¹³ and optionally differently.

[0050] Descriptions of compounds of the present invention are limited by principles of chemical bonding known to those skilled in the art. Accordingly, where a group may be substituted by one or more of a number of substituents, such substitutions are selected so as to comply with principles of chemical bonding and to give compounds which are not inherently
30 unstable and/or would be known to one of ordinary skill in the art as likely to be unstable under

ambient conditions, such as aqueous, neutral, and several known physiological conditions. For example, a heterocycloalkyl or heteroaryl is attached to the remainder of the molecule via a ring heteroatom in compliance with principles of chemical bonding known to those skilled in the art thereby avoiding inherently unstable compounds.

5 [0051] The term “pharmaceutically acceptable salts” is meant to include salts of the active compounds that are prepared with relatively nontoxic acids or bases, depending on the particular substituents found on the compounds described herein. When compounds of the present disclosure contain relatively acidic functionalities, base addition salts can be obtained by contacting the neutral form of such compounds with a sufficient amount of the desired base,
10 either neat or in a suitable inert solvent. Examples of pharmaceutically acceptable base addition salts include sodium, potassium, calcium, ammonium, organic amino, or magnesium salt, or a similar salt. When compounds of the present disclosure contain relatively basic functionalities, acid addition salts can be obtained by contacting the neutral form of such compounds with a sufficient amount of the desired acid, either neat or in a suitable inert solvent. Examples of
15 pharmaceutically acceptable acid addition salts include those derived from inorganic acids like hydrochloric, hydrobromic, nitric, carbonic, monohydrogencarbonic, phosphoric, monohydrogenphosphoric, dihydrogenphosphoric, sulfuric, monohydrogensulfuric, hydriodic, or phosphorous acids and the like, as well as the salts derived from relatively nontoxic organic acids like acetic, propionic, isobutyric, maleic, malonic, benzoic, succinic, suberic, fumaric, lactic,
20 mandelic, phthalic, benzenesulfonic, p-tolylsulfonic, citric, tartaric, oxalic, methanesulfonic, and the like. Also included are salts of amino acids such as arginate and the like, and salts of organic acids like glucuronic or galactunoric acids and the like (*see*, for example, Berge *et al.*, “Pharmaceutical Salts”, *Journal of Pharmaceutical Science*, **1977**, *66*, 1-19). Certain specific compounds of the present disclosure contain both basic and acidic functionalities that allow the
25 compounds to be converted into either base or acid addition salts.

[0052] The compounds of the present invention may exist as salts, such as with pharmaceutically acceptable acids. The present invention includes such salts. Non-limiting examples of such salts include hydrochlorides, hydrobromides, phosphates, sulfates, methanesulfonates, nitrates, maleates, acetates, citrates, fumarates, proprionates, tartrates (e.g.,
30 (+)-tartrates, (-)-tartrates, or mixtures thereof including racemic mixtures), succinates, benzoates,

and salts with amino acids such as glutamic acid, and quaternary ammonium salts (e.g. methyl iodide, ethyl iodide, and the like). These salts may be prepared by methods known to those skilled in the art.

[0053] The neutral forms of the compounds are preferably regenerated by contacting the salt with a base or acid and isolating the parent compound in the conventional manner. The parent form of the compound may differ from the various salt forms in certain physical properties, such as solubility in polar solvents.

[0054] In addition to salt forms, the present disclosure provides compounds, which are in a prodrug form. Prodrugs of the compounds described herein are those compounds that readily undergo chemical changes under physiological conditions to provide the compounds of the present disclosure. Prodrugs of the compounds described herein may be converted *in vivo* after administration. Additionally, prodrugs can be converted to the compounds of the present disclosure by chemical or biochemical methods in an *ex vivo* environment, such as, for example, when contacted with a suitable enzyme or chemical reagent. In embodiments, conversion of a prodrug to a corresponding drug may occur through reaction with an enzyme (e.g., esterase, amidase, cytochrome, or other metabolic enzyme).

[0055] Certain compounds of the present invention can exist in unsolvated forms as well as solvated forms, including hydrated forms. In general, the solvated forms are equivalent to unsolvated forms and are encompassed within the scope of the present invention. Certain compounds of the present invention may exist in multiple crystalline or amorphous forms. In general, all physical forms are equivalent for the uses contemplated by the present invention and are intended to be within the scope of the present invention.

[0056] “Contacting” is used in accordance with its plain ordinary meaning and refers to the process of allowing at least two distinct species (e.g. a natural material and an extraction fluid) to become sufficiently proximal to react, interact or physically touch. It should be appreciated, however, that the resulting reaction product can be produced directly from a reaction between the added reagents or from an intermediate from one or more of the added reagents that can be produced in the reaction mixture.

[0057] The term “contacting” may include allowing two species to react, interact, or physically touch, wherein the two species may be, for example, a natural material as described herein and an extraction fluid. In some embodiments, contacting includes allowing a natural material described herein to physically touch an extraction fluid capable of extracting a natural organic compound or natural product from the natural material.

[0058] “Fungi” are defined as any of a kingdom (Fungi) of saprophytic and parasitic spore-producing eukaryotic typically filamentous organisms formerly classified as plants that lack chlorophyll and include molds, rusts, mildews, smuts, mushrooms, and yeasts. Several other groups that historically have been associated with fungi, such as slime molds and water molds are now not considered to be fungi. The phyla of fungi are distinguished primarily by their sexual reproductive structures.

[0059] Yeasts are single-celled, eukaryotic microorganisms belonging to the fungus kingdom. Yeasts do not form a single taxonomic or phylogenetic grouping. Yeast are typically 3-4 μm in diameter, however some yeasts can reach sized of up to 40 μm . Non-limiting examples of yeasts include *Saccharomyces cerevisiae*, *Cryptococcus albidus*, *Cryptococcus neoformans*, and *Candida albicans*. Some yeasts, for example *Candida albicans*, are human pathogens.

[0060] Bacteria constitute a large domain of prokaryotic microorganisms. Bacteria have a number of shapes, ranging from spheres to rods and spirals. Bacterial cells are typically 0.5–5. μm in length. The bacterial cell is surrounded by a cell membrane, which encloses the contents of the cell and acts as a barrier to hold nutrients, proteins and other essential components of the cytoplasm within the cell. In some bacteria, a cell wall is present on the outside of the cell membrane. As they are prokaryotes, bacteria do not usually have membrane-bound organelles in their cytoplasm, and thus contain few large intracellular structures. They lack a true nucleus, mitochondria, chloroplasts and the other organelles present in eukaryotic cells.

[0061] A virus is a small infectious agent that replicates only inside the living cells of other organisms. Viruses can infect all types of life forms, from animals and plants to microorganisms, including bacteria and archaea. Viruses contemplated herein may be DNA or RNA viruses. Non-limiting examples of DNA viruses include Adenovirus, Papillomavirus, polyomaviridae, simian vacuolating virus, Parvovirus B19, canine parvovirus, Herpes simplex virus, varicella-zoster virus, cytomegalovirus, Epstein–Barr virus, Smallpox

virus, cow pox virus, sheep pox virus, orf virus, monkey pox virus, vaccinia virus, Hepatitis B virus, and Torque teno virus. Non-limiting examples of RNA viruses include Reovirus, rotavirus, Enterovirus, rhinovirus, hepatovirus, cardiovirus, aphthovirus, poliovirus, parechovirus, erbovirus, kobuvirus, teschovirus, coxsackie, Norwalk virus, Rubella virus, alphavirus, Lymphocytic choriomeningitis virus, Dengue virus, hepatitis C virus, yellow fever virus, Influenzavirus A, influenzavirus B, influenzavirus C, isavirus, thogotovirus, Measles virus, mumps virus, respiratory syncytial virus, Rinderpest virus, canine distemper virus, California encephalitis virus, hantavirus, Rabies virus, Ebola virus, Marburg virus, Corona virus, Astrovirus, Borna disease virus, Arterivirus, equine arteritis virus, Hepatitis E virus, and HIV.

[0062] The term “animal” is used in accordance with its well understood common meaning and represents a multicellular, eukaryotic organism of the kingdom Animalia (also called Metazoa). Animals are divided into various sub-groups, some of which are: vertebrates (birds, mammals, amphibians, reptiles, fish); molluscs (clams, oysters, octopuses, squid, snails); arthropods (millipedes, centipedes, insects, spiders, scorpions, crabs, lobsters, shrimp); annelids (earthworms, leeches); sponges; and jellyfish.

[0063] The term “aromatic compound,” also known as an arene or aromatic, refers to a compound including at least one conjugated planar ring system with delocalized pi electron clouds as opposed to discrete alternating single and double bonds. An aromatic compound includes at least one aromatic moiety (e.g., aryl or heteroaryl). Non-limiting examples of aromatic compounds are benzene and toluene.

[0064] As used herein, “fluorophilic” refers to a chemical component or portion thereof capable of mixing with, solubilizing, and/or a substantial chemical attractive interaction with a fluorinated compound such as a hydrofluorocarbon and/or fluorocarbon. In embodiments, fluorophilic refers to a chemical component or portion thereof capable of mixing with and/or solubilizing a fluorinated compound such as a hydrofluorocarbon and/or fluorocarbon. For example, a fluorophilic compound or portion thereof may be fluorinated, wherein the fluorophilic compound or portion thereof is a linear, branched, cyclic, saturated, or unsaturated fluorinated hydrocarbon. A fluorophilic compound may optionally include at least one heteroatom (e.g., O, N, S, P, Si; in the backbone of the component). In some cases, a fluorophilic compound may be highly fluorinated, i.e., at least 30%, at least 50%, at least 70%, or at least

90% of the hydrogen atoms of the component are replaced by fluorine atoms. The fluorophilic compound may include a fluorine to hydrogen ratio of, for example, at least 0.2:1, at least 0.5:1, at least 1:1, at least 2:1, at least 5:1, or at least 10:1. In embodiments, at least 30%, at least 50%, at least 70%, or at least 90% but less than 100% of the hydrogen atoms of the component are replaced by fluorine atoms. In other cases, the fluorophilic compound is perfluorinated, i.e., the component contains fluorine atoms but contains no hydrogen atoms. Fluorophilic compounds contemplated herein may have low toxicity, low surface tension, and the ability to dissolve and transport gases. Examples of types of fluorophilic components include, but are not limited to, hydrofluorocarbons, chlorofluorocarbons, and perfluorocarbons.

[0065] As used herein, a “fluorophilic compound” refers to a class of compounds that are capable of mixing with, solubilizing, and/or are substantial chemical attractive interaction with a fluorinated compound such as a hydrofluorocarbon and/or fluorocarbon. For example, a fluorophilic compound may include a hydrocarbon, hydrofluorocarbon, and/or fluorocarbon. In embodiments, fluorophilic compounds do not include chlorofluorocarbon (e.g. R-11 (Trichlorofluoromethane), CCl_3F ; R-12 (Dichlorodifluoromethane), CCl_2F_2 ; or R-13 (Chlorotrifluoromethane), CClF_3). In embodiments, the fluorophilic compound is dimethyl ether, methyl ethyl ether, methyl n-propyl ether, methyl isopropyl ether, methyl-n-butyl ether, diethyl ether, methyl tert-butyl ether, or ethyl tert-butyl ether. In embodiments, the fluorophilic compound is dimethyl ether. In embodiments, the fluorophilic compound is methyl ethyl ether. In embodiments, the fluorophilic compound is methyl n-propyl ether. In embodiments, the fluorophilic compound is methyl isopropyl ether. In embodiments, the fluorophilic compound is methyl-n-butyl ether. In embodiments, the fluorophilic compound is diethyl ether. In embodiments, the fluorophilic compound is methyl tert-butyl ether. In embodiments, the fluorophilic compound is ethyl tert-butyl ether.

[0066] A “fluorocarbon compound” or “fluorocarbon” is a compound including fluorine and carbon, but not hydrogen (e.g., no carbon-hydrogen bonds). In embodiments, a fluorocarbon compound is an FC- fluorocarbon compound (“FC”), which consists solely of fluorine and carbon. In embodiments, a fluorocarbon compound is a chlorofluorocarbon (CFC) compound. FC and CFC are common terms used to define refrigerants (see, for example, Downing, Ralph C. Fluorocarbon refrigerants handbook Prentice Hall (1988)). Non-limiting examples of

fluorocarbon compounds include fluoroether compounds, fluoroketone compounds, fluoroaromatic compounds and fluoroolefin compounds. Fluorocarbon compounds may also include compounds wherein one or more optional substituents therein may be selected from one or more of bromine, chlorine and iodine. In embodiments, the fluorocarbon compound includes one or more of bromine, chlorine, and iodine. In embodiments, the fluorocarbon compound includes one or more of bromine. In embodiments, the fluorocarbon compound includes one or more of chlorine. In embodiments, the fluorocarbon compound includes one or more of iodine. Fluorocarbon molecules may have various structures, including straight or branched chain or cyclic structures. The chemical properties of certain of these compounds, because of the unusual polarity of the carbon-fluorine bond, are unexpected. For example, perfluorotrimethyl iodide, a gas which boils at -22.5°C, is relatively stable in the absence of light (which can produce heterolysis and subsequent free radical formation) even in the presence of water below 100°C or moderately basic solutions. Brominated perfluorocarbons such as 1-bromo-heptadecafluorooctane ($C_8F_{17}Br$), sometimes designated perfluorooctyl bromide α , ω -dibromo-F-butane; 1-bromopenta-decafluoroheptane ($C_7F_{15}Br$); 1-bromo-nonafluorobutane (C_4F_9Br); and 1-bromotridecafluorohexane ($C_6F_{13}Br$) are quite stable under the present extraction conditions. It is also contemplated that fluorocarbons having nonfluorinated substituents, such as perfluorooctyl chloride may be used in the apparatus, methods, and compositions described herein, as well as similar compounds having different numbers of carbon atoms, e.g., 2-8 carbon atoms. In embodiments, the fluorocarbon is perfluorooctyl chloride. Those skilled in the art will appreciate that esters, thioesters, amines, amides, and other variously modified fluorocarbon compounds are also encompassed within the definition of fluorocarbon materials suitable for use in the present invention. Certain perfluorinated compounds are relatively inert and have unexpected properties; for example, perfluorotributylamine is not at all basic. See, for example, Hong, Angela C., Cora J. Young, Michael D. Hurley, Timothy J. Wallington, and Scott A. Mabury. "Perfluorotributylamine: A novel long-lived greenhouse gas." *Geophysical Research Letters* 40, no. 22 (2013): 6010-6015, which is incorporated herein by reference for all purposes.

[0067] It is also contemplated that perfluorooctyl hydride may be used in the apparatus, methods, and compositions described herein. Those skilled in the art will appreciate that other variously modified fluorocarbon-hydrocarbon compounds are also materials suitable for use in the present invention.

[0068] A “hydrofluorocarbon compound” or “hydrofluorocarbon” is a compound including fluorine, carbon, and at least one hydrogen atom (e.g., at least one carbon-hydrogen bond). In embodiments, a hydrofluorocarbon compound is an HFC-hydrofluorocarbon compound (“HFC”), which consists solely of fluorine, carbon and hydrogen. In embodiments, a hydrofluorocarbon compound is a hydrochlorofluorocarbon (HCFC) compound. HFC and HCFC are common terms used to define refrigerants (see Downing, Ralph C. *supra.*). Non-limiting examples of hydrofluorocarbons include trifluoromethane (HFC-23), difluoromethane (HFC-32), pentafluoroethane (HFC-125), 1,1,2,2-tetrafluoroethane (HFC-134), 1,1,1,2-tetrafluoroethane (HFC-134a), 1,1,1-trifluoroethane (HFC-143a), 1,1-difluoroethane (HFC-152a) and fluoroethane (HFC-161). Hydrofluorocarbon compounds may be, for example, hydrofluoroether compounds, hydrofluoroketone compounds, hydrofluoroaromatic compounds or hydrofluoroolefin compounds. Non-limiting examples of hydrofluorocarbon compounds include methyl nonafluoroisobutyl ether, methyl nonafluorobutyl ether, ethyl nonafluoroisobutyl ether, ethyl nonafluorobutyl ether, and 3-ethoxy-1, 1,1,2,3,4,4,5, 5,6,6,6- dodecafluoro-2-trifluoromethylhexane. In embodiments, hydrofluorocarbon compounds include compounds wherein one or more optional substituents may be one or more bromine, chlorine, or iodine. In embodiments, the hydrofluorocarbon is chlorodifluoromethane, methyl nonafluoroisobutyl ether, methyl nonafluorobutyl ether, ethyl nonafluoroisobutyl ether, ethyl nonafluorobutyl ether, 3-ethoxy-1, 1,1,2,3,4,4,5, 5,6,6,6- dodecafluoro-2-trifluoromethylhexane. trifluoromethane (HFC-23), difluoromethane (HFC-32), pentafluoroethane (HFC-125), 1,1,2,2-tetrafluoroethane (HFC-134), 1,1,1,2-tetrafluoroethane (HFC-134a), 1,1,1-trifluoroethane (HFC-143a), 1,1-difluoroethane (HFC-152a), (1,1,1,3,3,3-hexafluoro-2-(fluoromethoxy)propane, 1,2,2,2-tetrafluoroethyl difluoromethyl ether, 2-chloro-1,1,2-trifluoroethyl difluoromethyl ether, 1-chloro-2,2,2-trifluoroethyl difluoromethyl ether, 2,2-dichloro-1,1-difluoromethyl ether, or fluoroethane (HFC-161). In embodiments, the hydrofluorocarbon is chlorodifluoromethane. In embodiments, the hydrofluorocarbon is methyl nonafluoroisobutyl ether. In embodiments, the hydrofluorocarbon is methyl nonafluorobutyl ether. In embodiments, the hydrofluorocarbon is ethyl nonafluoroisobutyl ether. In embodiments, the hydrofluorocarbon is ethyl nonafluorobutyl ether. In embodiments, the hydrofluorocarbon is 3-ethoxy-1, 1,1,2,3,4,4,5,5,6,6,6- dodecafluoro-2-trifluoromethylhexane. trifluoromethane (HFC-23). In embodiments, the hydrofluorocarbon is difluoromethane (HFC-32). In embodiments, the hydrofluorocarbon is pentafluoroethane (HFC-

125). In embodiments, the hydrofluorocarbon is 1,1,2,2-tetrafluoroethane (HFC-134). In
embodiments, the hydrofluorocarbon is 1,1,1,2- tetrafluoroethane (HFC-134a). In embodiments,
the hydrofluorocarbon is 1,1,1-trifluoroethane (HFC-143a). In embodiments, the
hydrofluorocarbon is 1,1- difluoroethane (HFC-152a). In embodiments, the hydrofluorocarbon
5 is 1,1,1,3,3,3-hexafluoro-2-(fluoromethoxy)propane. In embodiments, the hydrofluorocarbon is
1,2,2,2-tetrafluoroethyl difluoromethyl ether. In embodiments, the hydrofluorocarbon is 2-
chloro-1,1,2,-trifluoroethyl difluoromethyl ether. In embodiments, the hydrofluorocarbon is 1-
chloro-2,2,2-trifluoroethyl difluoromethyl ether. In embodiments, the hydrofluorocarbon is 2,2-
dichloro-1,1-difluoromethyl ether. In embodiments, the hydrofluorocarbon is fluoroethane
10 (HFC-161).

[0069] Within the compounds described herein, including within the class of fluorophilic
compounds, hydrofluorocarbon compounds, and fluorocarbon compounds, “optionally
substituted” indicates that one or more fluorine or hydrogen atoms may be replaced with an
independently selected alkyl, alkenyl, alkoxy, fluoroalkoxy, perfluoroalkoxy, fluoroalkyl,
15 perfluoroalkyl, aryl or heteroaryl group or compound moiety (e.g., one or more hydrogens on the
carbon chain of the group or compound may be independently substituted with one or more of
independently selected substituents (e.g., substituent groups). For example, a substituted C_2H_5
group may, without limitation, be $-CF_2CF_3$, $-CH_2CH_2OH$ or $-CF_2CF_2I$.

[0070] A “refrigerant” is a substance that is capable of removing heat from its surroundings
20 (e.g., when it changes phase from liquid to vapor (i.e. when it evaporates)). Refrigerants may
add heat to its surroundings in a complementary reaction (e.g., when it changes phase from vapor
to liquid (i.e. when it condenses)) (e.g., FC-fluorocarbon, an HFC-hydrofluorocarbon, a
chlorofluorocarbon, a hydrochlorofluorocarbon, an alkane, an alkene, or an aromatic compound;
or ammonia, carbon dioxide or other gases such as hydrogen, oxygen, nitrogen and argon).
25 Refrigerant substances may contain oxygen, or bromine, chlorine or iodine, as described above,
for example, in relation to hydrofluorocarbon and fluorocarbon compounds.

[0071] An “azeotrope”, or an “azeotropic” or “constant boiling” is a mixture of two or more
components whose proportions cannot be altered by simple distillation. When boiled, the vapor
has the same proportions of the constituents as the un-boiled mixture. In embodiments, a
30 constant boiling mixture is a “near- azeotropic” mixture, which is a mixture that maintains a

substantially constant vapor pressure even after evaporative losses, thereby exhibiting constant boiling behavior. Azeotropic and constant boiling mixtures also include mixtures wherein the boiling points of two or more of the components thereof are separated by only about 5°C or less.

[0072] The “critical pressure” of a substance is the pressure required to liquefy a gas at its critical temperature, which is the temperature above which vapor of the substance cannot be liquefied, regardless of how much pressure is applied.

[0073] As used herein, “nonaqueous” is meant to define material such as a fluid that is immiscible with water. That is, a liquid that when mixed with water will form a stable two-phase mixture. The non-aqueous phase need not be liquid, but can be a solid or semi-solid lipid or other nonpolar substance that is not soluble in water. In some instances, the nonaqueous phase can include a lipophilic component (e.g., a hydrocarbon) or a fluorinated component (e.g., a fluorocarbon). The aqueous phase can be any liquid miscible with water; that is, any liquid that, when admixed with water, can form a room-temperature, single-phase solution that is stable. In some cases, the aqueous phase can comprise one or more reagents and/or solvents, etc. Non-limiting examples of aqueous phase materials include (besides water itself) methanol, ethanol, DMF (dimethylformamide), or DMSO (dimethyl sulfoxide).

[0074] The term “chirality” refers to the geometric property of a rigid object (or spatial arrangement of points or atoms) of being non-superimposable on its mirror image. If the object is superimposable on its mirror image the object is described as being achiral.

[0075] The term “chiral center” refers to an atom holding a set of ligands in a spatial arrangement, which is not superimposable on its mirror image. A chirality center may be considered a generalized extension of the concept of the asymmetric carbon atom to central atoms of any element. Each chiral center (*C) is labeled R or S according to a system by which its substituents are each designated a priority according to the Cahn Ingold Prelog priority rules (CIP), based on atomic number.

[0076] The term, “enantiomer” refers to one of a pair of optical isomers containing one or more asymmetric carbons whose molecular configurations have left- and right-hand (chiral) forms. Enantiomers have identical physical properties, except for the direction of rotation of the

plane of polarized light. Enantiomers have identical chemical properties except toward optically active reagents.

[0077] An “ionic liquid” is a salt in liquid form. An ionic liquid may include an organic compound (e.g., and counter ion), typically a salt of an organic acid and an organic base, which
5 may exist in a zwitterionic form, which is present in a liquid state (e.g., at room temperature or substantially close to room temperature, wherein room temperature is defined as a range of temperatures from about 4°C to about 50°C, and most typically between 15°C and 30°C, and more typically about 25°C). Thus, in embodiments, an ionic liquid includes an organic compound. In embodiments, an ionic liquid includes a salt of an organic acid. In embodiments,
10 an ionic liquid includes a salt of an organic base. In embodiments, an ionic liquid includes a salt of an organic base and a salt of an organic acid.

[0078] An ionic liquid differs from most salts in that it has a very low melting point, and tends to be liquid over a wide temperature range. An ionic liquid may not be soluble in non-polar hydrocarbons; may be immiscible with water, depending on the anion; or may be highly ionizing
15 (but has a low dielectric strength). In embodiments, an ionic liquid is not soluble in non-polar hydrocarbons. In embodiments, an ionic liquid is immiscible in water. In embodiments, an ionic liquid is highly ionizing. In embodiments, an ionic liquid has low dielectric strength.

[0079] An ionic liquid may have essentially no vapor pressure. In embodiments, an ionic liquid is air and water stable, and can be neutral, acidic, or basic. In embodiments, an ionic liquid
20 has low or essentially no vapor pressure. In embodiments, very low or no vapor pressure refers to a vapor pressure of less than about 10^{-3} Pa at 25°C. In embodiments, very low or no vapor pressure refers to a vapor pressure of less than about 10^{-4} Pa at 25°C. In embodiments, very low or no vapor pressure refers to a vapor pressure of less than about 10^{-5} Pa at 25°C. In
embodiments, very low or no vapor pressure refers to a vapor pressure of less than about 10^{-6} Pa
25 at 25°C. In embodiments, very low or no vapor pressure refers to a vapor pressure of less than about 10^{-7} Pa at 25°C. In embodiments, very low or no vapor pressure refers to a vapor pressure of less than about 10^{-8} Pa at 25°C. In embodiments, very low or no vapor pressure refers to a
vapor pressure of less than about 10^{-9} Pa at 25°C. In embodiments, very low or no vapor pressure
30 refers to a vapor pressure of less than about 10^{-10} Pa at 25°C. In embodiments, very low or no vapor pressure refers to a vapor pressure of less than about 10^{-11} Pa at 25°C. In embodiments,

very low or no vapor pressure refers to a vapor pressure of less than about 10^{-12} Pa at 25°C. In
embodiments, very low or no vapor pressure refers to a vapor pressure of about 10^{-3} to about 10^{-12}
 10^{-12} Pa at 25°C. In embodiments, very low or no vapor pressure refers to a vapor pressure of about
 10^{-4} to about 10^{-12} Pa at 25°C. In embodiments, very low or no vapor pressure refers to a vapor
5 pressure of about 10^{-5} to about 10^{-12} Pa at 25°C. In embodiments, very low or no vapor pressure
refers to a vapor pressure of about 10^{-6} to about 10^{-12} Pa at 25°C. In embodiments, very low or
no vapor pressure refers to a vapor pressure of about 10^{-7} to about 10^{-12} Pa at 25°C. In
embodiments, very low or no vapor pressure refers to a vapor pressure of about 10^{-8} to about 10^{-12}
 10^{-12} Pa at 25°C. In embodiments, very low or no vapor pressure refers to a vapor pressure of about
10 10^{-9} to about 10^{-12} Pa at 25°C. In embodiments, very low or no vapor pressure refers to a vapor
pressure of about 10^{-10} to about 10^{-12} Pa at 25°C. In embodiments, very low or no vapor pressure
refers to a vapor pressure of about 10^{-11} to about 10^{-12} Pa at 25°C.

[0080] In embodiments, very low or no vapor pressure refers to a vapor pressure of less than
 10^{-3} Pa at 25°C. In embodiments, very low or no vapor pressure refers to a vapor pressure of less
15 than 10^{-4} Pa at 25°C. In embodiments, very low or no vapor pressure refers to a vapor pressure of
less than 10^{-5} Pa at 25°C. In embodiments, very low or no vapor pressure refers to a vapor
pressure of less than 10^{-6} Pa at 25°C. In embodiments, very low or no vapor pressure refers to a
vapor pressure of less than 10^{-7} Pa at 25°C. In embodiments, very low or no vapor pressure refers
to a vapor pressure of less than 10^{-8} Pa at 25°C. In embodiments, very low or no vapor pressure
20 refers to a vapor pressure of less than 10^{-9} Pa at 25°C. In embodiments, very low or no vapor
pressure refers to a vapor pressure of less than 10^{-10} Pa at 25°C. In embodiments, very low or no
vapor pressure refers to a vapor pressure of less than 10^{-11} Pa at 25°C. In embodiments, very low
or no vapor pressure refers to a vapor pressure of less than 10^{-12} Pa at 25°C. In embodiments,
very low or no vapor pressure refers to a vapor pressure between 10^{-3} to 10^{-12} Pa at 25°C. In
25 embodiments, very low or no vapor pressure refers to a vapor pressure between 10^{-4} to 10^{-12} Pa at
25°C. In embodiments, very low or no vapor pressure refers to a vapor pressure between 10^{-5} to
 10^{-12} Pa at 25°C. In embodiments, very low or no vapor pressure refers to a vapor pressure
between 10^{-6} to 10^{-12} Pa at 25°C. In embodiments, very low or no vapor pressure refers to a
vapor pressure between 10^{-7} to 10^{-12} Pa at 25°C. In embodiments, very low or no vapor pressure
30 refers to a vapor pressure between 10^{-8} to 10^{-12} Pa at 25°C. In embodiments, very low or no
vapor pressure refers to a vapor pressure between 10^{-9} to 10^{-12} Pa at 25°C. In embodiments, very

low or no vapor pressure refers to a vapor pressure between 10^{-10} to 10^{-12} Pa at 25°C. In embodiments, very low or no vapor pressure refers to a vapor pressure between 10^{-11} to 10^{-12} Pa at 25°C. In embodiments, very low or no vapor pressure refers to a vapor pressure between 10^{-12} to 10^{-9} Pa at 25°C.

5 **[0081]** In embodiments, an ionic liquid is air stable (e.g., stable under open air and ambient room conditions). In embodiments, an ionic liquid is water stable. In embodiments, an ionic liquid is neutral. In embodiments, an ionic liquid is acidic. In embodiments, an ionic liquid is basic.

10 **[0082]** The properties of an ionic liquid can be tailored by varying the cation and anion. In ionic liquids the cation or anion of the ionic liquid can be any cation or anion such that the cation and anion together form a salt (e.g., organic salt) that is liquid at or below about 100°C (e.g., room temperature). Thus, in embodiments, a cation and anion of an ionic liquid form a salt (e.g., organic salt) at or below 100°C (e.g., room temperature).

15 **[0083]** An ionic liquid may be formed by reacting a nitrogen-containing heterocyclic ring, preferably a heteroaromatic ring, with an alkylating agent (for example, an alkyl halide) to form a quaternary ammonium salt, and performing ion exchange or other suitable reactions with various Lewis acids or their conjugate bases to form the ionic liquid. Examples of suitable heteroaromatic rings include substituted pyridines, imidazole, substituted imidazole, pyrrole and substituted pyrroles. These rings can be alkylated with virtually any straight, branched, or cyclic
20 C₁-C₂₀ alkyl group (e.g., the alkyl groups are C₁-C₁₆ groups). Various triarylphosphines, thioethers and cyclic and non-cyclic quaternary ammonium salts may also be used for this purpose. Non-limiting examples of counterions that may be used include chloroaluminate, bromoaluminate, gallium chloride, tetrafluoroborate, tetrachloroborate, hexafluorophosphate, nitrate, trifluoromethane sulfonate, methylsulfonate, p-toluenesulfonate, hexafluoroantimonate,
25 hexafluoroarsenate, tetrachloroaluminate, tetrabromoaluminate, perchlorate, hydroxide anion, copper dichloride anion, iron trichloride anion, zinc trichloride anion, as well as various lanthanum, potassium, lithium, nickel, cobalt, manganese, or other metal-containing anions.

30 **[0084]** Ionic liquids may be synthesized by salt metathesis, by an acid-base neutralization reaction or by quaternizing a selected nitrogen-containing compound; or they may be obtained commercially from several companies such as Merck (Darmstadt, Germany) or BASF (Mount

- Olive, NJ). Representative examples of useful ionic liquids are described in sources such as Clare, Bronya, Amal Sirwardana, and Douglas R. MacFarlane. "Synthesis, purification and characterization of ionic liquids." In *Ionic Liquids*, pp. 1-40. Springer Berlin Heidelberg, 2010; Valderrama, J. O., and P. A. Robles. "Critical properties, normal boiling temperatures, and acentric factors of fifty ionic liquids." *Industrial & Engineering Chemistry Research* 46, no. 4 (2007): 1338-1344. ; Kan, Huang-Chuan, Ming-Chung Tseng, and Yen-Ho Chu. "Bicyclic imidazolium-based ionic liquids: synthesis and characterization." *Tetrahedron* 63, no. 7 (2007): 1644-1653; Tsunashima, Katsuhiko, Yuki Sakai, and Masahiko Matsumiya. "Physical and electrochemical properties of phosphonium ionic liquids derived from trimethylphosphine." *Electrochemistry Communications* 39 (2014): 30-33; Poole, Colin F., and Salwa K. Poole. "Extraction of organic compounds with room temperature ionic liquids." *Journal of Chromatography A* 1217, no. 16 (2010): 2268-2286; Rabari, Dharamashi, and Tamal Banerjee. "Biobutanol and n-propanol recovery using a low density phosphonium based ionic liquid at T= 298.15 K and p= 1atm." *Fluid Phase Equilibria* 355 (2013): 26-33; González, Begoña, and Sandra Corderí. "Capacity of two 1-butyl-1-methylpyrrolidinium-based ionic liquids for the extraction of ethanol from its mixtures with heptane and hexane." *Fluid Phase Equilibria* 354 (2013): 89-94; Lago, Sara, Héctor Rodríguez, Alberto Arce, and Ana Soto. "Improved concentration of citrus essential oil by solvent extraction with acetate ionic liquids." *Fluid Phase Equilibria* 361 (2014): 37-44.; see also Jiao, Jiao, Qing-Yan Gai, Yu-Jie Fu, Yuan-Gang Zu, Meng Luo, Wei Wang, and Chun-Jian Zhao. "Microwave-assisted ionic liquids pretreatment followed by hydro-distillation for the efficient extraction of essential oil from *Dryopteris fragrans* and evaluation of its antioxidant efficacy in sunflower oil storage." *Journal of Food Engineering* 117, no. 4 (2013): 477-485; Shiflett, Mark B., Mark A. Harmer, Christopher P. Junk, and A. Yokozeki. "Solubility and diffusivity of 1, 1, 1, 2-tetrafluoroethane in room-temperature ionic liquids." *Fluid phase equilibria* 242, no. 2 (2006): 220-232, which are incorporated herein by reference for all purposes. A library, i.e. a combinatorial library, of ionic liquids may be prepared, for example, by preparing various alkyl derivatives of the quaternary ammonium cation, and varying the associated anions. The acidity of the ionic liquids can be adjusted by varying the molar equivalents and type and combinations of Lewis acids.
- [0085]** The term "non-ideal mixture" or "non-ideal fluid" refers to a fluid mixture wherein the enthalpy of mixing is non-zero and the volume change upon mixing is non-zero. In

embodiments, a non-ideal mixture displays a vapor pressure lower than expected from Raoult's law (negative deviation), which may be evidence of adhesive forces between different components of the mixture being stronger than the average cohesive forces between the like components. When cohesive forces between like components are stronger than between
5 different components, the vapor pressure is greater than expected from Raoult's law (positive deviation).

[0086] The term "supercritical fluid" refers to any substance at a temperature and pressure above its critical point, where distinct liquid and gas phases as conventionally defined do not exist. Supercritical fluids can effuse through solids like a gas, and dissolve materials like a
10 liquid.

[0087] The term "essential oil" refers to a concentrated liquid (e.g., hydrophobic liquid) containing volatile aroma compounds from plants. Essential oils may also be called volatile oils, ethereal oils, aetherolea, or simply as the oil of the plant from which they were extracted, such as oil of clove. An oil is "essential" in the sense that it contains the "essence of" the plant's
15 fragrance - the characteristic fragrance of the plant from which it is derived.

[0088] The term "aromatic oil" or "aroma oil" refers to an oil contained in certain plants that is a complex substance containing a large number of individual compounds, some of which are relatively volatile or relatively thermally unstable (e.g., relative to a control or relative to the average volatility or thermal stability of the compounds in the oil or in the plant or of a similar
20 size).

[0089] The term "natural" as used for "natural product," "natural organic compound" and "natural compound" refers to something that is found in, or isolated from, nature (e.g., natural material) and is not itself synthetic, artificial, and/or man-made. A "natural product" is a molecule, compound, or substance that is produced by a living organism, e.g., is found in nature.
25 In embodiments, natural products are isolated from natural sources (e.g., natural materials) that are produced by pathways of primary and secondary metabolism. In embodiments, natural products are isolated from natural sources (e.g., natural materials) that are produced where expression of the product is influenced artificially. In embodiments, natural products are isolated from natural sources (e.g., natural materials) that are produced through over-expression of the
30 natural product. In embodiments, the natural product is derived from a natural material. A

“natural organic compound” is an organic (carbon-containing chemical) compound isolated from a natural source (e.g., natural material). In embodiments, a natural organic compound is isolated from natural sources (e.g., natural materials) including plants, animals, fungi, viruses, and bacteria. In embodiments, natural organic compounds are isolated from natural sources (e.g., natural materials) that have been genetically modified or engineered, including plants, animals, fungi, viruses, and bacteria. In embodiments, natural organic compounds are isolated from natural sources (e.g., natural materials) through extraction. In embodiments, natural organic compounds are isolated from natural sources (e.g., natural materials) through extraction methods as described herein. In embodiments, a natural organic compound is derived from a natural material.

[0090] “Natural material” as referred to herein is a material derived from plants, animals, fungi, bacteria, or viruses. In embodiments, a natural material is derived from plants, animals, fungi, bacteria, or viruses that are found in nature (e.g., not itself synthetic, artificial, and/or man-made). In embodiments, a natural material is derived from plants, animals, fungi, bacteria, or viruses that have been artificially influenced. For example, the plant, animal, fungus, bacterium, or virus, may be artificially influenced (e.g., genetically modified) to induce desirable properties in the organism. Genetic modifications may include modifications to over-express, under-express, or prevent expression of compounds (e.g., chemicals, proteins, nucleic acids) or express exogenous compounds (e.g., chemicals, proteins, nucleic acids not typically found in the organism) that increase or decrease levels of a natural product or a natural organic compound. For example, a natural material may be derived from a cannabis plant genetically modified to produce levels (e.g., concentrations) of THC (e.g., a natural organic compound) greater than levels (e.g., concentrations) produced in the absence of the genetic modification. Thus, in embodiments, a natural material is derived from plants, animals, fungi, bacteria, or viruses that have been genetically modified. In embodiments, the genetic modification increases production of a natural organic compound. In embodiments, genetic modification increases production of a natural product. In embodiments, the natural material includes fiber, stalk, cob, skin, peel, coir, husk, hull, pulp, shell, leaf, baste/stem, straw, root, seed, pod, bean, or oil of a plant.

[0091] The term “derived” as used herein refers to any method suitable for obtaining a desired natural material. For example, a natural material may be isolated, purified, solubilized, or

extracted from a plant, animal, fungus, bacteria, or virus. In embodiments, the natural material is isolated from a plant, animal, fungus, bacteria, or virus. In embodiments, the natural material is purified from a plant, animal, fungus, bacterium, or virus. In embodiments, the natural material is solubilized from a plant, animal, fungus, bacterium, or virus. In embodiments, the natural material is extracted from a plant, animal, fungus, bacterium, or virus. In embodiments, the natural material is extracted from a plant, animal, fungus, bacterium, or virus using a method as described herein.

[0092] The term “flavonoid” (or bioflavonoid) refers to a class of plant and fungus secondary metabolites. Flavonoids have the general structure of a 15-carbon skeleton, which includes two phenyl rings and a heterocyclic ring. Flavonoids may be classified as flavonoids (or bioflavonoids), isoflavonoids (derived from 3-phenylchromen-4-one (3-phenyl-1,4-benzopyrone) structure), or neoflavonoids (derived from 4-phenylcoumarine (4-phenyl-1,2-benzopyrone) structure). The term “prenylflavonoid” (or prenylated flavonoids) refers to a subclass of flavonoids. Chemically, they have a prenyl group attached to the flavonoid backbone.

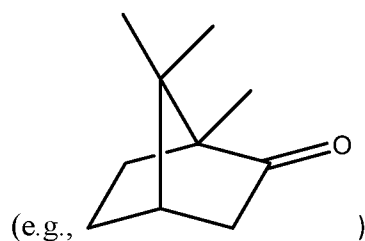
[0093] The term “kavalactone” refers to a class of lactone compounds found in the kava plant. In embodiments, kavalactones possess a wide variety of pharmacological effects including analgesic, anticonvulsant, amnestic, nootropic, and sedative activity.

[0094] The term “salvorin” refers to a terpenoid with psychotropic properties found in the *Salvia divinorum* plant.

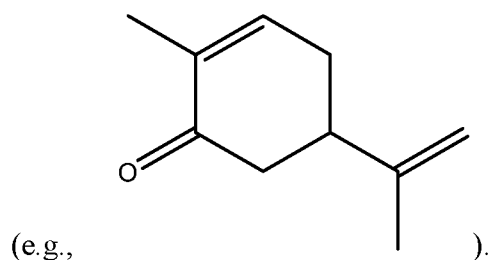
[0095] The term “terpene” refers to a large class of hydrocarbon organic compound found in a variety of plants, including conifers, and some insects, such as termites and swallowtail butterflies. Terpenes are derived biosynthetically from units of isoprene, which has the molecular formula C_5H_8 . The basic molecular formulae of terpenes are multiples of that, $(C_5H_8)_n$ where n is the number of linked isoprene units. This is called the isoprene rule or the C5 rule.

Terpenes are the primary constituents of the essential oils of many flowers and plants. Terpenes may include monoterpenes, diterpenes, sesquiterpenes, triterpenes, sesterterpenes, norterpenes, nortriterpenes, and norsesquiterpenes. Diterpenes refers to diterpene acids, esters, alkaloids (such as indolo-terpenes) which are composed of two isoprene units.

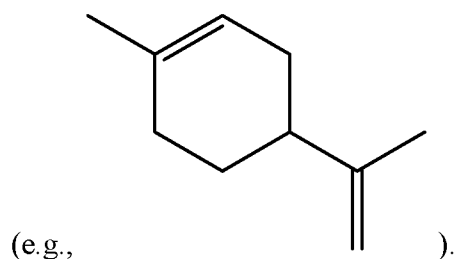
[0096] In embodiments, the terpene is a camphor or a derivative, analog, or prodrug thereof



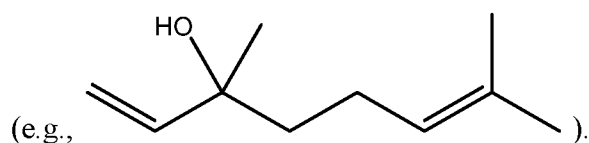
[0097] In embodiments, the terpene is a carvone or a derivative, analog, or prodrug thereof



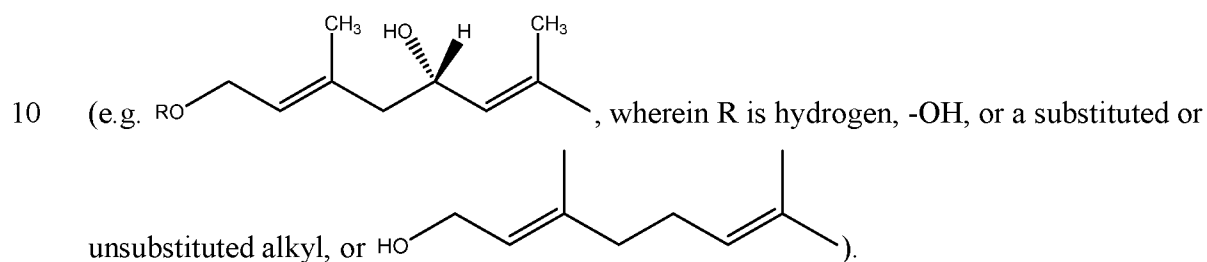
5 [0098] In embodiments, the terpene is a limonene or a derivative, analog, or prodrug thereof



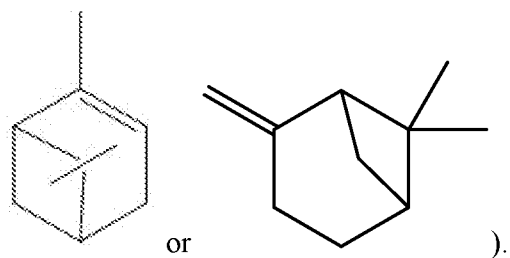
[0099] In embodiments, the terpene is a linalool or a derivative, analog, or prodrug thereof



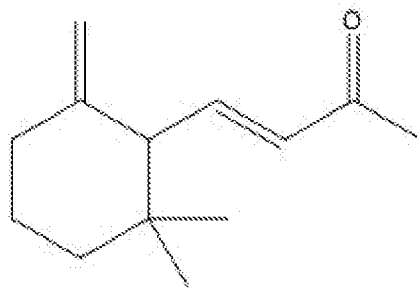
[0100] In embodiments, the terpene is a geraniol or a derivative, analog, or prodrug thereof



[0101] In embodiments, the terpene is a pinene or a derivative, analog, or prodrug thereof (e.g.

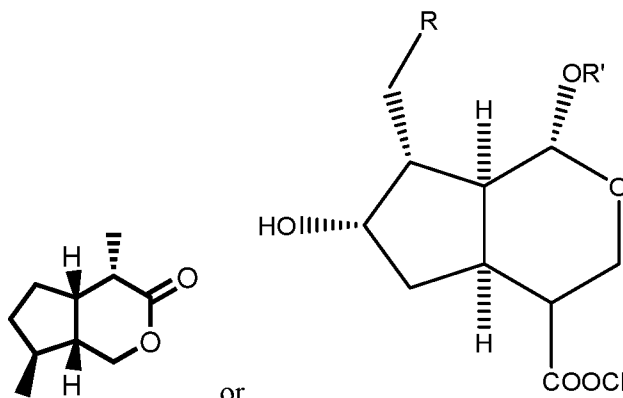


[0102] In embodiments, the terpene is a ionone (e.g., alpha-ionone, beta-ionone, or gamma-



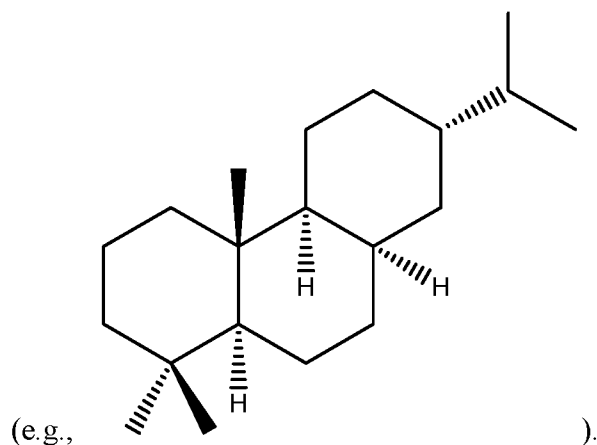
ionone) or a derivative, analog, or prodrug thereof (e.g.,).

5 [0103] In embodiments, the terpene is a iridoid (e.g., cyclopentanopyran) or a derivative,

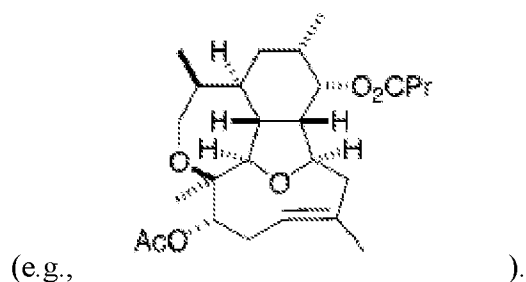


analog, or prodrug thereof (e.g., , or COOCH_3 , where R and R' are each independently hydrogen, -OH, or a substituted or unsubstituted alkyl).

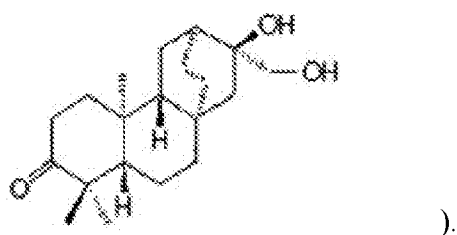
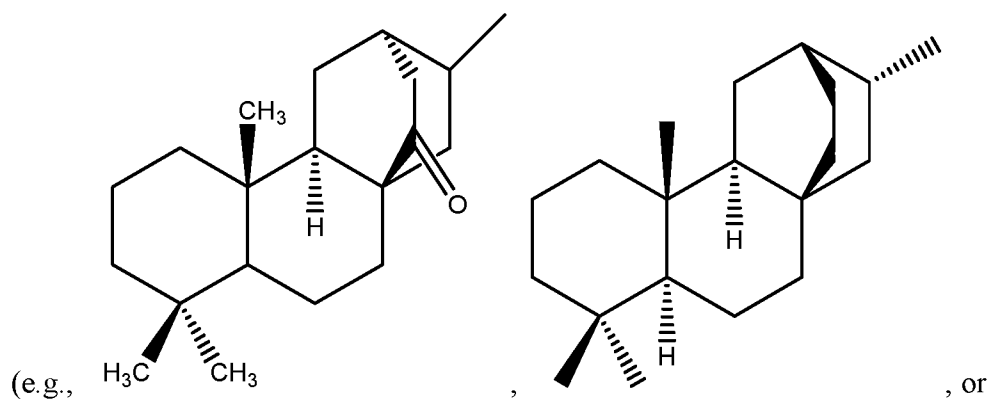
[0104] In embodiments, the terpene is an abietane or a derivative, analog, or prodrug thereof



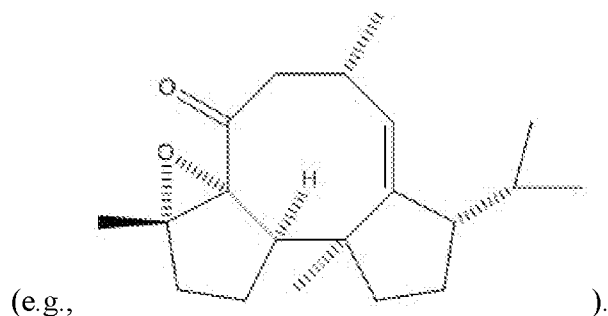
[0105] In embodiments, the terpene is an absentinin or a derivative, analog, or prodrug thereof



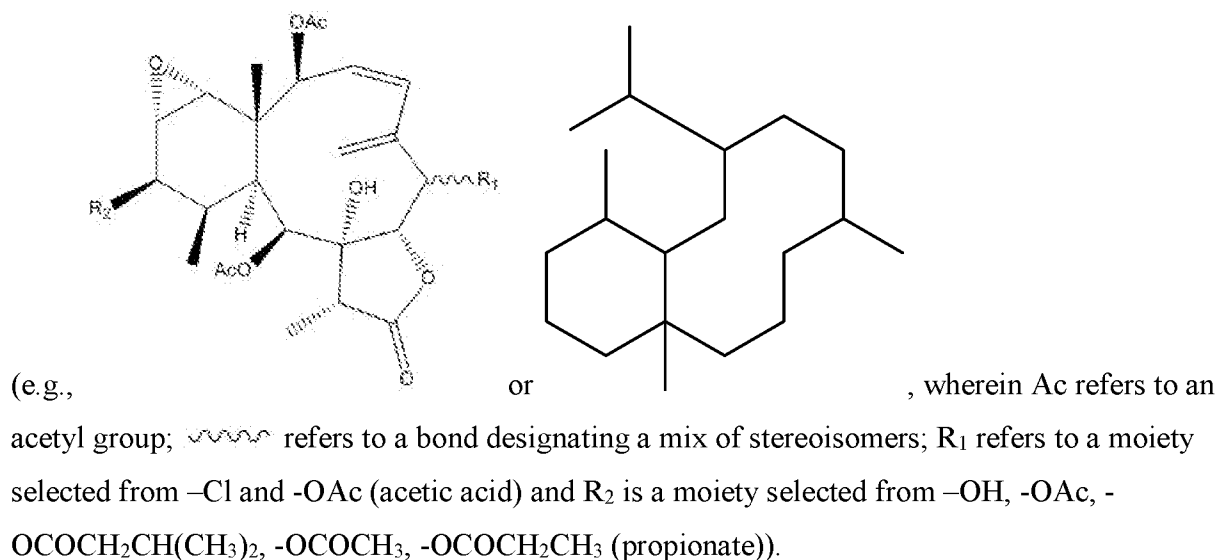
5 [0106] In embodiments, the terpene is an atisane or a derivative, analog, or prodrug thereof



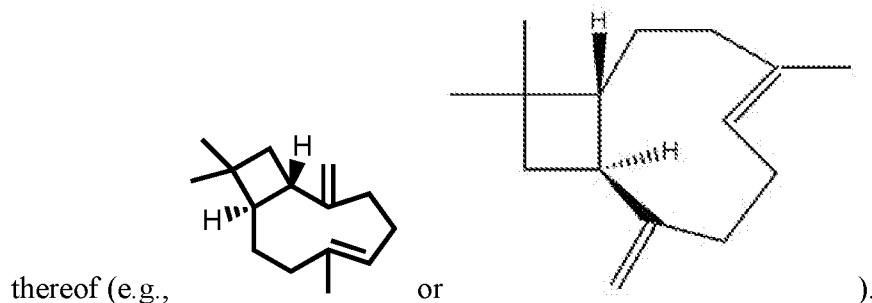
[0107] In embodiments, the terpene is a basmane or a derivative, analog, or prodrug thereof



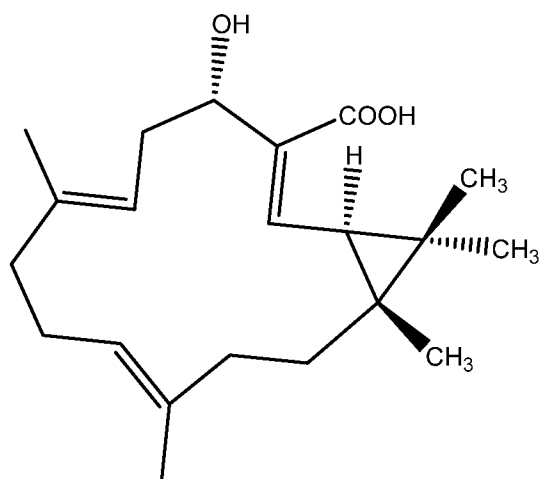
[0108] In embodiments, the terpene is a briarane or a derivative, analog, or prodrug thereof



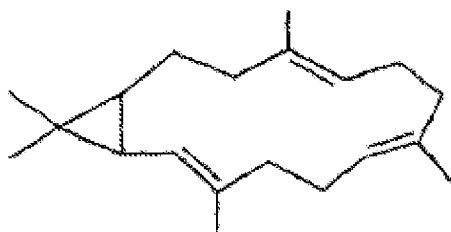
[0109] In embodiments, the terpene is a carophyllene or a derivative, analog, or prodrug



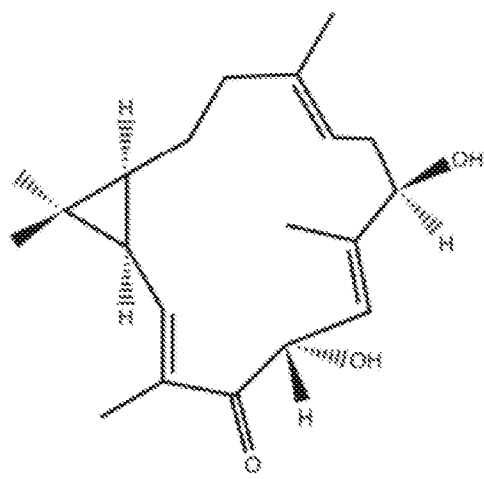
[0110] In embodiments, the terpene is a casbane or a derivative, analog, or prodrug thereof



(e.g.



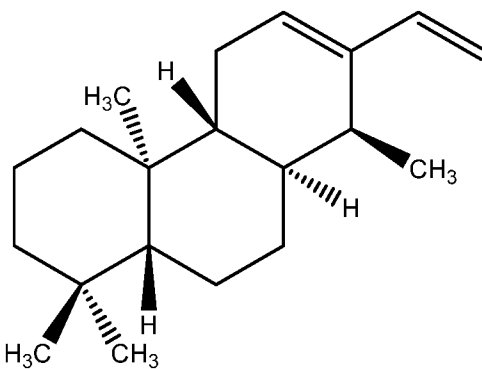
or



).

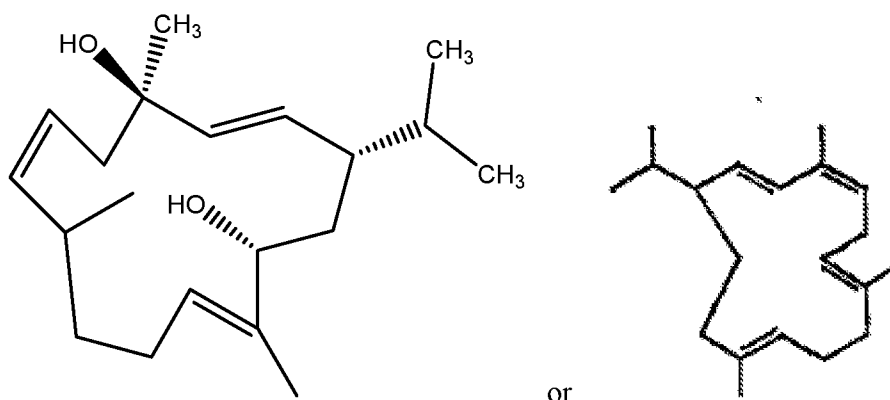
- 5 [0111] In embodiments, the terpene is a cassane or a derivative (e.g., 3 β -hydroxyphanginin H, 3 β -acetoxyphanginin H, 7 β -acetoxyphanginin H, 7 β -hydroxyphanginin H, 4-epi-3 β -

hydroxycaesalpinilinn, 4-epi-3 β -acetoxycasalpinilinn, 20-acetoxytapeenin D, or tomocin E),



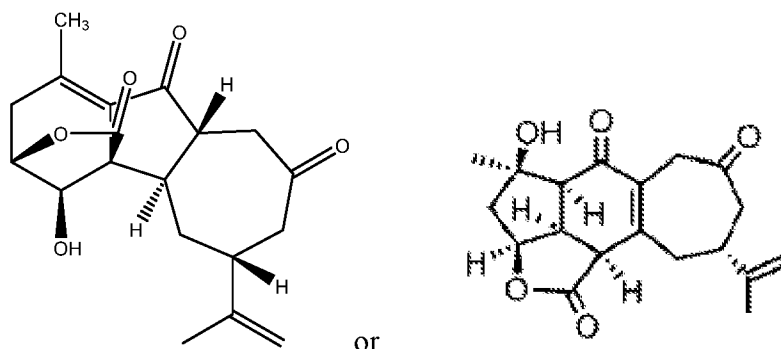
analog, or prodrug thereof (e.g. ).

[0112] In embodiments, the terpene is a cembranoid or a derivative, analog, or prodrug thereof



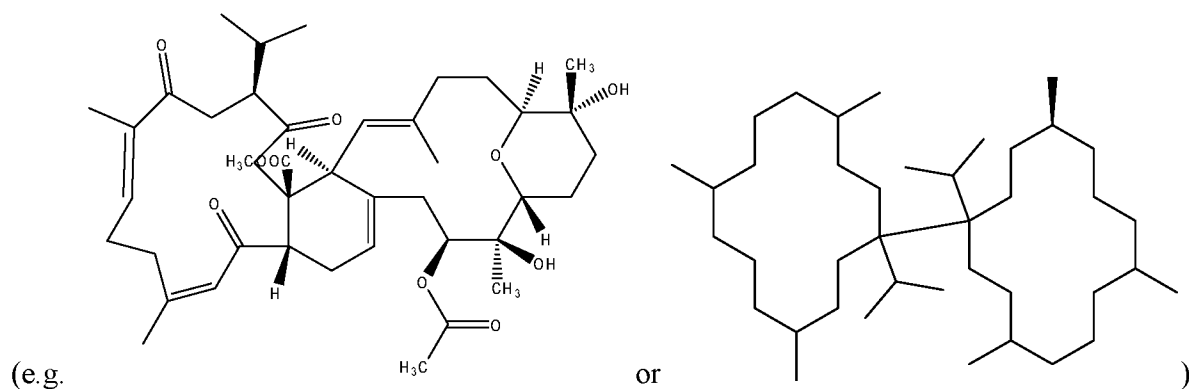
(e.g.,  or ).

5 [0113] In embodiments, the terpene is a norcembranoid or a derivative, analog, or prodrug

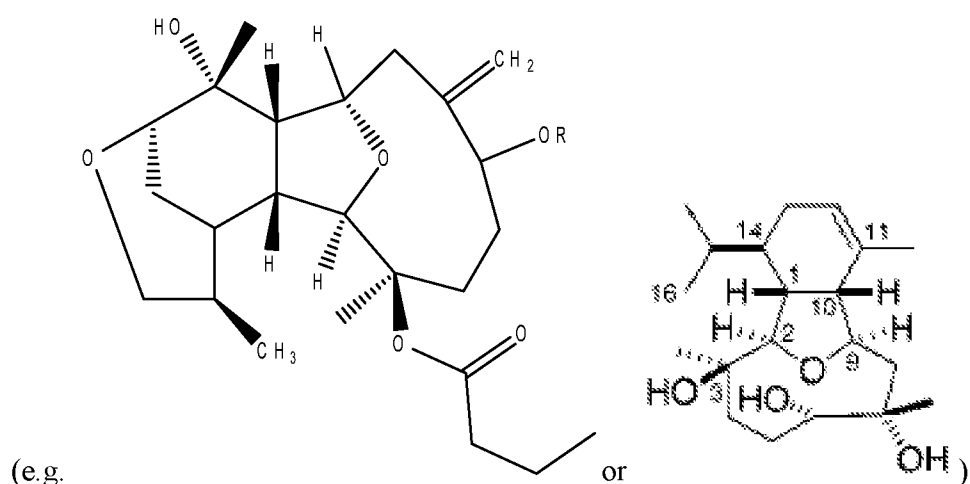


thereof (e.g.  or ).

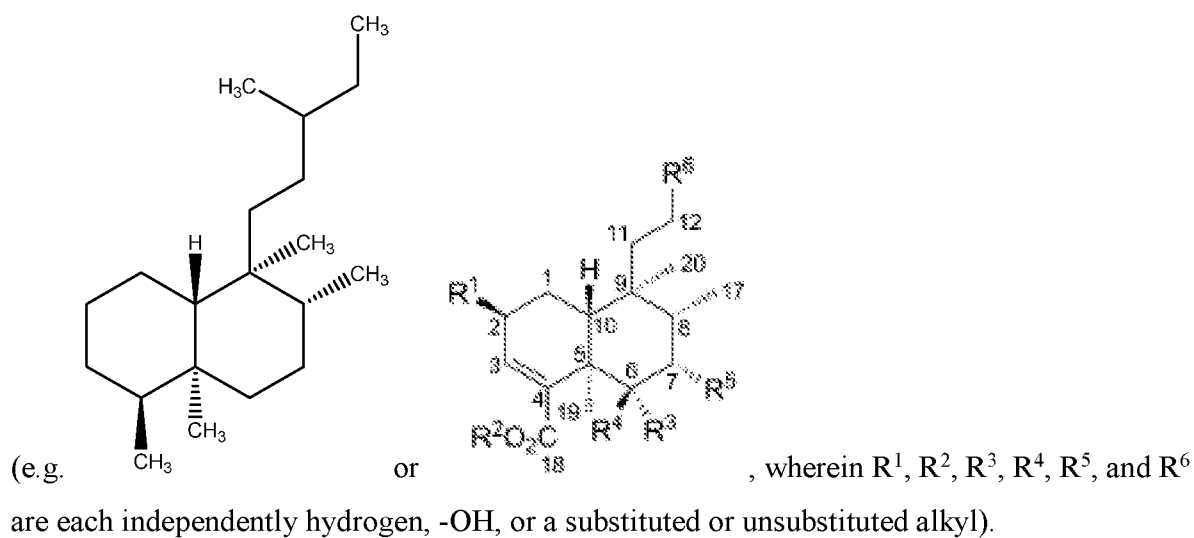
[0114] In embodiments, the terpene is a bicembrane or a derivative, analog, or prodrug thereof



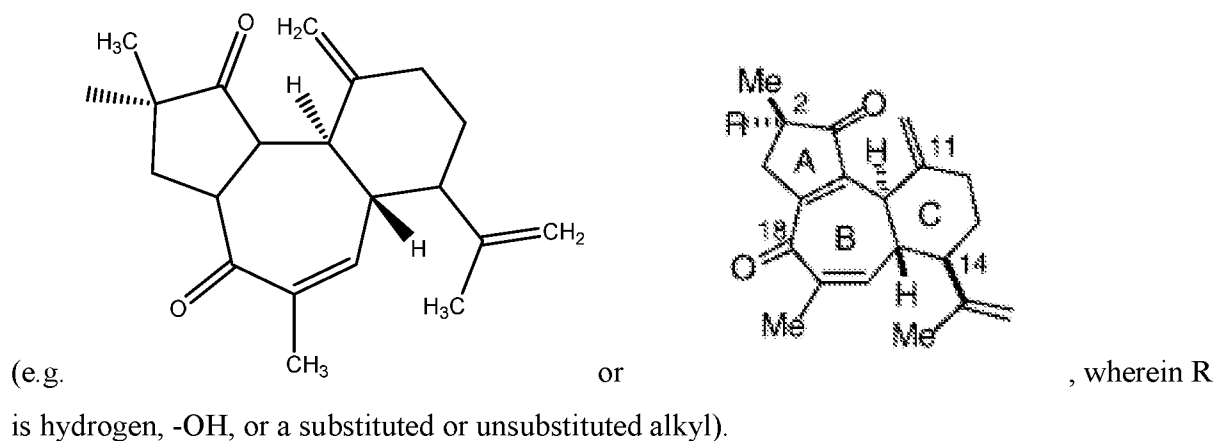
[0115] In embodiments, the terpene is a cladiellane or a derivative, analog, or prodrug thereof



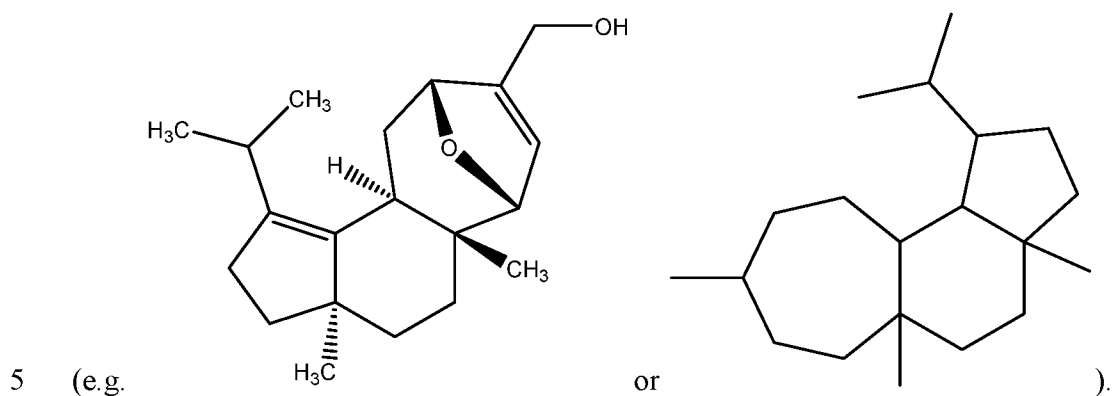
5 [0116] In embodiments, the terpene is a clerodane or a derivative, analog, or prodrug thereof



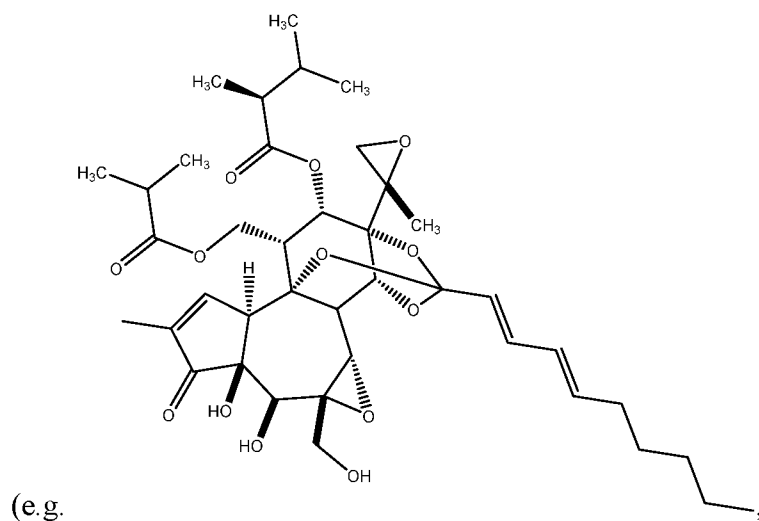
[0117] In embodiments, the terpene is a curcusone or a derivative, analog, or prodrug thereof

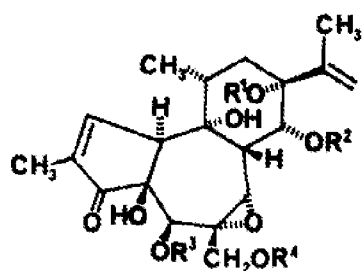


[0118] In embodiments, the terpene is a cyathane or a derivative, analog, or prodrug thereof

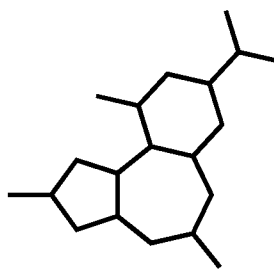


[0119] In embodiments, the terpene is a daphnane or a derivative, analog, or prodrug thereof





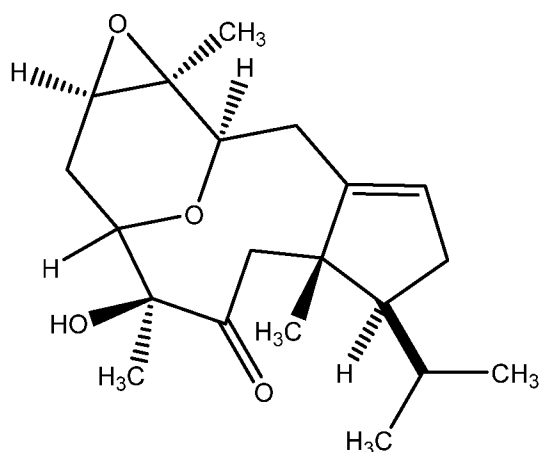
, or



wherein, the R groups

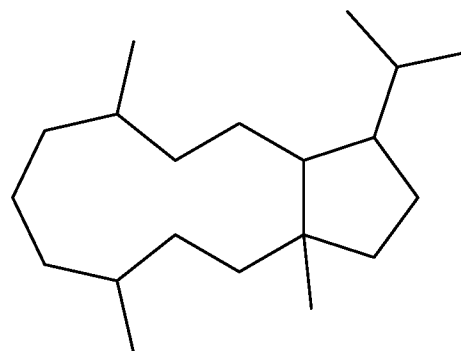
are hydrogen, a substituent group, a size limited substituent group, or a lower substituent group).

[0120] In embodiments, the terpene is a dolabellane or a derivative, analog, or prodrug thereof



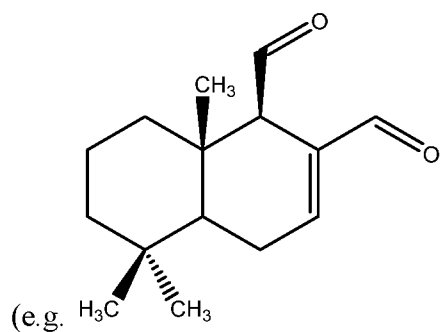
(e.g.

or

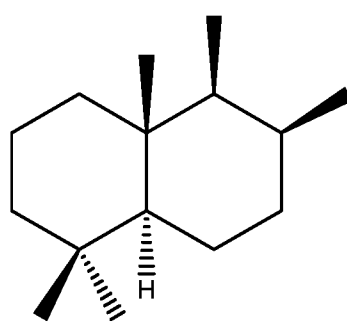


,).

5 [0121] In embodiments, the terpene is a drimane or a derivative, analog, or prodrug thereof

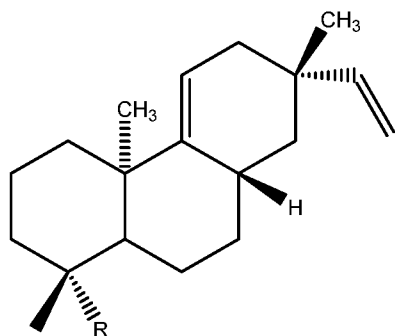
(e.g. H₃C CH₃

or



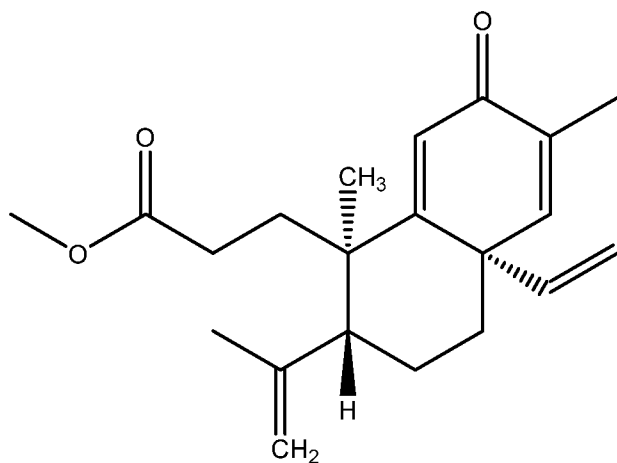
).

[0122] In embodiments, the terpene is a pimane or a derivative, analog, or prodrug thereof (e.g.



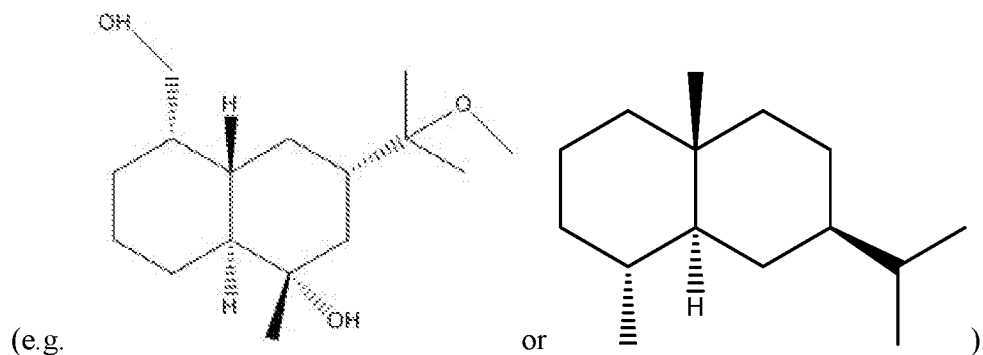
, wherein R is a moiety selected from $-H$, $-OH$, $-CH_2OH$, $-CO_2CH_3$, $-CHO$, $-CH_2OAc$, $-COOH$, and $-CH_3$).

[0123] In embodiments, the terpene is a ent-pimane or a derivative, analog, or prodrug thereof

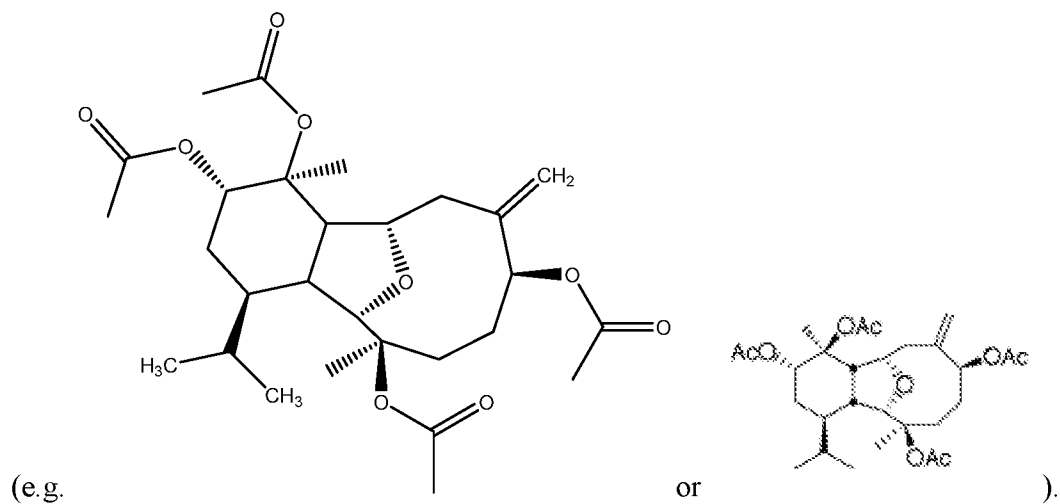


5 (e.g.).

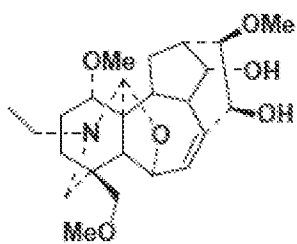
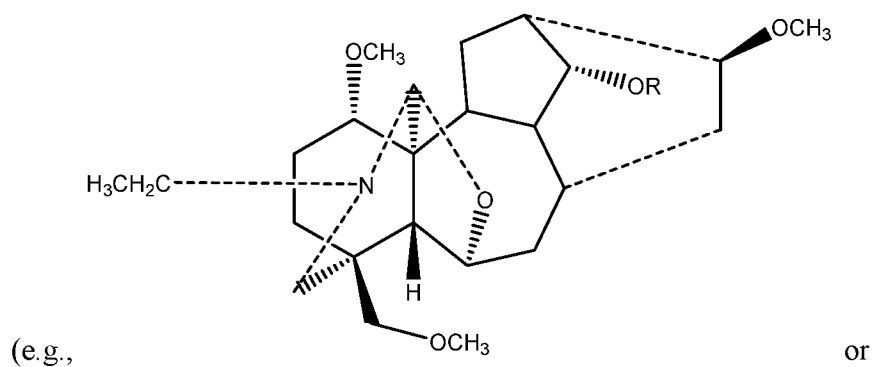
[0124] In embodiments, the terpene is a eudesmane or a derivative, analog, or prodrug thereof



[0125] In embodiments, the terpene is a eunicellin or a derivative, analog, or prodrug thereof

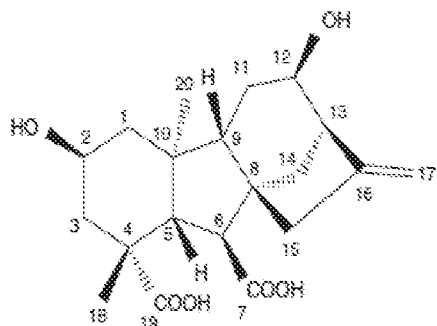


[0126] In embodiments, the terpene is a franchetine or a derivative, analog, or prodrug thereof



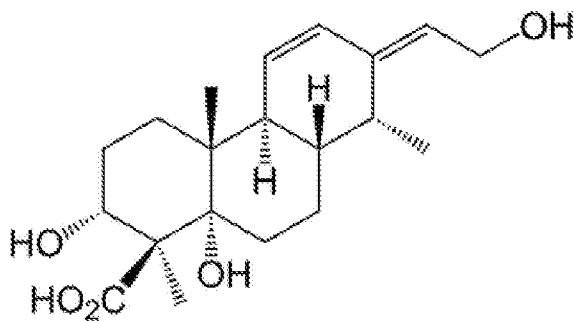
, wherein R represents a benzyl group).

[0127] In embodiments, the terpene is a gibberelin or a derivative, analog, or prodrug thereof

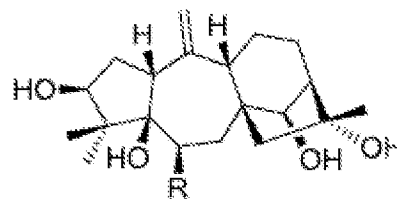


(e.g.,).

[0128] In embodiments, the terpene is a grayane or a derivative, analog, or prodrug thereof



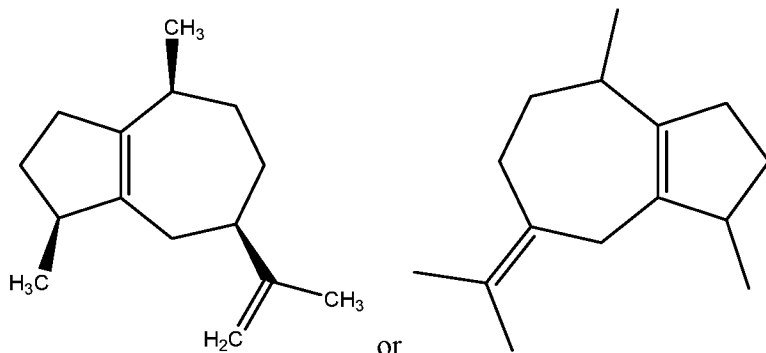
(e.g., or



,

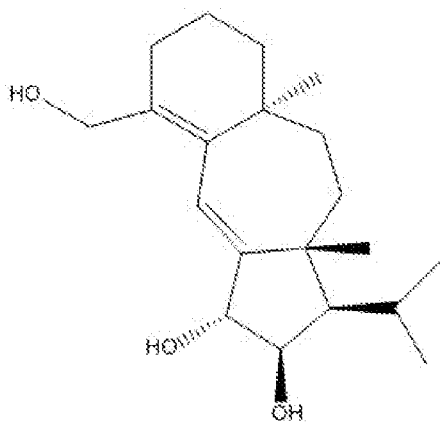
5 wherein the R group is hydrogen, a substituent group, a size limited substituent group, or a lower substituent group).

[0129] In embodiments, the terpene is a guaiene or a derivative, analog, or prodrug thereof



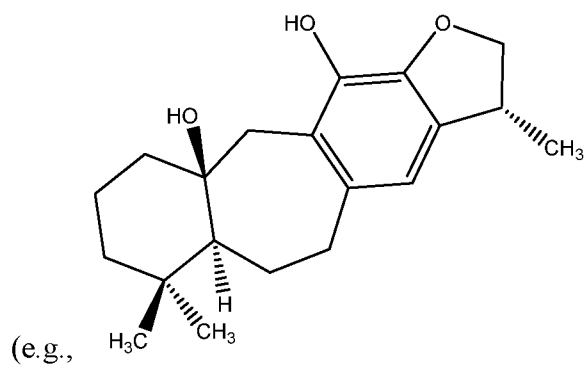
(e.g., or).

[0130] In embodiments, the terpene is a guanacastane or a derivative, analog, or prodrug



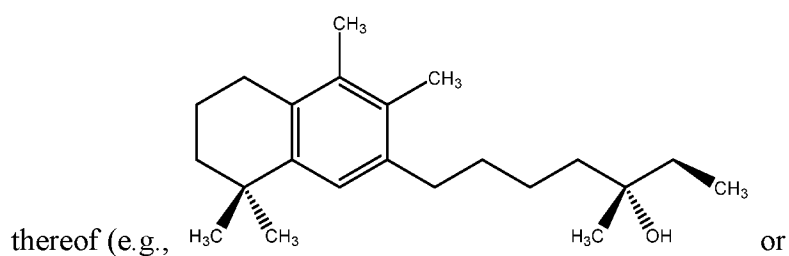
thereof (e.g.,).

[0131] In embodiments, the terpene is a icetaxane or a derivative, analog, or prodrug thereof

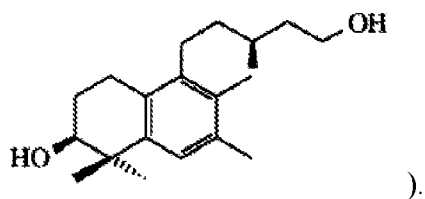


(e.g.,).

5 [0132] In embodiments, the terpene is a isofregenedane or a derivative, analog, or prodrug

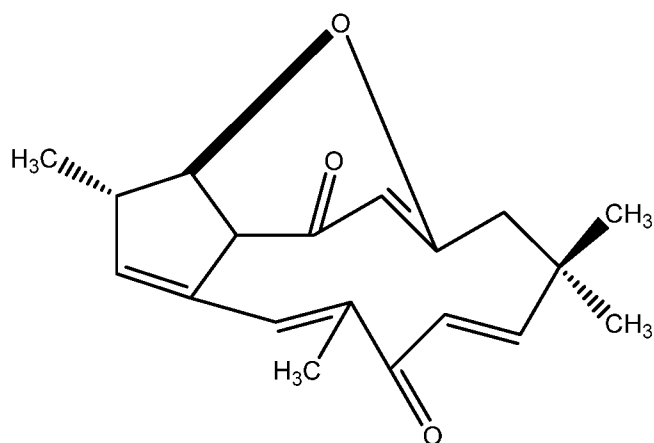


thereof (e.g., or



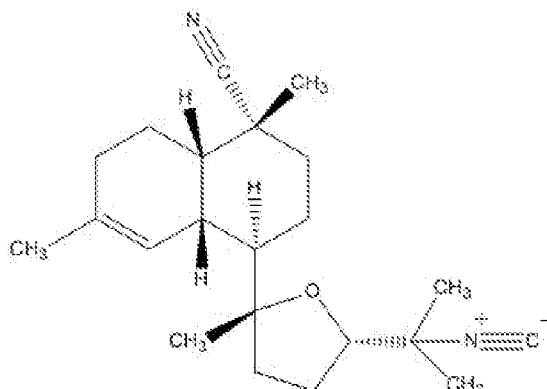
).

[0133] In embodiments, the terpene is a jatrophane or a derivative, analog, or prodrug thereof



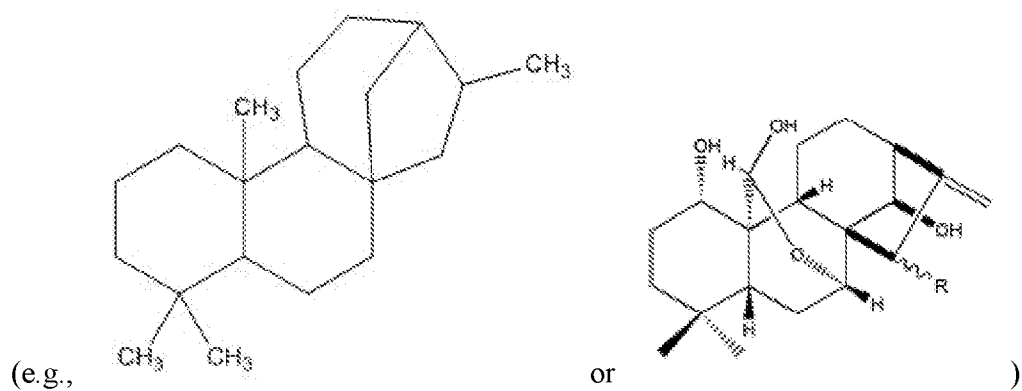
(e.g.).

[0134] In embodiments, the terpene is a kalihinene or a derivative, analog, or prodrug thereof

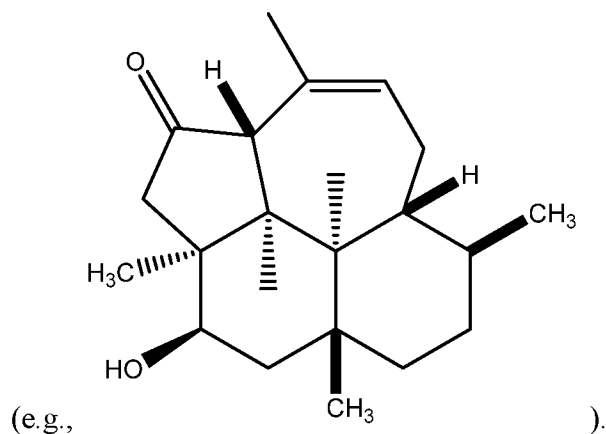


(e.g.,).

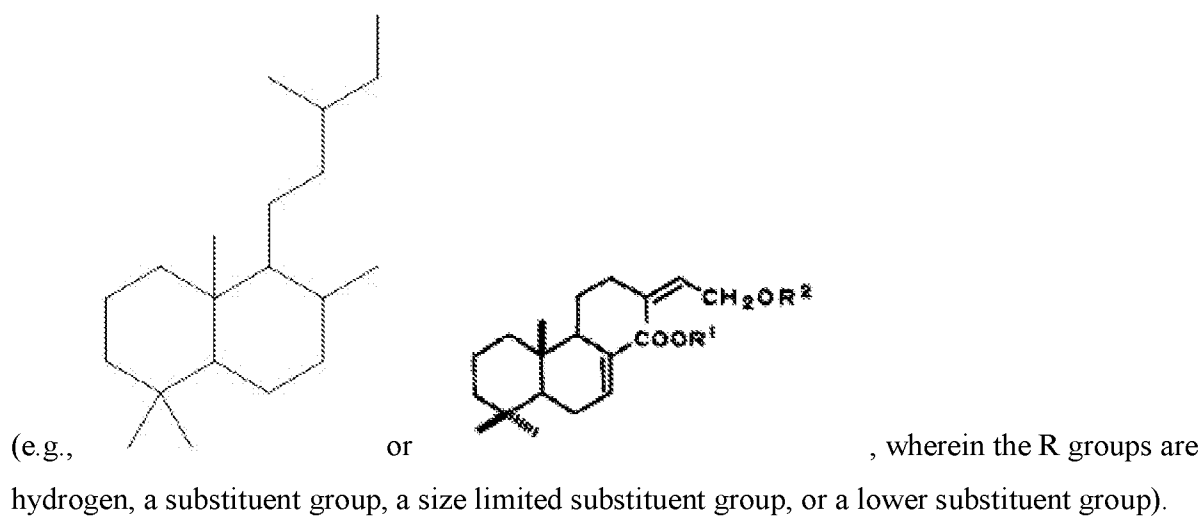
5 [0135] In embodiments, the terpene is a kaurane or a derivative, analog, or prodrug thereof



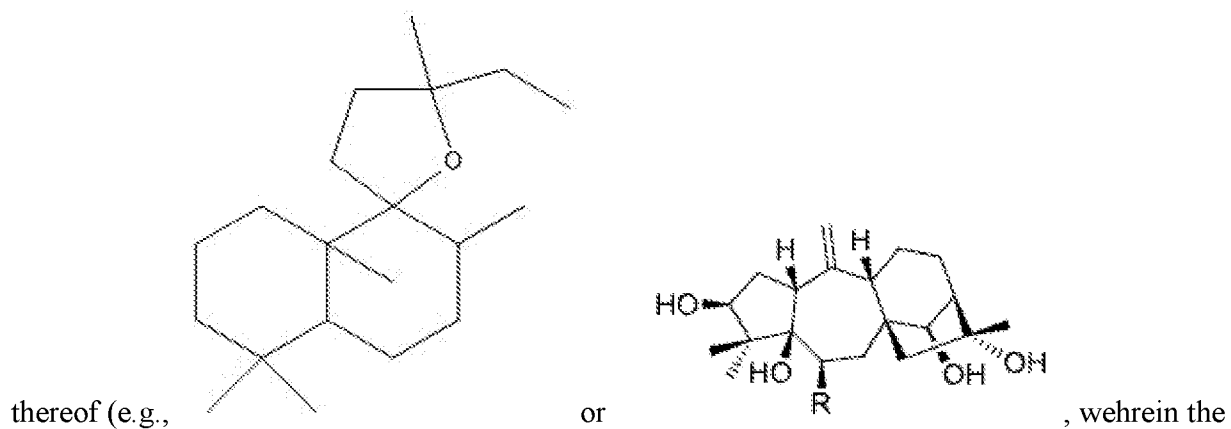
[0136] In embodiments, the terpene is a kempene or a derivative, analog, or prodrug thereof



[0137] In embodiments, the terpene is a labdane or a derivative, analog, or prodrug thereof

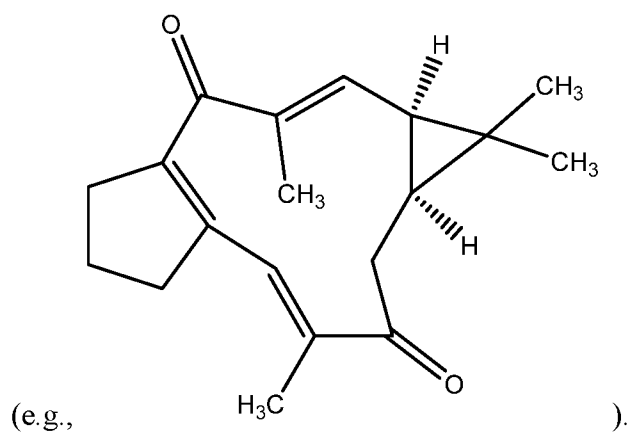


[0138] In embodiments, the terpene is a grindelane labdane or a derivative, analog, or prodrug

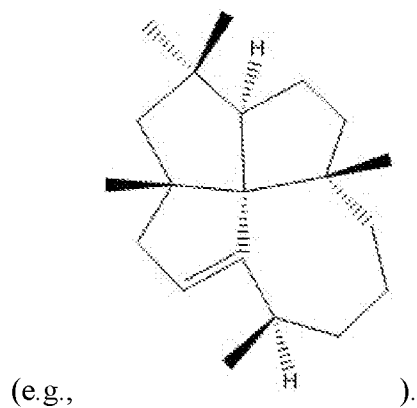


R groups are hydrogen, a substituent group, a size limited substituent group, or a lower substituent group).

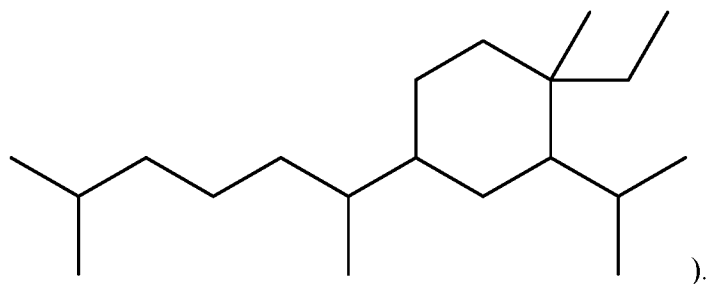
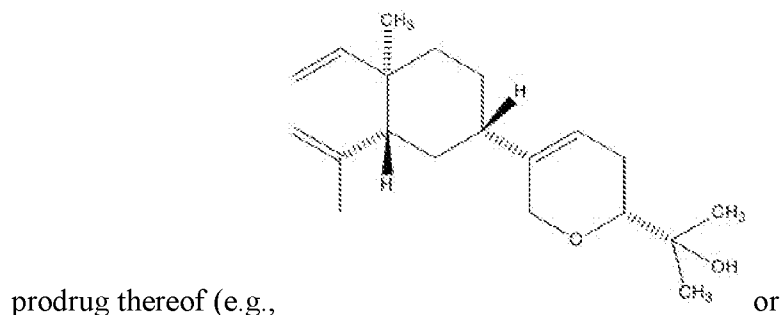
[0139] In embodiments, the terpene is a lathyrane or a derivative, analog, or prodrug thereof



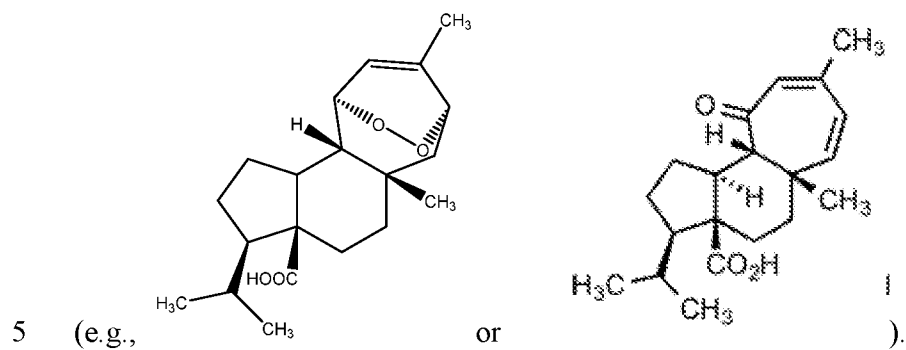
5 [0140] In embodiments, the terpene is a laurenene or a derivative, analog, or prodrug thereof



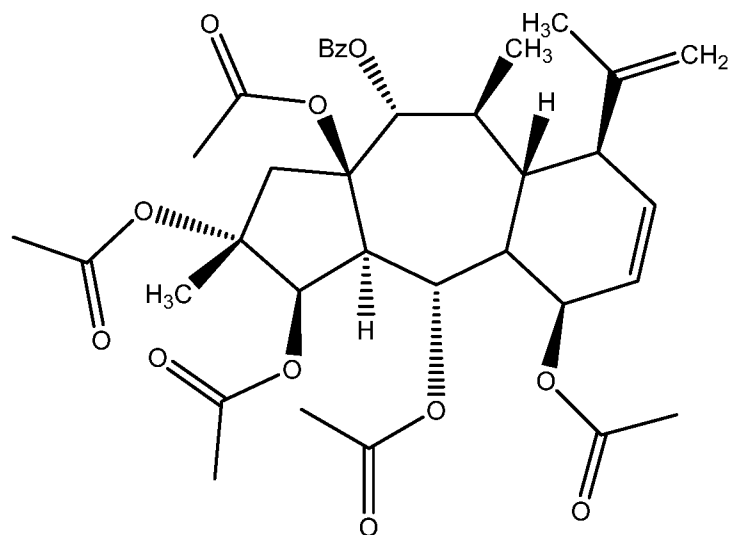
[0141] In embodiments, the terpene is a lobane (e.g., lobatriene) or a derivative, analog, or



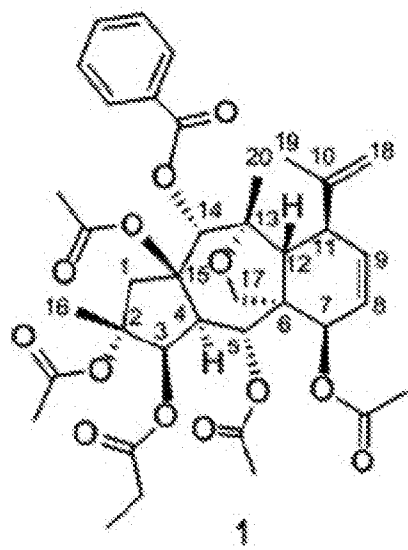
[0142] In embodiments, the terpene is a mulinane or a derivative, analog, or prodrug thereof



[0143] In embodiments, the terpene is a myrsinol or a derivative, analog, or prodrug thereof (e.g.,

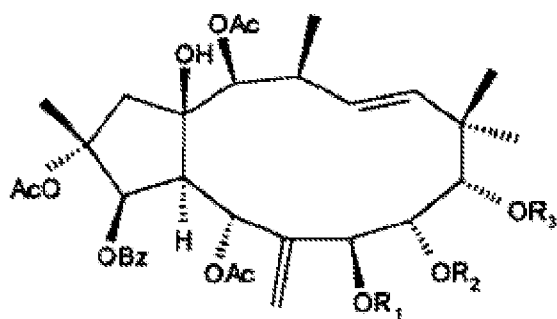
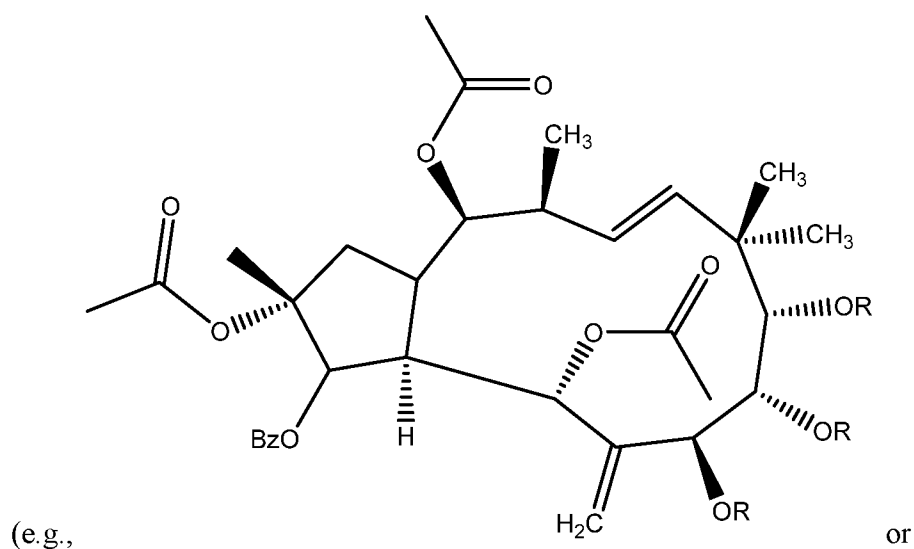


or



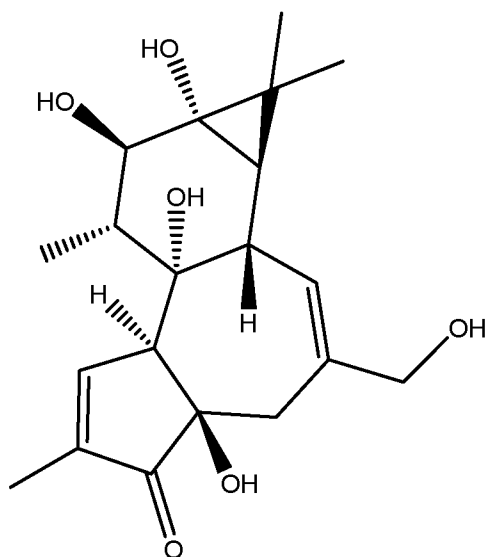
).

[0144] In embodiments, the terpene is a pepluane or a derivative, analog, or prodrug thereof



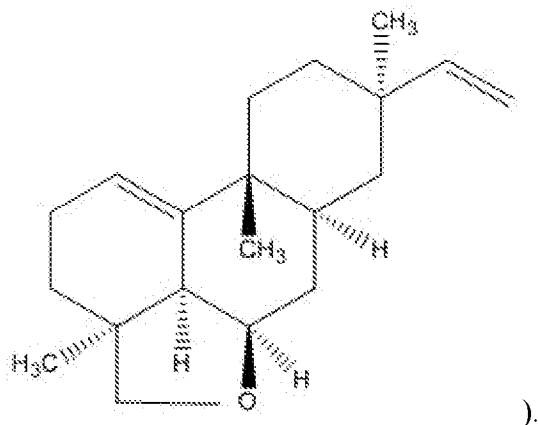
, wherein the R groups are hydrogen, a substituent group, a size limited substituent group, or a lower substituent group).

[0145] In embodiments, the terpene is a phorbol or a derivative, analog, or prodrug thereof



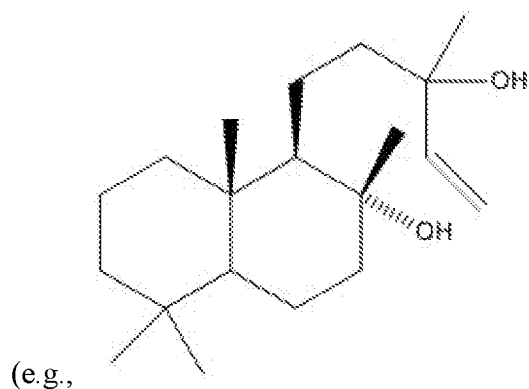
(e.g., phorbol).

[0146] In embodiments, the terpene is a rosane or a derivative, analog, or prodrug thereof (e.g.,



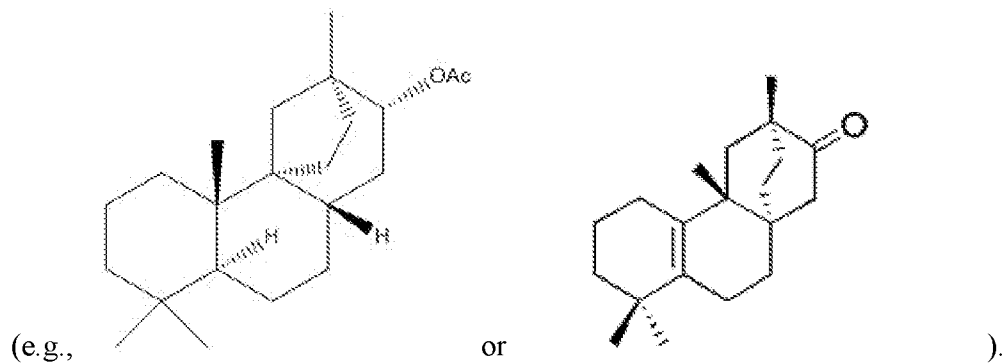
).

5 [0147] In embodiments, the terpene is a sclaeol or a derivative, analog, or prodrug thereof

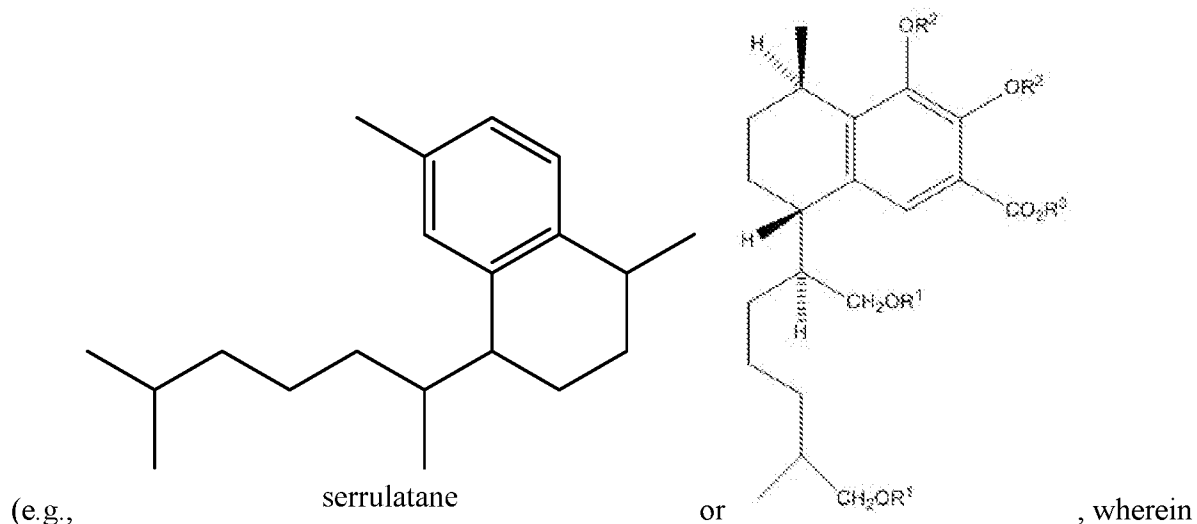


(e.g.,).

[0148] In embodiments, the terpene is a scopadulane or a derivative, analog, or prodrug thereof



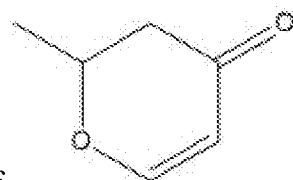
[0149] In embodiments, the terpene is a serrulatane or a derivative, analog, or prodrug thereof



5 R^1 is selected from -H, -OH, -N, -NH, -NOH, -CH₃,

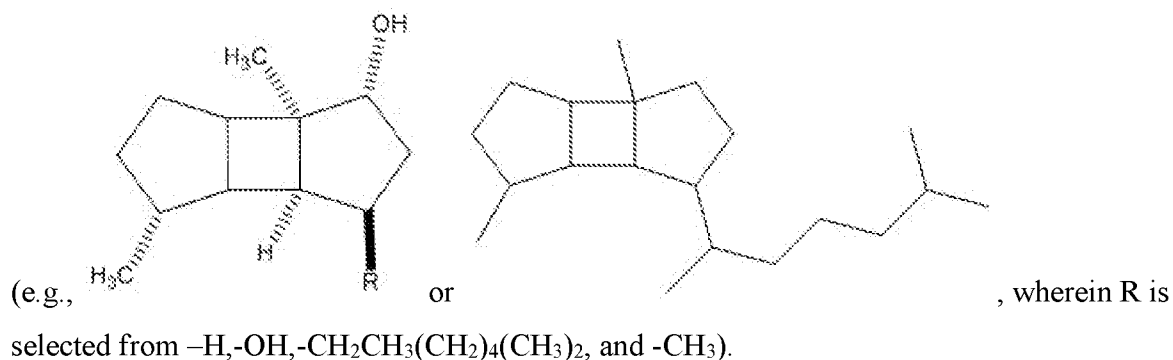
-CO-heteroaryl, -CH₂OCOC₄H₉N₂, -CNOH, -CH₂, and a moiety of

R^2 is selected from -H, -NO₂, -CH₃, and halogen).

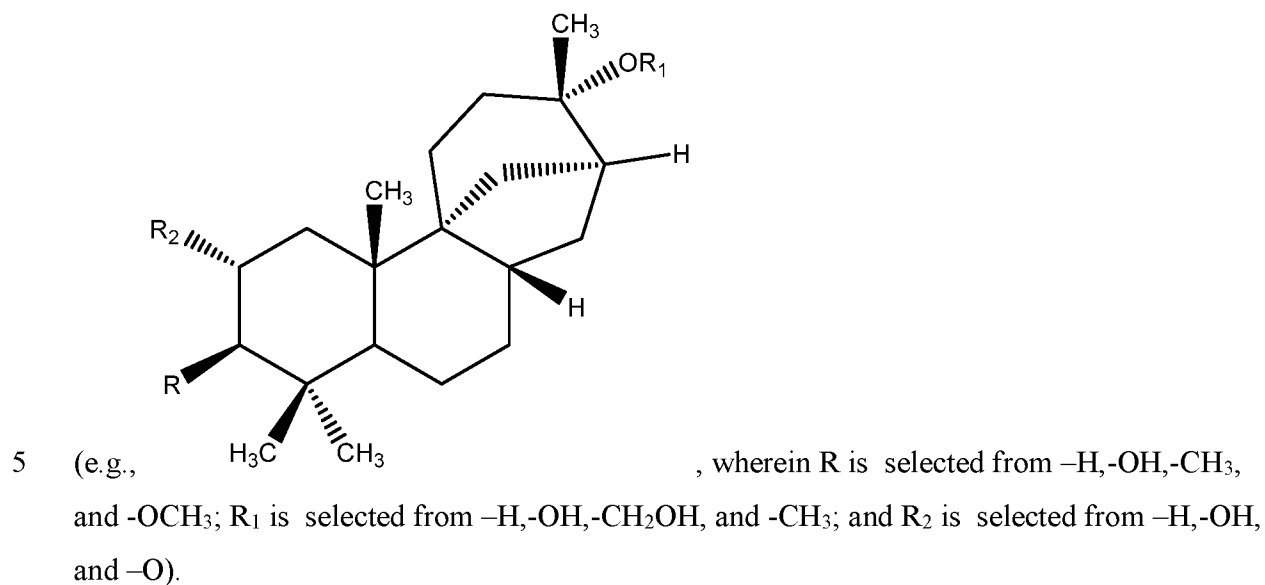


and

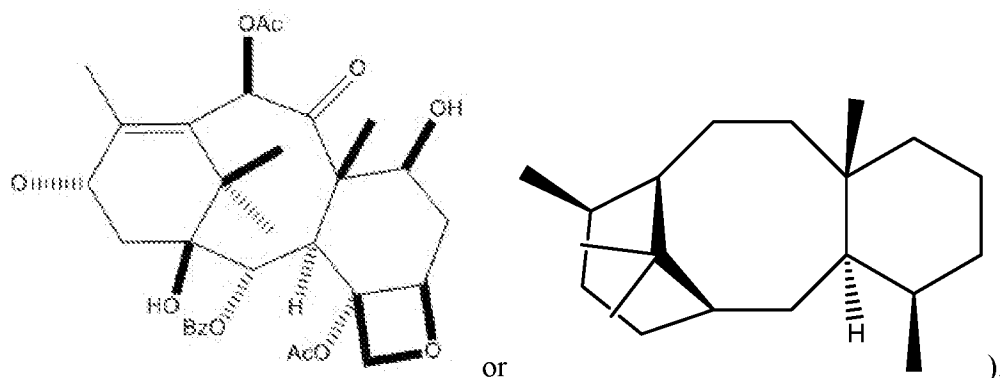
[0150] In embodiments, the terpene is a spatane or a derivative, analog, or prodrug thereof



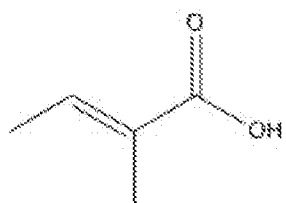
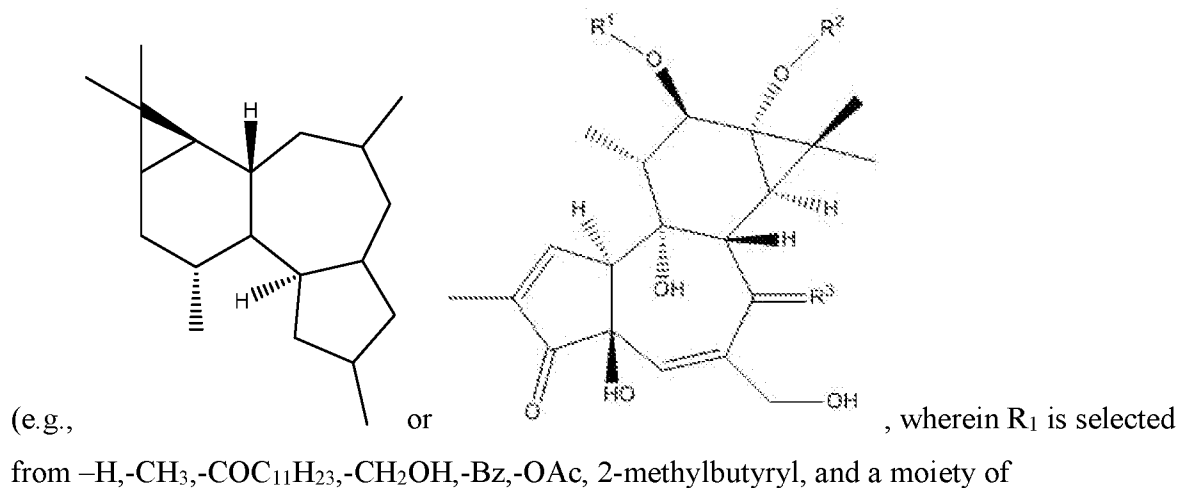
[0151] In embodiments, the terpene is a stemodane or a derivative, analog, or prodrug thereof



[0152] In embodiments, the terpene is a taxane or a derivative, analog, or prodrug thereof (e.g.,

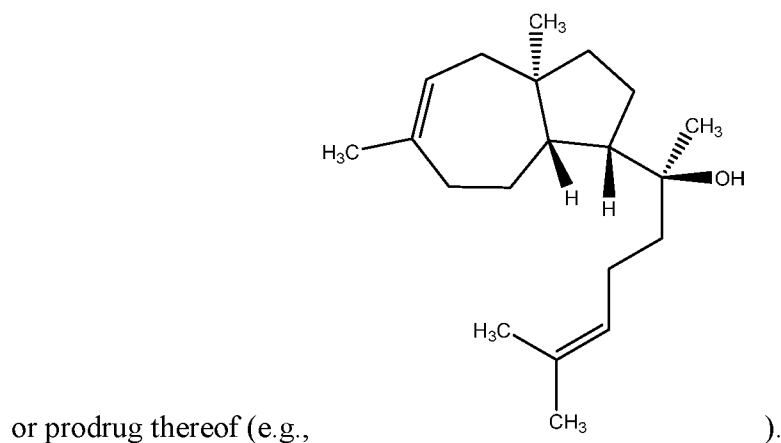


[0153] In embodiments, the terpene is a tigliane or a derivative, analog, or prodrug thereof

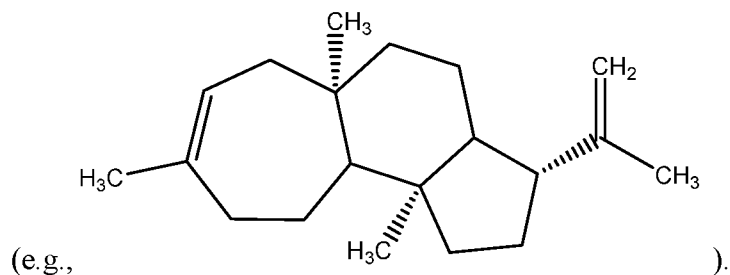


5 ; R₂ is selected from -CH₃, -COCH₃, -Bz, -OAc, isobutyryl, and 2-methylbutyryl; and R₃ is selected from -O, and -CH₂).

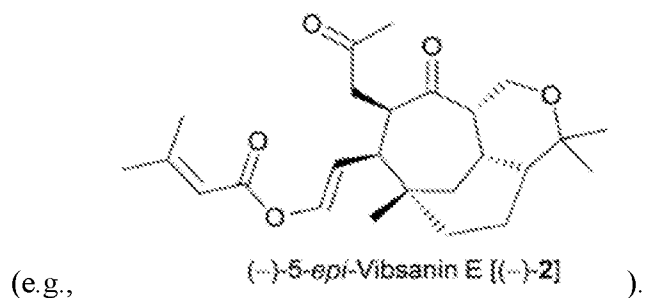
[0154] In embodiments, the terpene is a torsesane (e.g., torsesolane) or a derivative, analog,



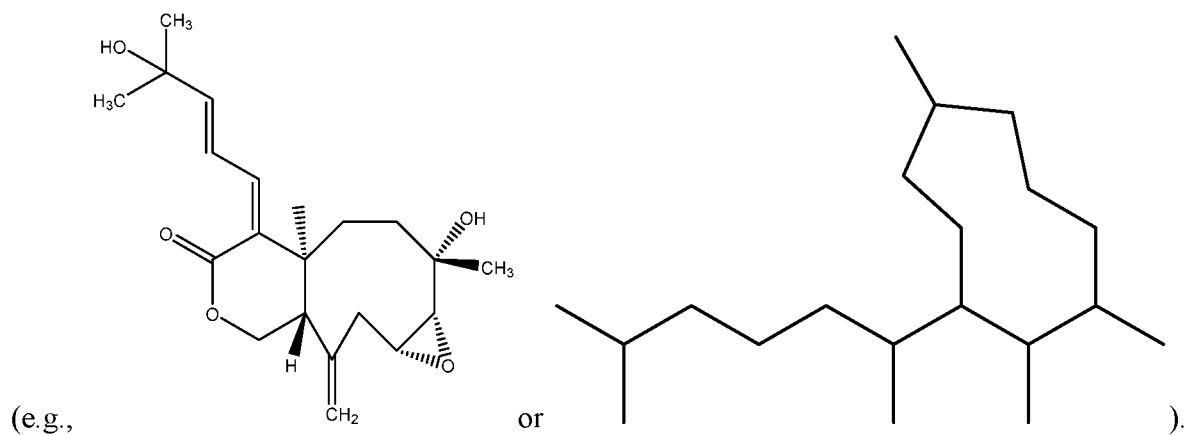
[0155] In embodiments, the terpene is a valparane or a derivative, analog, or prodrug thereof



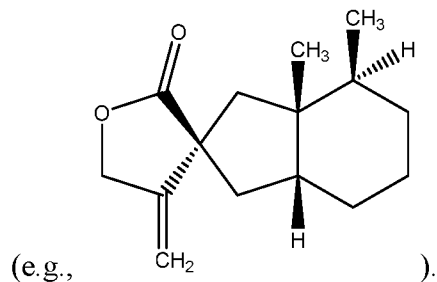
[0156] In embodiments, the terpene is a vibsane or a derivative, analog, or prodrug thereof



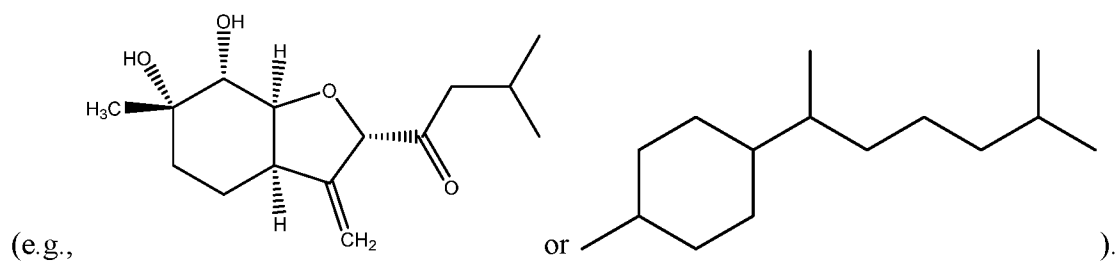
5 [0157] In embodiments, the terpene is a xenicane or a derivative, analog, or prodrug thereof



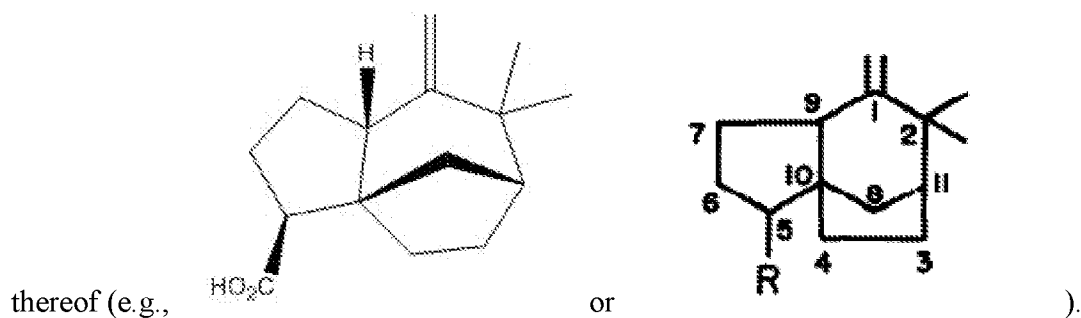
[0158] In embodiments, the terpene is a bakkane or a derivative, analog, or prodrug thereof



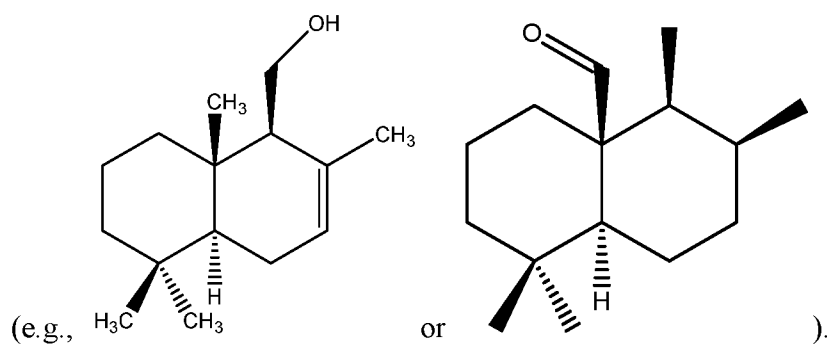
[0159] In embodiments, the terpene is a bisabolane or a derivative, analog, or prodrug thereof



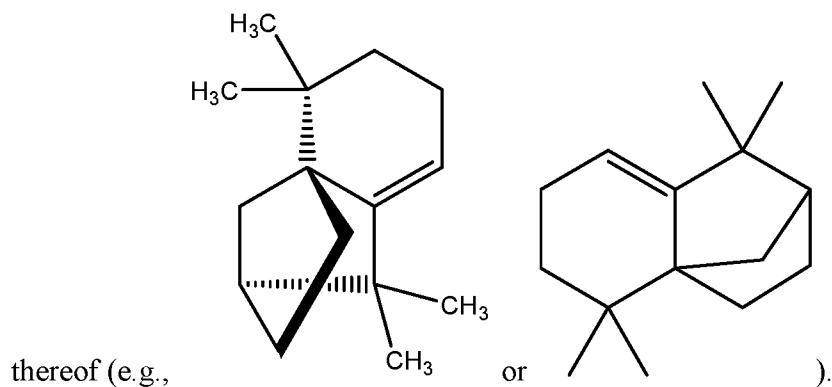
[0160] In embodiments, the terpene is a zizanoic acid or a derivative, analog, or prodrug



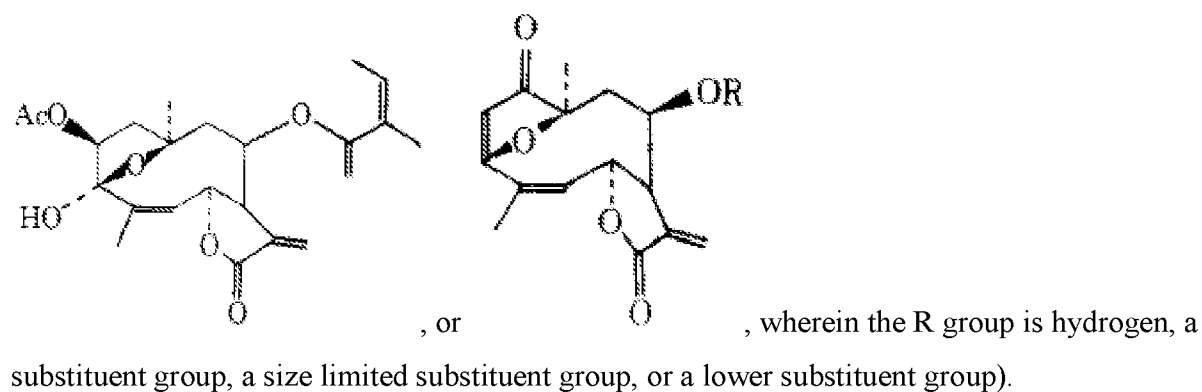
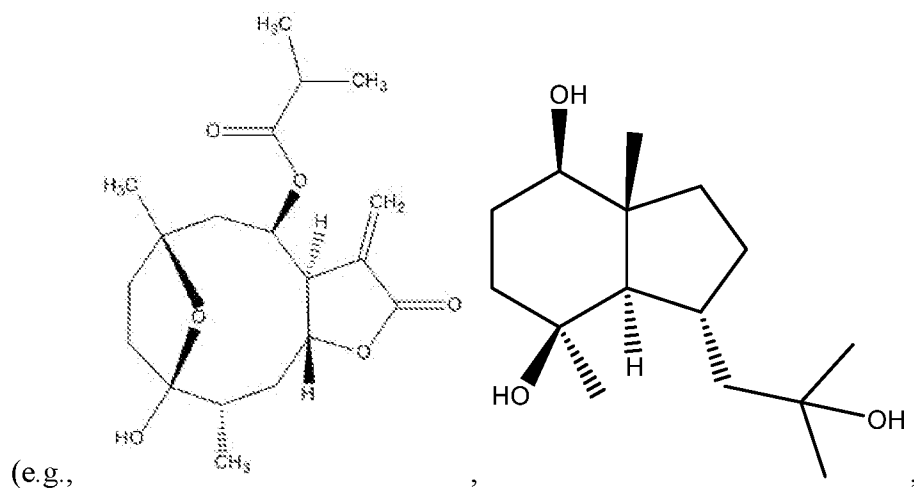
5 [0161] In embodiments, the terpene is a drimenol or a derivative, analog, or prodrug thereof



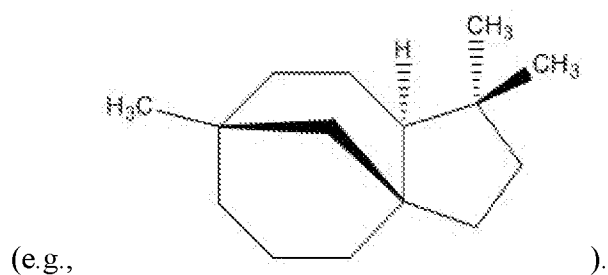
[0162] In embodiments, the terpene is a isolongifolene or a derivative, analog, or prodrug



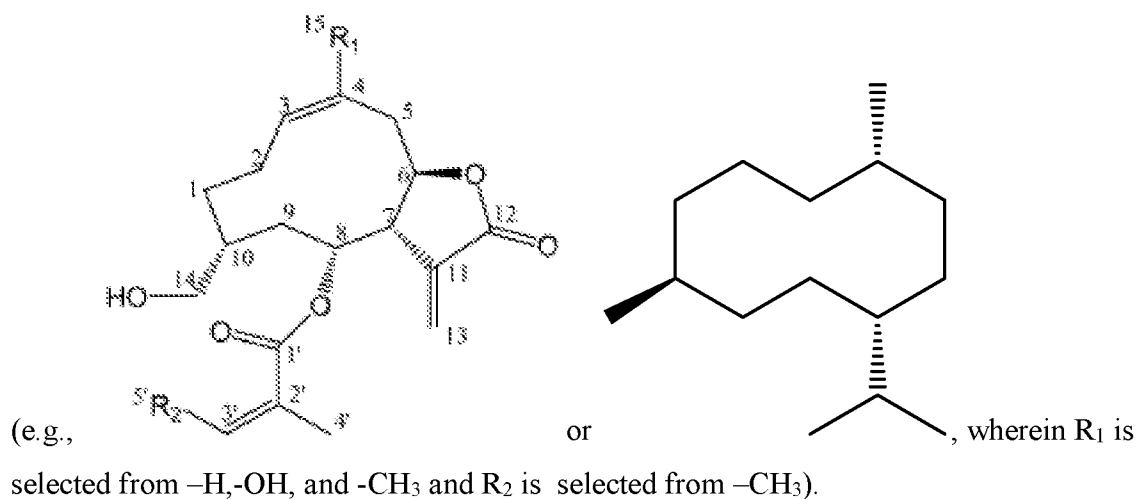
[0163] In embodiments, the terpene is a tirotundin or a derivative, analog, or prodrug thereof



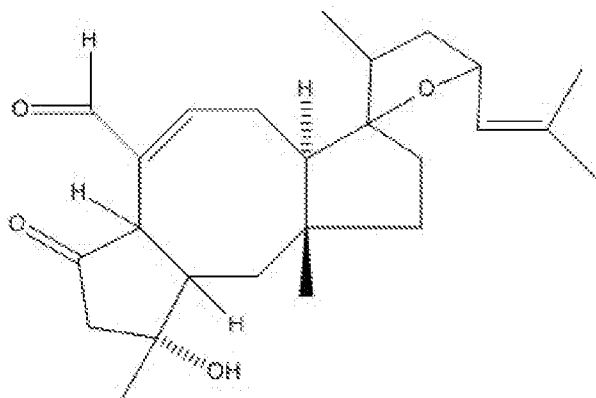
5 [0164] In embodiments, the terpene is a clovane or a derivative, analog, or prodrug thereof



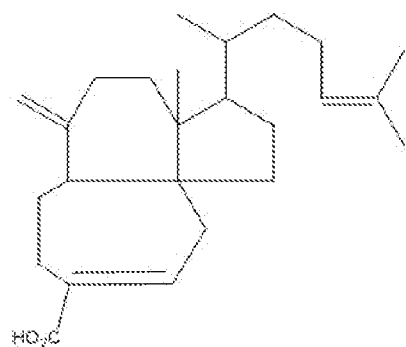
[0165] In embodiments, the terpene is a germacrane or a derivative, analog, or prodrug thereof



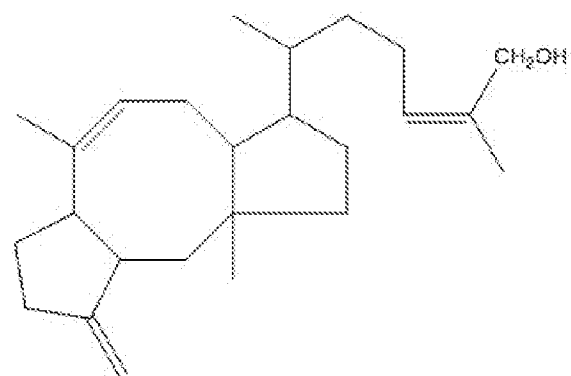
[0166] In embodiments, the terpene is a sesterterpene (e.g., a terpene with 25 carbon atoms) or a derivative, analog, or prodrug thereof (e.g.,



Ophiobolin A,

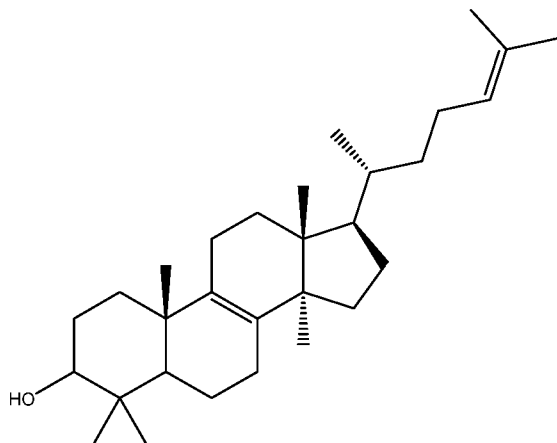


Gascardic acid,



Ceroplastol).

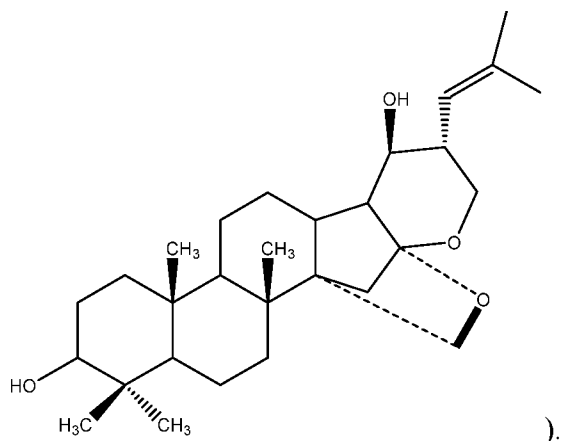
[0167] In embodiments, the terpene is a triterpene or a derivative, analog, or prodrug thereof



(e.g., lanosterol:

lanosterol

or Jubogenin



).

[0168] The term “humulone” (or α -lupulic acid) refers to a prevalent member of the class of compounds known as alpha acids, which provide a characteristically bitter flavor. Humulone is a phloroglucinol derivative with three isoprenoid side-chains. Two side-chains are prenyl groups and one is an isovaleryl group. The acidity of the ring enol moieties that give rise to its designation as an acid lie in the vinylogous relationship with the ring and side chain carbonyl functional groups.

[0169] The term “humulene” (also known as α -humulene or α -caryophyllene), refers to a monocyclic sesquiterpene ($C_{15}H_{24}$), containing an 11-membered ring and including three isoprene units containing three non-conjugated $C=C$ double bonds, two of them being triply substituted and one being doubly substituted. It is found in the essential oils of *Humulus lupulus*.

Humulene is an isomer of β -caryophyllene, and the two are often found together as a mixture in many aromatic plants.

[0170] The term “caryophyllene” (or $(-)$ - β -caryophyllene), refers to a bicyclic sesquiterpene that is a constituent of many essential oils, especially clove oil, the oil from the stems and
5 flowers of *Syzygium aromaticum* (cloves), the essential oil of *Cannabis sativa*, rosemary, and hops. It is usually found as a mixture with isocaryophyllene (the cis double bond isomer) and α -humulene. Caryophyllene possesses both a cyclobutane ring and as a trans-double bond in an 8-membered ring.

[0171] The term “lupulone” (or β -lupulic acid) refers to a beta acid found in *Humulus lupulus*
10 (Hops). Lupulones are sensitive to oxidative decomposition; their break down creates flavors that may adversely affect the taste of beer.

[0172] The term “myrcene” (or β -myrcene) refers to an olefinic organic hydrocarbon, classified as a monoterpene. It is a component of the essential oil of several plants including bay, cannabis, ylang-ylang, wild thyme, parsley, and hops.

[0173] The term “alkaloid” refers to a group of naturally occurring chemical compounds that
15 mostly contain basic nitrogen atoms. This group also includes some related compounds with neutral and even weakly acidic properties. In addition to carbon, hydrogen, and nitrogen, alkaloids may also contain oxygen, sulfur, chlorine, bromine, and phosphorus. Alkaloids are produced by a large variety of organisms including bacteria, fungi, plants, and animals.

[0174] The term “cannabinoid” refers to a class of chemical compounds that act on
20 cannabinoid receptors. Cannabinoid receptors are G-protein-coupled receptors denoted by the terms CB₁ and CB₂ receptors. The structure of the CB₁ receptor has been determined; see Hua, T., Vemuri, K., Pu, M., Qu, L., Han, G.W., Wu, Y., Zhao, S., Shui, W., Li, S., Korde, A. and Laprairie, R.B., 2016. Crystal structure of the human cannabinoid receptor CB 1. *Cell*, 167(3),
25 pp.750-762, which is incorporated herein by reference for all purposes. The anatomical distribution of these receptors is complex, but broadly CB₁ receptors in the central nervous system mediate many of the effects of cannabinoids in the brain, whereas CB₂ receptors in the periphery mediate anti-inflammatory and related actions of cannabinoids. See Munro, S., Thomas, K.L. and Abu-Shaar, M., 1993. Molecular characterization of a peripheral receptor for

cannabinoids. *Nature*, 365(6441), p.61, which is incorporated herein by reference for all purposes

[0175] There are at least 113 different cannabinoids isolated from cannabis, exhibiting varied effects. Many of these compounds are structurally related to Δ 9-tetrahydrocannabinol (THC).

- 5 Classes of natural cannabinoids isolated from cannabis include cannabigerol, cannabichromene, cannabidiol, tetrahydrocannabinol, cannabinol, cannabielsoin, *iso*-tetrahydrocannabinol, cannabicyclol, and cannabicitran. Examples of well-studied cannabinoids include cannabidiol, tetrahydrocannabinol (THC), and cannabinol (CBN).

II. Methods

- 10 [0176] Provided herein are processes, methods, and compositions, including for the extraction of natural products from plant material, employing pure fluorocarbon liquids or gases and optionally admixtures of fluorocarbon and non-fluorocarbon gases and liquids. The extraction may be carried out in a highly selective manner such that specific components including pure compounds or defined mixtures thereof may be extracted from plant or animal material without
15 extracting undesired materials, obviating the need for subsequent purification steps following the extraction, wherein the specific components are valuable in the preparation of pharmaceutical and/or nutraceutical compositions which are useful in the prevention and treatment of various diseases and syndromes in humans and animals.

- [0177] In an aspect is provided a method of extracting a natural organic compound from a
20 natural material, the method including contacting the natural material with an extraction fluid thereby extracting the natural organic compound from the natural material into the extraction fluid to form an extracted fluid solution. An “extraction fluid” as referred to herein is a fluid capable of extracting or removing a natural product or natural organic compound from a natural material. The extraction fluid extracts and carries the natural product out of the natural material
25 and can be further processed such that the natural product or natural organic compound is removed from the extraction fluid and collected. In embodiments, the extraction fluid includes a fluorophilic compound and a hydrofluorocarbon. In another embodiment, the extraction fluid is a non-ideal fluid. In embodiments, the extraction fluid includes a fluorophilic compound. In embodiments, the extraction fluid includes a hydrofluorocarbon.

[0178] In embodiments, the natural material is a material derived from a plant, an animal, a fungi, a bacteria or a virus. In embodiments, the natural material is a material derived from a plant. In embodiments, the natural material is a material derived from an animal. In
 5 embodiments, the natural material is a material derived from a fungus. In embodiments, the natural material is a material derived from a bacteria. In embodiments, the natural material is a material derived from a virus.

[0179] In embodiments, the plant is *Piper methysticum*, *Cannabis spp.*, *Salvia spp.*, *Banisteriopsis caapi*, *Psychotria viridis* (chacruna), *Diplopterys cabrerana*, *Peganum harmala*, *Humulus lupulus* or mixture thereof. In embodiments, the plant is *Piper methysticum*. In
 10 embodiments, the plant is *Cannabis spp.* In embodiments, the plant is *Salvia spp.* In embodiments, the plant is *Banisteriopsis caapi*. In embodiments, the plant is *Psychotria viridis* (chacruna). In embodiments, the plant is *Diplopterys cabrerana*. In embodiments, the plant is *Peganum harmala*. In embodiments, the plant is *Humulus lupulus*. In embodiments, the *Cannabis spp.* plant is *Cannabis Sativa*.

[0180] In embodiments, the plant is *Echinacea purpurea*, *Echinacea angustifolia*, *Acmella oleracea*, *Helichrysum umbraculigerum*, or *Radula marginata*. In embodiments, the plant is an *Echinacea spp.* In embodiments, the plant is *Echinacea purpurea*. In embodiments, the plant is *Echinacea angustifolia*. In embodiments, the plant is *Acmella oleracea*. In embodiments, the
 15 plant is *Helichrysum umbraculigerum*. In embodiments, the plant is *Radula marginata*.

[0181] In embodiments, the natural organic compound is a biologically active organic compound. In embodiments, the natural organic compound is an aromatic compound. In
 20 embodiments, the natural organic compound is a compound having an aroma. In embodiments, the natural organic compound forms part of an aromatic oil or essential oil. In embodiments, the natural organic compound forms an aromatic oil. In embodiments, the natural organic compound
 25 forms an essential oil. In embodiments, the natural organic compound is a component of an aromatic oil. In embodiments, the natural organic compound is a component of an essential oil. In embodiments, the natural organic compound is caffeine. In one embodiment, the natural organic compound is a terpene, a humulone, a lupulone, a myrcene, a humulene, a caryophyllene, an alkaloid, a flavonoid, a cannabinoid, menthol, capsaicin, anise or camphor. In
 30 embodiments, the natural organic compound is a terpene. In embodiments, the natural organic

compound is a humulone. In embodiments, the natural organic compound is a lupulone. In
embodiments, the natural organic compound is a myrcene. In embodiments, the natural organic
compound is a humulene. In embodiments, the natural organic compound is a caryophyllene. In
embodiments, the natural organic compound is an alkaloid. In embodiments, the natural organic
5 compound is a flavonoid. In embodiments, the natural organic compound is menthol. In
embodiments, the natural organic compound is capsaicin. In embodiments, the natural organic
compound is anise. In embodiments, the natural organic compound is camphor. In embodiments,
the natural organic compound is xanthohumol, 8-prenylnaringenin or isoxanthohumol. In
embodiments, the natural organic compound is xanthohumol. In embodiments, the natural
10 organic compound is 8-prenylnaringenin. In embodiments, the natural organic compound is
isoxanthohumol. In embodiments, the natural organic compound is a prenylflavonoid. In
embodiments, the natural organic compound is a kavalactone. In embodiments, the natural
organic compound is a salvorin.

[0182] In embodiments, the natural organic compound is a cannabinoid. In embodiments, the
15 natural organic compound is tetrahydrocannabinol, cannabidiol or cannabinol. In embodiments,
the natural organic compound is cannabidiol. In embodiments, the natural organic compound is
cannabinol. In embodiments, the natural organic compound is tetrahydrocannabinol.

[0183] In embodiments, the natural organic compound is cannabigerol, cannabichromene,
cannabicyclol, cannabivarin, tetrahydrocannabivarin, cannabidivarin, cannabichromevarin,
20 cannabigerovarin, cannabigerol monomethyl ether, tetrahydrocannabinolic acid, or cannabidiolic
acid. In embodiments, the natural organic compound is cannabigerol. In embodiments, the
natural organic compound is cannabichromene. In embodiments, the natural organic compound
is cannabicyclol. In embodiments, the natural organic compound is cannabivarin. In
embodiments, the natural organic compound is tetrahydrocannabivarin. In embodiments, the
25 natural organic compound is cannabidivarin. In embodiments, the natural organic compound is
cannabichromevarin. In embodiments, the natural organic compound is cannabigerovarin. In
embodiments, the natural organic compound is cannabigerol monomethyl ether. In embodiments,
the natural organic compound is tetrahydrocannabinolic acid. In embodiments, the natural organic
compound is cannabidiolic acid.

[0184] In embodiments, at least 20 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, at least 10 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, at least 5 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, at least 4 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, at least 3 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, at least 2 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, at least 1 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, at least 500 g of the natural organic compound is present in the extracted fluid solution. In embodiments, at least 400 g of the natural organic compound is present in the extracted fluid solution. In embodiments, at least 300 g of the natural organic compound is present in the extracted fluid solution. In embodiments, at least 200 g of the natural organic compound is present in the extracted fluid solution. In embodiments, at least 100 g of the natural organic compound is present in the extracted fluid solution. In embodiments, about 20 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, about 10 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, about 5 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, about 4 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, about 3 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, about 2 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, about 1 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, about 500 g of the natural organic compound is present in the extracted fluid solution. In embodiments, about 400 g of the natural organic compound is present in the extracted fluid solution. In embodiments, about 300 g of the natural organic compound is present in the extracted fluid solution. In embodiments, about 200 g of the natural organic compound is present in the extracted fluid solution. In embodiments, about 100 g of the natural organic compound is present in the extracted fluid solution. In embodiments, about 100 g to about 15 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, about 100 g to about 10 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, about 100 g to about 5 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments,

about 100 g to about 1 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, about 500 g to about 15 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, about 1 Kg to about 10 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, about 1 Kg to
5 about 5 Kg of the natural organic compound is present in the extracted fluid solution.

[0185] In embodiments, 20 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, 10 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, 5 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, 4 Kg of the natural organic compound is present in the
10 extracted fluid solution. In embodiments, 3 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, 2 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, 1 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, 500 g of the natural organic compound is present in the extracted fluid solution. In embodiments, 400 g of the natural organic compound is present
15 in the extracted fluid solution. In embodiments, 300 g of the natural organic compound is present in the extracted fluid solution. In embodiments, 200 g of the natural organic compound is present in the extracted fluid solution. In embodiments, 100 g of the natural organic compound is present in the extracted fluid solution. In embodiments, 100 g to 15 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, 100 g to 10
20 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, 100 g to 5 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, 100 g to 1 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, 500 g to 15 Kg of the natural organic compound is present in the extracted fluid solution. In embodiments, 1 Kg to 10 Kg of the natural organic compound is
25 present in the extracted fluid solution. In embodiments, 1 Kg to 5 Kg of the natural organic compound is present in the extracted fluid solution.

[0186] In embodiments, the extraction fluid does not include supercritical CO₂, argon, xenon, or nitrous oxide. In embodiments, the extraction fluid does not include supercritical CO₂, argon, xenon, and nitrous oxide. In embodiments, the extraction fluid does not include supercritical
30 CO₂. In embodiments, extraction fluid does not include argon. In embodiments, the extraction

fluid does not include xenon. In embodiments, the extraction fluid does not include nitrous oxide.

[0187] In embodiments, the extraction fluid includes trifluoroethanol or hexafluoroisopropanol. In embodiments, the extraction fluid includes trifluoroethanol. In
5 embodiments, the extraction fluid includes hexafluoroisopropanol.

[0188] In embodiments, the extraction fluid is above about 15°C. In embodiments, the extraction fluid is above about 20°C. In embodiments, the extraction fluid is from about 15°C to about 35°C. In embodiments, the extraction fluid is from about 20°C to about 30°C. In
10 embodiments, the extraction fluid is about 15°C. In embodiments, the extraction fluid is about 16°C. In embodiments, the extraction fluid is about 17°C. In embodiments, the extraction fluid is about 18°C. In embodiments, the extraction fluid is about 19°C. In embodiments, the extraction fluid is about 20°C. In embodiments, the extraction fluid is about 21°C. In embodiments, the extraction fluid is about 22°C. In embodiments, the extraction fluid is about 23°C. In
15 embodiments, the extraction fluid is about 24°C. In embodiments, the extraction fluid is about 25°C. In embodiments, the extraction fluid is about 26°C. In embodiments, the extraction fluid is about 27°C. In embodiments, the extraction fluid is about 28°C. In embodiments, the extraction fluid is about 29°C. In embodiments, the extraction fluid is about 30°C. In embodiments, the extraction fluid is about 31°C. In embodiments, the extraction fluid is about 32°C. In
20 embodiments, the extraction fluid is about 33°C. In embodiments, the extraction fluid is about 34°C. In embodiments, the extraction fluid is about 35°C.

[0189] In embodiments, the extraction fluid is above 15°C. In embodiments, the extraction fluid is above 20°C. In embodiments, the extraction fluid is from 15°C to 35°C. In embodiments, the extraction fluid is from 20°C to 30°C. In embodiments, the extraction fluid is 15°C. In
25 embodiments, the extraction fluid is 16°C. In embodiments, the extraction fluid is 17°C. In embodiments, the extraction fluid is 18°C. In embodiments, the extraction fluid is 19°C. In embodiments, the extraction fluid is 20°C. In embodiments, the extraction fluid is 21°C. In embodiments, the extraction fluid is 22°C. In embodiments, the extraction fluid is 23°C. In embodiments, the extraction fluid is 24°C. In embodiments, the extraction fluid is 25°C. In
30 embodiments, the extraction fluid is 26°C. In embodiments, the extraction fluid is 27°C. In embodiments, the extraction fluid is 28°C. In embodiments, the extraction fluid is 29°C. In

embodiments, the extraction fluid is 30°C. In embodiments, the extraction fluid is 31°C. In embodiments, the extraction fluid is 32°C. In embodiments, the extraction fluid is 33°C. In embodiments, the extraction fluid is 34°C. In embodiments, the extraction fluid is 35°C.

[0190] In embodiments, the hydrofluorocarbon is a hydrofluoroether, a hydrofluoroketone, a hydrofluoroaromatic or a hydrofluoroolefin. In embodiments, the hydrofluorocarbon is a hydrofluoroether. In embodiments, the hydrofluorocarbon is a hydrofluoroketone. In embodiments, the hydrofluorocarbon is a hydrofluoroaromatic. In embodiments, the hydrofluorocarbon is a hydrofluoroolefin.

[0191] In embodiments, the hydrofluorocarbon is chlorodifluoromethane, methyl nonafluoroisobutyl ether, methyl nonafluorobutyl ether, ethyl nonafluoroisobutyl ether, ethyl nonafluorobutyl ether, 3-ethoxy-1, 1,1,2,3,4,4,5, 5,6,6,6- dodecafluoro-2-trifluoromethylhexane, trifluoromethane (HFC-23), difluoromethane (HFC-32), pentafluoroethane (HFC-125), 1,1,2,2-tetrafluoroethane (HFC-134), 1,1,1,2- tetrafluoroethane (HFC-134a), 1,1,1-trifluoroethane (HFC-143a), 1,1- difluoroethane (HFC-152a) or fluoroethane (HFC-161). In embodiments, the hydrofluorocarbon is chlorodifluoromethane. In embodiments, the hydrofluorocarbon is methyl nonafluoroisobutyl ether. In embodiments, the hydrofluorocarbon is methyl nonafluorobutyl ether. In embodiments, the hydrofluorocarbon is ethyl nonafluoroisobutyl ether. In embodiments, the hydrofluorocarbon is ethyl nonafluorobutyl ether. In embodiments, the hydrofluorocarbon is 3-ethoxy-1, 1,1,2,3,4,4,5, 5,6,6,6- dodecafluoro-2-trifluoromethylhexane, trifluoromethane (HFC-23). In embodiments, the hydrofluorocarbon is difluoromethane (HFC-32). In embodiments, the hydrofluorocarbon is pentafluoroethane (HFC-125). In embodiments, the hydrofluorocarbon is 1,1,2,2-tetrafluoroethane (HFC-134). In embodiments, the hydrofluorocarbon is 1,1,1,2- tetrafluoroethane (HFC-134a). In embodiments, the hydrofluorocarbon is 1,1,1-trifluoroethane (HFC-143a). In embodiments, the hydrofluorocarbon is 1,1- difluoroethane (HFC-152a). In embodiments, the hydrofluorocarbon is fluoroethane (HFC-161).

[0192] In embodiments, the fluorophilic compound is dimethyl ether.

[0193] In embodiments, the method includes, prior to contacting the natural material with the extraction fluid, freezing the natural material at a temperature from about 0°C to about -60°C (e.g., at about 0 to -50, 0 to -40, 0 to -30, 0 to -20, 0 to -10, 0, -1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -

15, -20, -25, -30, -35, -40, -45, or -50°C). In embodiments, freezing the natural material uses a freezer. In embodiments, freezing the natural material uses a blast freezer. In embodiments, freezing the natural material uses compressed cryogenic gas (e.g., CO₂, N₂, He).

[0194] In embodiments, the method includes a recirculating pump to administer the extraction
5 fluid to the natural material. In embodiments, the method includes volatilizing the extraction fluid. In embodiments, the natural organic compound is not volatilized when the extraction fluid is volatilized. In embodiments, the method includes extracting the volatilized extraction fluid. In embodiments, the method includes chilling the extracted volatilized extraction fluid (e.g., with a heat exchanger). In embodiments, the method includes compressing the chilled extracted
10 volatilized extraction fluid (e.g., to an extraction liquid). In embodiments, the method includes warming the extraction liquid resulting from chilling the extracted volatilized extraction fluid. In embodiments the method includes recirculating the warmed extraction liquid resulting from chilling the extracted volatilized extraction fluid (e.g. continuously for a fixed amount of time). In embodiments the method includes warming the recirculated extraction fluid to a temperature
15 range from about 40°C to about 80°C (e.g., to about 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, or 80°C). In embodiments the method includes warming the recirculated extraction fluid to a temperature of about 80°C. In embodiments the method includes collecting portions of the recirculating extraction fluid while warming the recirculating extraction fluid to a temperature of
20 about 80°C (e.g., from 40 to 80°C). In embodiments, the method includes separating the extraction fluid from the natural material by volatilizing the extraction fluid to form a volatilized extraction fluid. In embodiments, the method includes chilling and compressing the volatilized extraction fluid to form a liquid extraction fluid. In embodiments, the method includes recirculating the liquid extraction fluid to the natural material. In embodiments, the method
25 includes collecting separated fractions of the liquid extraction fluid.

[0195] In embodiments, the extraction fluid includes an additional hydrofluorocarbon (i.e. a hydrofluorocarbon and at least one additional hydrofluorocarbon). Thus, in embodiments, the extraction fluid includes a first hydrofluorocarbon and a second hydrofluorocarbon, wherein the first hydrofluorocarbon and second hydrofluorocarbon are different. In embodiments, the first
30 hydrofluorocarbon is chlorodifluoromethane, methyl nonafluoroisobutyl ether, methyl

nonafluorobutyl ether, ethyl nonafluoroisobutyl ether, ethyl nonafluorobutyl ether, 3-ethoxy-1, 1,1,2,3,4,4,5, 5,6,6,6- dodecafluoro-2-trifluoromethylhexane.trifluoromethane (HFC-23), difluoromethane (HFC-32), pentafluoroethane (HFC-125), 1,1,2,2-tetrafluoroethane (HFC-134), 1,1,1,2- tetrafluoroethane (HFC-134a), 1,1,1-trifluoroethane (HFC-143a), 1,1- difluoroethane (HFC-152a), (1,1,1,3,3,3-hexafluoro-2-(fluoromethoxy)propane, 1,2,2,2-tetrafluoroethyl difluoromethyl ether, 2-chloro-1,1,2,-trifluoroethyl difluoromethyl ether, 1-chloro-2,2,2-trifluoroethyl difluoromethyl ether, 2,2-dichloro-1,1-difluoromethyl ether, or fluoroethane (HFC-161).

[0196] In embodiments, the first hydrofluorocarbon is chlorodifluoromethane. In embodiments, the first hydrofluorocarbon is methyl nonafluoroisobutyl ether. In embodiments, the first hydrofluorocarbon is methyl nonafluorobutyl ether. In embodiments, the first hydrofluorocarbon is ethyl nonafluoroisobutyl ether. In embodiments, the first hydrofluorocarbon is ethyl nonafluorobutyl ether. In embodiments, the first hydrofluorocarbon is 3-ethoxy-1, 1,1,2,3,4,4,5, 5,6,6,6- dodecafluoro-2-trifluoromethylhexane.trifluoromethane (HFC-23). In embodiments, the first hydrofluorocarbon is difluoromethane (HFC-32). In embodiments, the first hydrofluorocarbon is pentafluoroethane (HFC-125). In embodiments, the first hydrofluorocarbon is 1,1,2,2-tetrafluoroethane (HFC-134). In embodiments, the first hydrofluorocarbon is 1,1,1,2-tetrafluoroethane (HFC-134a). In embodiments, the first hydrofluorocarbon is 1,1,1-trifluoroethane (HFC-143a). In embodiments, the first hydrofluorocarbon is 1,1- difluoroethane (HFC-152a). In embodiments, the first hydrofluorocarbon is 1,1,1,3,3,3-hexafluoro-2-(fluoromethoxy)propane. In embodiments, the first hydrofluorocarbon is 1,2,2,2-tetrafluoroethyl difluoromethyl ether. In embodiments, the first hydrofluorocarbon is 2-chloro-1,1,2,-trifluoroethyl difluoromethyl ether. In embodiments, the first hydrofluorocarbon is 1-chloro-2,2,2-trifluoroethyl difluoromethyl ether. In embodiments, the first hydrofluorocarbon is 2,2-dichloro-1,1-difluoromethyl ether. In embodiments, the first hydrofluorocarbon is fluoroethane (HFC-161).

[0197] In embodiments, the second hydrofluorocarbon is different than the first hydrofluorocarbon. In embodiments, the second hydrofluorocarbon is chlorodifluoromethane. In embodiments, the second hydrofluorocarbon is methyl nonafluoroisobutyl ether. In embodiments, the second hydrofluorocarbon is methyl nonafluorobutyl ether. In embodiments, the second

hydrofluorocarbon is ethyl nonafluoroisobutyl ether. In embodiments, the second hydrofluorocarbon is ethyl nonafluorobutyl ether. In embodiments, the second hydrofluorocarbon is 3-ethoxy-1, 1,1,2,3,4,4,5,5,6,6,6- dodecafluoro-2-trifluoromethylhexane.trifluoromethane (HFC-23). In embodiments, the second hydrofluorocarbon is difluoromethane (HFC-32). In 5 embodiments, the second hydrofluorocarbon is pentafluoroethane (HFC-125). In embodiments, the second is hydrofluorocarbon 1,1,2,2-tetrafluoroethane (HFC-134). In embodiments, the second hydrofluorocarbon is 1,1,1,2- tetrafluoroethane (HFC-134a). In embodiments, the second hydrofluorocarbon is 1,1,1-trifluoroethane (HFC-143a). In embodiments, the second hydrofluorocarbon is 1,1- difluoroethane (HFC-152a). In embodiments, the second 10 hydrofluorocarbon is 1,1,1,3,3,3-hexafluoro-2-(fluoromethoxy)propane. In embodiments, the second hydrofluorocarbon is 1,2,2,2-tetrafluoroethyl difluoromethyl ether. In embodiments, the second hydrofluorocarbon is 2-chloro-1,1,2,-trifluoroethyl difluoromethyl ether. In embodiments, the second hydrofluorocarbon is 1-chloro-2,2,2-trifluoroethyl difluoromethyl ether. In embodiments, the second hydrofluorocarbon is 2,2-dichloro-1,1-difluoromethyl ether. In 15 embodiments, the second hydrofluorocarbon is fluoroethane (HFC-161).

[0198] In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least two-fold (e.g., at least 2-fold, 3-fold, 4-fold, 5-fold, 6-fold, 7-fold, 8-fold, 9-fold, 10-fold, 15-fold, 20-fold, or 25-fold) greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 20 at least three-fold greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least four-fold greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 5-fold greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In 25 embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 6-fold greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 7-fold greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 8-fold 30 greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 9-fold

greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In
embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 10-fold
greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In
embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 15-fold
5 greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In
embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 20-fold
greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In
embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 25-fold
greater than the total mole fraction of hydrofluorocarbons in the extraction fluid.

10 **[0199]** In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about
two-fold (e.g., about 5-fold, 6-fold, 7-fold, 8-fold, 9-fold, 10-fold, 15-fold, 20-fold, or 25-fold)
greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In
embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about three-fold
greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In
15 embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about four-fold
greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In
embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 5-fold greater
than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the
extraction fluid includes a mole fraction of a fluorocarbon about 6-fold greater than the total
20 mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid
includes a mole fraction of a fluorocarbon about 7-fold greater than the total mole fraction of
hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole
fraction of a fluorocarbon about 8-fold greater than the total mole fraction of hydrofluorocarbons
in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a
25 fluorocarbon about 9-fold greater than the total mole fraction of hydrofluorocarbons in the
extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon
about 10-fold greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In
embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 15-fold
greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In
30 embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 20-fold
greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In

embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 25-fold greater than the total mole fraction of hydrofluorocarbons in the extraction fluid.

[0200] In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 2-fold greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In

5 embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 3-fold greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 4-fold greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 5-fold greater than the total mole fraction of

10 hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 6-fold greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 7-fold greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In

15 embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 8-fold greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 9-fold greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 10-fold greater than the total mole fraction of

20 hydrofluorocarbons in the extraction fluid. In embodiments, extraction fluid includes a mole fraction of a fluorocarbon 15-fold greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 20-fold greater than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 25-fold greater than the total mole fraction of hydrofluorocarbons in the extraction fluid.

25 **[0201]** In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least two-fold (e.g., at least 3-fold, 4-fold, 5-fold, 6-fold, 7-fold, 8-fold, 9-fold, 10-fold, 15-fold, 20-fold, or 25-fold) greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 3-fold greater than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the

30 extraction fluid includes a mole fraction of a fluorocarbon at least 4-fold greater than the mole

fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 5-fold greater than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 6-fold greater than the mole fraction of the first

5 hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 7-fold greater than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 8-fold greater than the mole fraction of the first

hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole
10 fraction of a fluorocarbon at least 9-fold greater than the mole fraction of the first

hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 10-fold greater than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 15-fold greater than the mole fraction of the first

15 hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 20-fold greater than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 25-fold greater than the mole fraction of the first hydrofluorocarbon in the extraction fluid.

20 **[0202]** In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about two-fold (e.g., about 3-fold, 4-fold, 5-fold, 6-fold, 7-fold, 8-fold, 9-fold, 10-fold, 15-fold, 20-fold, or 25-fold) greater than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 3-fold greater than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In

25 embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 4-fold greater than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 5-fold greater than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 6-fold greater than the mole fraction of the
30 first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 7-fold greater than the mole fraction of the first

hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 8-fold greater than the mole fraction of the first

hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 9-fold greater than the mole fraction of the first

5 hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 10-fold greater than the mole fraction of the first

hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 15-fold greater than the mole fraction of the first

hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole

10 fraction of a fluorocarbon about 20-fold greater than the mole fraction of the first

hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 25-fold greater than the mole fraction of the first

hydrofluorocarbon in the extraction fluid.

[0203] In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 2-fold greater than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In

embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 3-fold greater than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the

extraction fluid includes a mole fraction of a fluorocarbon 4-fold greater than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid

20 includes a mole fraction of a fluorocarbon 5-fold greater than the mole fraction of the first

hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 6-fold greater than the mole fraction of the first hydrofluorocarbon in

the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a

fluorocarbon 7-fold greater than the mole fraction of the first hydrofluorocarbon in the extraction

25 fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 8-fold greater than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In

embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 9-fold greater than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the

extraction fluid includes a mole fraction of a fluorocarbon 10-fold greater than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid

includes a mole fraction of a fluorocarbon 15-fold greater than the mole fraction of the first

hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 20-fold greater than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 25-fold greater than the mole fraction of the first hydrofluorocarbon in the extraction fluid.

[0204] In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least two-fold (e.g., at least 3-fold, 4-fold, 5-fold, 6-fold, 7-fold, 8-fold, 9-fold, 10-fold, 15-fold, 20-fold, or 25-fold) greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 3-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 4-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 5-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 6-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 7-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 8-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 9-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 10-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 15-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 20-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 25-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid.

[0205] In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about two-fold (e.g., about 3-fold, 4-fold, 5-fold, 6-fold, 7-fold, 8-fold, 9-fold, 10-fold, 15-fold, 20-fold, or 25-fold) greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 3-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In
5 embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 4-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 5-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction
10 fluid includes a mole fraction of a fluorocarbon about 6-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 7-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole
15 fraction of a fluorocarbon about 8-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 9-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole
20 fraction of a fluorocarbon about 10-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 15-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole
25 fraction of a fluorocarbon about 20-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 25-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid.

[0206] In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 2-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In
embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 3-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the
30 extraction fluid includes a mole fraction of a fluorocarbon 4-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid

includes a mole fraction of a fluorocarbon 5-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 6-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 7-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 8-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 9-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 10-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 15-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 20-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 25-fold greater than the mole fraction of the second hydrofluorocarbon in the extraction fluid.

[0207] In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least two-fold (e.g., at least 3-fold, 4-fold, 5-fold, 6-fold, 7-fold, 8-fold, 9-fold, 10-fold, 15-fold, 20-fold, or 25-fold) less than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 3-fold less than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 4-fold less than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 5-fold less than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 6-fold less than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 7-fold less than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 8-fold less than the total mole fraction of hydrofluorocarbons in the extraction fluid. In

fluorocarbon about 25-fold less than the total mole fraction of hydrofluorocarbons in the extraction fluid.

[0209] In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 2-fold less than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 3-fold less than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 4-fold less than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 5-fold less than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 6-fold less than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 7-fold less than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 8-fold less than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 9-fold less than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 10-fold less than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 15-fold less than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 20-fold less than the total mole fraction of hydrofluorocarbons in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 25-fold less than the total mole fraction of hydrofluorocarbons in the extraction fluid.

[0210] In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least two-fold (e.g., at least 3-fold, 4-fold, 5-fold, 6-fold, 7-fold, 8-fold, 9-fold, 10-fold, 15-fold, 20-fold, or 25-fold) less than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, extraction fluid includes a mole fraction of a fluorocarbon at least 3-fold less than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 4-fold less than the mole

fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 5-fold less than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 6-fold less than the mole fraction of the first

- 5 hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 7-fold less than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 8-fold less than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole
- 10 fraction of a fluorocarbon at least 9-fold less than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 10-fold less than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 15-fold less than the mole fraction of the first
- 15 hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 20-fold less than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 25-fold less than the mole fraction of the first hydrofluorocarbon in the extraction fluid.

- 20 **[0211]** In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 2-fold less than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 3-fold less than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 4-fold less than the mole
- 25 fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 5-fold less than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 6-fold less than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole
- 30 fraction of a fluorocarbon about 7-fold less than the mole fraction of the first hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a

a mole fraction of a fluorocarbon 25-fold less than the mole fraction of the first hydrofluorocarbon in the extraction fluid.

[0213] In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least two-fold (e.g., at least 3-fold, 4-fold, 5-fold, 6-fold, 7-fold, 8-fold, 9-fold, 10-fold, 15-fold, 20-fold, or 25-fold) less than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 3-fold less than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 4-fold less than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 5-fold less than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 6-fold less than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 7-fold less than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 8-fold less than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 9-fold less than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 10-fold less than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 15-fold less than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 20-fold less than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon at least 25-fold less than the mole fraction of the second hydrofluorocarbon in the extraction fluid.

[0214] In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 2-fold less than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon about 3-fold less

fluorocarbon 7-fold less than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 8-fold less than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 9-fold less than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 10-fold less than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 15-fold less than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 20-fold less than the mole fraction of the second hydrofluorocarbon in the extraction fluid. In embodiments, the extraction fluid includes a mole fraction of a fluorocarbon 25-fold less than the mole fraction of the second hydrofluorocarbon in the extraction fluid.

[0216] In embodiments, the extraction fluid includes an additional component (e.g., fluorophilic compound, fluorophilic amine, alcohol, or non-fluorinated hydroxy-alkyl, non-fluorinated hydroxy-cycloalkyl, or non-fluorinated hydroxyl-aryl, inert gas (e.g., SF₆, CO₂, N₂O, CH₄, C₂H₆, argon)). In embodiments, the extraction fluid includes a fluorophilic compound as an additional component. In embodiments, the extraction fluid includes a fluorophilic amine as an additional component. In embodiments, the extraction fluid includes an alcohol as an additional component. In embodiments, the extraction fluid includes ethanol as an additional component. In embodiments, the extraction fluid includes a non-fluorinated hydroxy-alkyl as an additional component. In embodiments, the extraction fluid includes a non-fluorinated hydroxy-cycloalkyl as an additional component. In embodiments, the extraction fluid includes a non-fluorinated hydroxyl-aryl as an additional component. In embodiments, the extraction fluid includes an inert gas as an additional component. In embodiments, the inert gas is SF₆. In embodiments, the inert gas is CO₂. In embodiments, the inert gas is N₂O. In embodiments, the inert gas is CH₄. In embodiments, the inert gas is C₂H₆. In embodiments, the inert gas is argon. In embodiments, the extraction fluid includes isobutane as an additional component.

[0217] In embodiments, the mole fraction of the additional component of the extraction fluid is at least equal to or less (e.g., at least 1.1-fold, 1.2-fold, 1.3-fold, 1.4-fold, 1.5-fold, 2-fold, 3-fold, 4-fold, 5-fold, 6-fold, 7-fold, 8-fold, 9-fold, 10-fold, 15-fold, 20-fold, or 25-fold less) than the

total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is at least equal to the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 1.1-fold less than the total mole

5 fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 1.2-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 1.3-fold less than the total mole

10 fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 1.4-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 1.5-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 2-fold less than the total mole fraction

15 of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 3-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 4-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the

20 additional component of the extraction fluid is at least 5-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 6-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 7-fold less than the total mole fraction of

25 the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 8-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 9-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the

30 additional component of the extraction fluid is at least 10-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the

additional component of the extraction fluid is at least 15-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 20-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 25-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid.

[0218] In embodiments, the mole fraction of the additional component of the extraction fluid is about equal to the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is about 1.1-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is about 1.2-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is about 1.3-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is about 1.4-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is about 1.5-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is about 2-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is about 3-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is about 4-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is about 5-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is about 6-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is about 7-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is about 8-

fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In
embodiments, the mole fraction of the additional component of the extraction fluid is about 9-
fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In
embodiments, the mole fraction of the additional component of the extraction fluid is about 10-
5 fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In
embodiments, the mole fraction of the additional component of the extraction fluid is about 15-
fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In
embodiments, the mole fraction of the additional component of the extraction fluid is about 20-
fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In
10 embodiments, the mole fraction of the additional component of the extraction fluid is about 25-
fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid.

[0219] In embodiments, the mole fraction of the additional component of the extraction fluid is
equal to the total mole fraction of the hydrofluorocarbons in the extraction fluid. In
embodiments, the mole fraction of the additional component of the extraction fluid is 1.1-fold
15 less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In
embodiments, the mole fraction of the additional component of the extraction fluid is 1.2-fold
less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In
embodiments, the mole fraction of the additional component of the extraction fluid is 1.3-fold
less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In
20 embodiments, the mole fraction of the additional component of the extraction fluid is 1.4-fold
less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In
embodiments, the mole fraction of the additional component of the extraction fluid is 1.5-fold
less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In
embodiments, the mole fraction of the additional component of the extraction fluid is 2-fold less
25 than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments,
the mole fraction of the additional component of the extraction fluid is 3-fold less than the total
mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole
fraction of the additional component of the extraction fluid is 4-fold less than the total mole
fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of
30 the additional component of the extraction fluid is 5-fold less than the total mole fraction of the
hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional

component of the extraction fluid is 6-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is 7-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is 8-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is 9-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is 10-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is 15-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is 20-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid. In embodiments, the mole fraction of the additional component of the extraction fluid is 25-fold less than the total mole fraction of the hydrofluorocarbons in the extraction fluid.

[0220] In embodiments, the mole fraction of the additional component of the extraction fluid is at least equal to or less (e.g., at least 1.1-fold, 1.2-fold, 1.3-fold, 1.4-fold, 1.5-fold, 2-fold, 3-fold, 4-fold, 5-fold, 6-fold, 7-fold, 8-fold, 9-fold, 10-fold, 15-fold, 20-fold, or 25-fold less) than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least equal to the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 1.1-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 1.2-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 1.3-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 1.4-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 1.5-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 2-

fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 3-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 4-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 5-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 6-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 7-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 8-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 9-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 10-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 15-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 20-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 25-fold less than the mole fraction of the first hydrofluorocarbon.

[0221] In embodiments, the mole fraction of the additional component of the extraction fluid is about equal to the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is about 1.1-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is about 1.2-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is about 1.3-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is about 1.4-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is about 1.5-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional

component of the extraction fluid is about 2-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is about 3-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is about 4-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is about 5-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is about 6-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is about 7-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is about 8-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is about 9-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is about 10-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is about 15-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is about 20-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is about 25-fold less than the mole fraction of the first hydrofluorocarbon.

[0222] In embodiments, the mole fraction of the additional component of the extraction fluid is equal to the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is 1.1-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is 1.2-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is 1.3-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is 1.4-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is 1.5-fold less than the mole fraction of the first hydrofluorocarbon. In

embodiments, the mole fraction of the additional component of the extraction fluid is 2-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is 3-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is 4-fold less than the mole fraction of the first hydrofluorocarbon. In
5 embodiments, the mole fraction of the additional component of the extraction fluid is 5-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is 6-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is 7-fold less than the mole fraction of the first hydrofluorocarbon. In
10 embodiments, the mole fraction of the additional component of the extraction fluid is 8-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is 9-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is 10-fold less than the mole fraction of the first hydrofluorocarbon. In
15 embodiments, the mole fraction of the additional component of the extraction fluid is 15-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is 20-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is 25-fold less than the mole fraction of the first hydrofluorocarbon.

[0223] In embodiments, the mole fraction of the additional component of the extraction fluid is at least equal to or less (e.g., at least 1.1-fold, 1.2-fold, 1.3-fold, 1.4-fold, 1.5-fold, 2-fold, 3-fold, 4-fold, 5-fold, 6-fold, 7-fold, 8-fold, 9-fold, 10-fold, 15-fold, 20-fold, or 25-fold less) than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the
25 additional component of the extraction fluid is at least equal to the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 1.1-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 1.2-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole
30 fraction of the additional component of the extraction fluid is at least 1.3-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional

component of the extraction fluid is at least 1.4-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 1.5-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 2-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 3-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 4-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 5-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 6-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 7-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 8-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 9-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 10-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 15-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 20-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is at least 25-fold less than the mole fraction of the second hydrofluorocarbon.

[0224] In embodiments, the mole fraction of the additional component of the extraction fluid is about equal to the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is about 1.1-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is about 1.2-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is about 1.3-fold less than the mole fraction of the second hydrofluorocarbon. In

[0225] In embodiments, the mole fraction of the additional component of the extraction fluid is equal to the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is 1.1-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is 1.2-fold less than the mole fraction of the second hydrofluorocarbon. In
30 embodiments, the mole fraction of the additional component of the extraction fluid is 1.3-fold

less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is 1.4-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is 1.5-fold less than the mole fraction of the second hydrofluorocarbon. In
5 embodiments, the mole fraction of the additional component of the extraction fluid is 2-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is 3-fold less than the mole fraction of the second hydrofluorocarbon. In
10 embodiments, the mole fraction of the additional component of the extraction fluid is 4-fold less than the mole fraction of the second hydrofluorocarbon. In
15 embodiments, the mole fraction of the additional component of the extraction fluid is 5-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is 6-fold less than the mole fraction of the second hydrofluorocarbon. In
20 embodiments, the mole fraction of the additional component of the extraction fluid is 7-fold less than the mole fraction of the second hydrofluorocarbon. In
25 embodiments, the mole fraction of the additional component of the extraction fluid is 8-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is 9-fold less than the mole fraction of the second hydrofluorocarbon. In
30 embodiments, the mole fraction of the additional component of the extraction fluid is 10-fold less than the mole fraction of the second hydrofluorocarbon. In
embodiments, the mole fraction of the additional component of the extraction fluid is 15-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the additional component of the extraction fluid is 20-fold less than the mole fraction of the second hydrofluorocarbon. In
embodiments, the mole fraction of the additional component of the extraction fluid is 25-fold less than the mole fraction of the second hydrofluorocarbon.

[0226] In an aspect, is provided a fluid including chlorodifluoromethane and dimethyl ether. In one embodiment, the fluid is a non-ideal fluid.

[0227] In an aspect is provided an apparatus for the extraction of natural products (e.g., of medicinal, nutraceutical, health-promoting, or pharmacological, or other value or use) from a plant, animal, bacterial, fungal, or viral material, or mixtures thereof (e.g., which contain
30 multiple natural products, natural organic compounds). In embodiments, desired materials (e.g.,

natural organic compounds, natural products) are separated from undesired materials (e.g., leaving the undesired materials in the unextracted residue). In embodiments, the apparatus frees the desired material in solution. In embodiments, the natural product or the natural organic compound is further purified (e.g., by fractional distillation, flash chromatography, preparative high-pressure liquid chromatography on normal and reverse phase media, countercurrent liquid chromatography, liquid-liquid extraction, co-solvent precipitation, or crystallization).

[0228] In an aspect is provided a method (process) for the extraction of natural products (e.g., of medicinal, nutraceutical, health-promoting, or pharmacological, or other value or use) from a plant, animal, bacterial, fungal, or viral material, or mixtures thereof (e.g., which contain multiple natural products). In embodiments, desired materials (e.g., natural organic compounds, natural products) are separated from undesired materials (e.g., leaving the undesired materials in the unextracted residue). In embodiments, the method includes freeing the desired material (e.g., natural organic compound, natural product) in solution. In embodiments, the natural product or natural organic compound is further purified (e.g., by fractional distillation, flash chromatography, preparative high-pressure liquid chromatography on normal and reverse phase media, countercurrent liquid chromatography, liquid-liquid extraction, co-solvent precipitation, or crystallization).

[0229] In as aspect is provided a composition for the extraction of natural products (e.g., of medicinal, nutraceutical, health-promoting, or pharmacological, or other value or use) from a plant, animal, bacterial, fungal, or viral material, or mixtures thereof (e.g., which contain multiple natural products). In embodiments, desired materials (e.g., natural organic compounds, natural products) are separated from undesired materials (e.g., leaving the undesired materials in the unextracted residue). In embodiments, the composition frees the desired material (e.g., natural organic compounds, natural products) in solution. In embodiments, the natural product or natural organic compound is further purified (e.g., by fractional distillation, flash chromatography, preparative high-pressure liquid chromatography on normal and reverse phase media, countercurrent liquid chromatography, liquid-liquid extraction, co-solvent precipitation, or crystallization).

[0230] In embodiments, the composition includes a hydrofluorocarbon or fluorocarbon. In embodiments, the composition includes a hydrofluorocarbon and fluorocarbon. In embodiments,

the composition includes a hydrofluorocarbon. In embodiments, the composition includes a fluorocarbon. In embodiments, the composition includes hydrofluorocarbons, fluorocarbons, and optionally other substances selected from the alkanes, alkenes, alkynes, alcohols, and aromatic hydrocarbons. In embodiments, the composition includes at least one fluorocarbon which is Freon ^(TM) 134a (1,1,1,2-Tetrafluoroethane).

[0231] In embodiments, the method of extraction includes fractional distillation, flash chromatography, preparative high-pressure liquid chromatography on normal and reverse phase media, countercurrent liquid chromatography, liquid-liquid extraction, co-solvent precipitation, crystallization, or combinations thereof. In embodiments, the method of extraction includes fractional distillation. In embodiments, the method of extraction includes flash chromatography. In embodiments, the method of extraction includes preparative high-pressure liquid chromatography on normal and reverse phase media. In embodiments, the method of extraction includes fractional distillation, countercurrent liquid chromatography. In embodiments, the method of extraction includes liquid-liquid extraction. In embodiments, the method of extraction includes co-solvent precipitation. In embodiments, the method of extraction includes crystallization. Instruments for extraction may include a mass spectrometer (MS), a gas chromatograph (GC), a GC-mass spectrometer, a liquid chromatography mass spectrometer, a high-pressure liquid chromatograph, a tandem mass spectrometer-mass spectrometer, and combinations thereof.

[0232] Described herein is a multiplicity of co-solvents, (e.g., provided that the principal extraction medium is either a fluorocarbon or a hydrofluorocarbon in admixture with another fluorophilic compound). Mixtures of fluorocarbons, hydrofluorocarbons, and optionally alkanes, including but not limited to straight chain, branched chain, cycloalkanes, and alkylcycloalkanes, possess the previously unexpected ability to extract specific components (e.g., of high commercial and health-related value) from plant, animal, fungi, bacteria, or virus material. Solvents useful in the methods of the present invention include fluorocarbons and hydrofluorocarbons. In embodiments, solvents include fluorocarbons and hydrofluorocarbons. In embodiments, solvents include a fluorocarbon or hydrofluorocarbon. Furthermore, forming the continuous phase from mixtures of fluorocarbons is also contemplated herein. The instant conversion of a discontinuous phase to a continuous phase represents the conditions where the

maximum solubility of desired, highly hydrophobic plant, animal, fungi, bacteria, or virus materials may be maximally evidenced.

[0233] In embodiments, the extraction fluid (e.g. including extraction components) includes trifluorethanol. In embodiments, the extraction fluid (e.g. including extraction components) includes hexafluoroisopropanol. In embodiments, the extraction fluid (e.g. including extraction components) includes chlorodifluoromethane and dimethyl ether. In embodiments, the extraction fluid (e.g. including extraction components) includes chlorodifluoromethane. In embodiments, the extraction fluid (e.g. including extraction components) includes dimethyl ether. In embodiments, the extraction fluid (e.g. including extraction components) includes a liquid-gas mixture. In embodiments, the extraction fluid (e.g. including extraction components) is a non-ideal fluid. In embodiments, extraction fluid (e.g. including extraction components) does not include supercritical CO₂, argon, xenon, or nitrous oxide. In embodiments, extraction fluid (e.g. including extraction components) does not include supercritical CO₂. In embodiments, extraction fluid (e.g. including extraction components) does not include argon. In embodiments, extraction fluid (e.g. including extraction components) does not include xenon. In embodiments, extraction fluid (e.g. including extraction components) does not include nitrous oxide. In embodiments, the extraction fluid (e.g. including extraction components) includes a hydrofluorocarbon.

[0234] In embodiments, the extraction fluid includes a hydrofluorocarbon and a fluorophilic compound. The hydrofluorocarbon may include but is not limited to: a hydrofluoroether, a hydrofluoroketone, a hydrofluoroaromatic or a hydrofluoroolefin, chlorodifluoromethane, methyl nonafluoroisobutyl ether, methyl nonafluorobutyl ether, ethyl nonafluoroisobutyl ether, ethyl nonafluorobutyl ether, 3-ethoxy-1, 1,1,2,3,4,4,5, 5,6,6,6- dodecafluoro-2-trifluoromethylhexane, trifluoromethane (HFC-23), difluoromethane (HFC-32), pentafluoroethane (HFC-125), 1,1,2,2-tetrafluoroethane (HFC-134), 1,1,1,2- tetrafluoroethane (HFC-134a), 1,1,1-trifluoroethane (HFC-143a), 1,1- difluoroethane (HFC-152a) or fluoroethane (HFC-161). In embodiments, the hydrofluorocarbon includes a hydrofluoroether. In embodiments, the hydrofluorocarbon includes a hydrofluoroketone. In embodiments, the hydrofluorocarbon includes a hydrofluoroaromatic. In embodiments, the hydrofluorocarbon includes a hydrofluoroolefin. In embodiments, the hydrofluorocarbon includes

chlorodifluoromethane. In embodiments, the hydrofluorocarbon includes methyl nonafluoroisobutyl ether. In embodiments, the hydrofluorocarbon includes methyl nonafluorobutyl ether. In embodiments, the hydrofluorocarbon includes ethyl nonafluoroisobutyl ether. In embodiments, the hydrofluorocarbon includes ethyl nonafluorobutyl ether. In embodiments, the hydrofluorocarbon includes 3-ethoxy-1, 1,1,2,3,4,4,5, 5,6,6,6- dodecafluoro-2-trifluoromethylhexane.trifluoromethane (HFC-23). In embodiments, the hydrofluorocarbon includes difluoromethane (HFC-32). In embodiments, the hydrofluorocarbon includes pentafluoroethane (HFC-125). In embodiments, the hydrofluorocarbon includes 1,1,2,2-tetrafluoroethane (HFC-134). In embodiments, the hydrofluorocarbon includes 1,1,1,2- tetrafluoroethane (HFC-134a). In embodiments, the hydrofluorocarbon includes 1,1,1-trifluoroethane (HFC-143a). In embodiments, the hydrofluorocarbon includes 1,1- difluoroethane (HFC-152a). In embodiments, the hydrofluorocarbon includes fluoroethane (HFC-161). The fluorophilic compound may include dimethyl ether. In embodiments, the fluorophilic compound includes dimethyl ether.

[0235] In embodiments, the hydrofluorocarbon is a hydrofluoroether. In embodiments, the hydrofluorocarbon is a hydrofluoroketone. In embodiments, the hydrofluorocarbon is a hydrofluoroaromatic. In embodiments, the hydrofluorocarbon is a hydrofluoroolefin. In embodiments, the hydrofluorocarbon is chlorodifluoromethane. In embodiments, the hydrofluorocarbon is methyl nonafluoroisobutyl ether. In embodiments, the hydrofluorocarbon is methyl nonafluorobutyl ether. In embodiments, the hydrofluorocarbon is ethyl nonafluoroisobutyl ether. In embodiments, the hydrofluorocarbon is ethyl nonafluorobutyl ether. In embodiments, the hydrofluorocarbon is 3-ethoxy-1, 1,1,2,3,4,4,5, 5,6,6,6- dodecafluoro-2-trifluoromethylhexane.trifluoromethane (HFC-23). In embodiments, the hydrofluorocarbon is difluoromethane (HFC-32). In embodiments, the hydrofluorocarbon is pentafluoroethane (HFC-125). In embodiments, the hydrofluorocarbon is 1,1,2,2-tetrafluoroethane (HFC-134). In embodiments, the hydrofluorocarbon is 1,1,1,2- tetrafluoroethane (HFC-134a). In embodiments, the hydrofluorocarbon is 1,1,1-trifluoroethane (HFC-143a). In embodiments, the hydrofluorocarbon is 1,1- difluoroethane (HFC-152a). In embodiments, the hydrofluorocarbon is fluoroethane (HFC-161). The fluorophilic compound may include dimethyl ether. In embodiments, the fluorophilic compound is dimethyl ether.

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fluorophilic compound is at least nine-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is at least ten-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is at least twenty-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is at least fifty-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is at least seventy five-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is at least one hundred-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about equal to or greater (e.g., 1.1-fold greater, 1.2-fold greater, 1.3-fold greater, 1.4-fold greater, 1.5-fold greater, two-fold greater, three-fold greater, four fold greater, five-fold greater, six fold greater, seven fold greater, eight fold greater, nine fold greater, ten-fold greater, twenty fold greater, fifty fold greater, seventy five-fold greater, or one hundred fold greater) than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about equal to the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about 1.1-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about 1.2-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about 1.3-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about 1.4-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about 1.5-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about two-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the

fluorophilic compound is about three-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about four-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about five-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about six-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about seven-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about eight-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about nine-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about ten-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about twenty-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about fifty-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about seventy five-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about one hundred-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is equal to or greater (e.g., 1.1-fold greater, 1.2-fold greater, 1.3-fold greater, 1.4-fold greater, 1.5-fold greater, two-fold greater, three-fold greater, four fold greater, five-fold greater, six fold greater, seven fold greater, eight fold greater, nine fold greater, ten-fold greater, twenty fold greater, fifty fold greater, seventy five-fold greater, or one hundred fold greater) than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is equal to the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the

fluorophilic compound is 1.1-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is 1.2-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is 1.3-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is 1.4-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is 1.5-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is two-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is three-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is four-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is five-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is six-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is seven-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is eight-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is nine-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is ten-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is twenty-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is fifty-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is seventy five-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the

fluorophilic compound is one hundred-fold greater than the total mole fraction of the hydrofluorocarbons in the extraction solution.

[0237] In embodiments, the mole fraction of the fluorophilic compound is less (e.g., 1.1-fold less, 1.2-fold less, 1.3-fold less, 1.4-fold less, 1.5-fold less, two-fold less, three-fold less, four fold less, five-fold less, six fold less, seven fold less, eight fold less, nine fold less, ten-fold less, 5 twenty fold less, fifty fold less, seventy five-fold less, or one hundred fold less) than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is at least 1.1-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the 10 fluorophilic compound is at least 1.2-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is at least 1.3-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is at least 1.4-fold less than the total mole fraction of the 15 hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is at least 1.5-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is at least two-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the 20 fluorophilic compound is at least three-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is at least four-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is at least five-fold less than the total mole fraction of the 25 hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is at least six-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is at least seven-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the 30 fluorophilic compound is at least eight-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the

fluorophilic compound is at least nine-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is at least ten-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is at least twenty-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is at least fifty-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is at least seventy five-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is at least one hundred-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about 1.1-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about 1.2-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about 1.3-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about 1.4-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about 1.5-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about two-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about three-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about four-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about five-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about six-fold less than the total mole fraction of the

hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about seven-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about eight-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about nine-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about ten-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about twenty-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about fifty-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about seventy five-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is about one hundred-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is 1.1-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is 1.2-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is 1.3-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is 1.4-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is 1.5-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is two-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is three-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is four-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the

fluorophilic compound is five-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is six-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is seven-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is eight-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is nine-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is ten-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is twenty-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is fifty-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is seventy five-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution. In embodiments, the mole fraction of the fluorophilic compound is one hundred-fold less than the total mole fraction of the hydrofluorocarbons in the extraction solution.

[0238] In embodiments, the mole fraction of the fluorophilic compound is at least equal to or greater (e.g., 1.1-fold greater, 1.2-fold greater, 1.3-fold greater, 1.4-fold greater, 1.5-fold greater, two-fold greater, three-fold greater, four fold greater, five-fold greater, six fold greater, seven fold greater, eight fold greater, nine fold greater, ten-fold greater, twenty fold greater, fifty fold greater, seventy five-fold greater, or one hundred fold greater) than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least equal to the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least 1.1-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least 1.2-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least 1.3-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least 1.4-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the

mole fraction of the fluorophilic compound is at least 1.5-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least two-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least three-fold greater than the mole

5 fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least four-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least five-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least six-fold greater than the mole fraction of the first

10 hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least seven-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least eight-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least nine-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments,

15 the mole fraction of the fluorophilic compound is at least ten-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least twenty-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least fifty-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least seventy five-fold greater than the mole fraction of the first

20 hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least one hundred-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about equal to or greater (e.g., 1.1-fold greater, 1.2-fold greater, 1.3-fold greater, 1.4-fold greater, 1.5-fold greater, two-fold greater, three-fold

25 greater, four fold greater, five-fold greater, six fold greater, seven fold greater, eight fold greater, nine fold greater, ten-fold greater, twenty fold greater, fifty fold greater, seventy five-fold greater, or one hundred fold greater) than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about equal to the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound

30 is about 1.1-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about 1.2-fold greater than the mole fraction of

the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about 1.3-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about 1.4-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about 1.5-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about two-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about three-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about four-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about five-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about six-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about seven-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about eight-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about nine-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about ten-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about twenty-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about fifty-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about seventy five-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about one hundred-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is equal to or greater (e.g., 1.1-fold greater, 1.2-fold greater, 1.3-fold greater, 1.4-fold greater, 1.5-fold greater, two-fold greater, three-fold greater, four fold greater, five-fold greater, six fold greater, seven fold greater, eight fold greater, nine fold greater, ten-fold greater, twenty fold greater, fifty fold greater, seventy five-fold greater, or one hundred fold greater) than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is equal to the mole fraction of the first hydrofluorocarbon. In

embodiments, the mole fraction of the fluorophilic compound is 1.1-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is 1.2-fold greater than the mole fraction of the first hydrofluorocarbon. In
embodiments, the mole fraction of the fluorophilic compound is 1.3-fold greater than the mole
5 fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is 1.4-fold greater than the mole fraction of the first hydrofluorocarbon. In
embodiments, the mole fraction of the fluorophilic compound is 1.5-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic
compound is two-fold greater than the mole fraction of the first hydrofluorocarbon. In
10 embodiments, the mole fraction of the fluorophilic compound is three-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is four-fold greater than the mole fraction of the first hydrofluorocarbon. In
embodiments, the mole fraction of the fluorophilic compound is five-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic
15 compound is six-fold greater than the mole fraction of the first hydrofluorocarbon. In
embodiments, the mole fraction of the fluorophilic compound is seven-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is eight-fold greater than the mole fraction of the first hydrofluorocarbon. In
embodiments, the mole fraction of the fluorophilic compound is nine-fold greater than the mole
20 fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is ten-fold greater than the mole fraction of the first hydrofluorocarbon. In
embodiments, the mole fraction of the fluorophilic compound is twenty-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the
fluorophilic compound is fifty-fold greater than the mole fraction of the first hydrofluorocarbon.
25 In embodiments, the mole fraction of the fluorophilic compound is seventy five-fold greater than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the
fluorophilic compound is one hundred-fold greater than the mole fraction of the first
hydrofluorocarbon.

[0239] In embodiments, the mole fraction of the fluorophilic compound is less (e.g., 1.1-fold
30 less, 1.2-fold less, 1.3-fold less, 1.4-fold less, 1.5-fold less, two-fold less, three-fold less, four
fold less, five-fold less, six fold less, seven fold less, eight fold less, nine fold less, ten-fold less,

twenty fold less, fifty fold less, seventy five-fold less, or one hundred fold less) than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least 1.1-fold less than the mole fraction of the first hydrofluorocarbon. In
embodiments, the mole fraction of the fluorophilic compound is at least 1.2-fold less than the
5 mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the
fluorophilic compound is at least 1.3-fold less than the mole fraction of the first
hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least
1.4-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole
fraction of the fluorophilic compound is at least 1.5-fold less than the mole fraction of the first
10 hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least
two-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole
fraction of the fluorophilic compound is at least three-fold less than the mole fraction of the first
hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least
four-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole
15 fraction of the fluorophilic compound is at least five-fold less than the mole fraction of the first
hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least
six-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole
fraction of the fluorophilic compound is at least seven-fold less than the mole fraction of the first
hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least
20 eight-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole
fraction of the fluorophilic compound is at least nine-fold less than the mole fraction of the first
hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least
ten-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole
fraction of the fluorophilic compound is at least twenty-fold less than the mole fraction of the
25 first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at
least fifty-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the
mole fraction of the fluorophilic compound is at least seventy five-fold less than the mole
fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic
compound is at least one hundred-fold less than the mole fraction of the first hydrofluorocarbon.
30 In embodiments, the mole fraction of the fluorophilic compound is about 1.1-fold less than the
mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the

fluorophilic compound is about 1.2-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about 1.3-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about 1.4-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about 1.5-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about two-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about three-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about four-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about five-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about six-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about seven-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about eight-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about nine-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about ten-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about twenty-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about fifty-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about seventy five-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about one hundred-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is 1.1-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is 1.2-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is 1.3-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is 1.4-fold less than the mole fraction of the first hydrofluorocarbon.

In embodiments, the mole fraction of the fluorophilic compound is 1.5-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is two-fold less than the mole fraction of the first hydrofluorocarbon. In
embodiments, the mole fraction of the fluorophilic compound is three-fold less than the mole
5 fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is four-fold less than the mole fraction of the first hydrofluorocarbon. In
embodiments, the mole fraction of the fluorophilic compound is five-fold less than the mole
fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic
compound is six-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments,
10 the mole fraction of the fluorophilic compound is seven-fold less than the mole fraction of the
first hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is
eight-fold less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole
fraction of the fluorophilic compound is nine-fold less than the mole fraction of the first
hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is ten-fold
15 less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of
the fluorophilic compound is twenty-fold less than the mole fraction of the first
hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is fifty-fold
less than the mole fraction of the first hydrofluorocarbon. In embodiments, the mole fraction of
the fluorophilic compound is seventy five-fold less than the mole fraction of the first
20 hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is one
hundred-fold less than the mole fraction of the first hydrofluorocarbon.

[0240] In embodiments, the mole fraction of the fluorophilic compound is at least equal to or
greater (e.g., 1.1-fold greater, 1.2-fold greater, 1.3-fold greater, 1.4-fold greater, 1.5-fold greater,
two-fold greater, three-fold greater, four fold greater, five-fold greater, six fold greater, seven
25 fold greater, eight fold greater, nine fold greater, ten-fold greater, twenty fold greater, fifty fold
greater, seventy five-fold greater, or one hundred fold greater) than the mole fraction of the
second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at
least equal to the mole fraction of the second hydrofluorocarbon. In embodiments, the mole
fraction of the fluorophilic compound is at least 1.1-fold greater than the mole fraction of the
30 second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at
least 1.2-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments,

the mole fraction of the fluorophilic compound is at least 1.3-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least 1.4-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least 1.5-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least two-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least three-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least four-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least five-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least six-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least seven-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least eight-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least nine-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least ten-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least twenty-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least fifty-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least seventy five-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least one hundred-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about equal to or greater (e.g., 1.1-fold greater, 1.2-fold greater, 1.3-fold greater, 1.4-fold greater, 1.5-fold greater, two-fold greater, three-fold greater, four fold greater, five-fold greater, six fold greater, seven fold greater, eight fold greater, nine fold greater, ten-fold greater, twenty fold greater, fifty fold greater, seventy five-fold greater, or one hundred fold greater) than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole

fraction of the fluorophilic compound is about equal to the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about 1.1-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about 1.2-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about 1.3-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about 1.4-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about 1.5-fold greater than the mole fraction of the second hydrofluorocarbon. In
embodiments, the mole fraction of the fluorophilic compound is about two-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about three-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about four-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about five-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about six-fold greater than the mole fraction of the second hydrofluorocarbon. In
embodiments, the mole fraction of the fluorophilic compound is about seven-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about eight-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about nine-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about ten-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about twenty-fold greater than the mole fraction of the second hydrofluorocarbon. In
embodiments, the mole fraction of the fluorophilic compound is about fifty-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about seventy five-fold greater than the mole fraction of the second hydrofluorocarbon. In
embodiments, the mole fraction of the fluorophilic compound is about one hundred-fold greater than the mole fraction of the second hydrofluorocarbon. In
embodiments, the mole fraction of the fluorophilic compound is equal to or greater (e.g., 1.1-fold

greater, 1.2-fold greater, 1.3-fold greater, 1.4-fold greater, 1.5-fold greater, two-fold greater, three-fold greater, four fold greater, five-fold greater, six fold greater, seven fold greater, eight fold greater, nine fold greater, ten-fold greater, twenty fold greater, fifty fold greater, seventy five-fold greater, or one hundred fold greater) than the mole fraction of the second

- 5 hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is equal to the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is 1.1-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is 1.2-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole
- 10 fraction of the fluorophilic compound is 1.3-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is 1.4-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is 1.5-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is two-fold
- 15 greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is three-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is four-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is five-fold greater than the mole fraction of the second
- 20 hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is six-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is seven-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is eight-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole
- 25 fraction of the fluorophilic compound is nine-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is ten-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is twenty-fold greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is fifty-fold
- 30 greater than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is seventy five-fold greater than the mole fraction of the

second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is one hundred-fold greater than the mole fraction of the second hydrofluorocarbon.

[0241] In embodiments, the mole fraction of the fluorophilic compound is less (e.g., 1.1-fold less, 1.2-fold less, 1.3-fold less, 1.4-fold less, 1.5-fold less, two-fold less, three-fold less, four

5 fold less, five-fold less, six fold less, seven fold less, eight fold less, nine fold less, ten-fold less, twenty fold less, fifty fold less, seventy five-fold less, or one hundred fold less) than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least 1.1-fold less than the mole fraction of the second hydrofluorocarbon. In

embodiments, the mole fraction of the fluorophilic compound is at least 1.2-fold less than the

10 mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least 1.3-fold less than the mole fraction of the second

hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least

1.4-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole

fraction of the fluorophilic compound is at least 1.5-fold less than the mole fraction of the second

15 hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least

two-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole

fraction of the fluorophilic compound is at least three-fold less than the mole fraction of the

second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at

least four-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the

20 mole fraction of the fluorophilic compound is at least five-fold less than the mole fraction of the

second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at

least six-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the

mole fraction of the fluorophilic compound is at least seven-fold less than the mole fraction of

the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound

25 is at least eight-fold less than the mole fraction of the second hydrofluorocarbon. In

embodiments, the mole fraction of the fluorophilic compound is at least nine-fold less than the

mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the

fluorophilic compound is at least ten-fold less than the mole fraction of the second

hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least

30 twenty-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the

mole fraction of the fluorophilic compound is at least fifty-fold less than the mole fraction of the

second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is at least seventy five-fold less than the mole fraction of the second hydrofluorocarbon. In
embodiments, the mole fraction of the fluorophilic compound is at least one hundred-fold less
than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of
5 the fluorophilic compound is about 1.1-fold less than the mole fraction of the second
hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about
1.2-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole
fraction of the fluorophilic compound is about 1.3-fold less than the mole fraction of the second
hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about
10 1.4-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole
fraction of the fluorophilic compound is about 1.5-fold less than the mole fraction of the second
hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is about
two-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole
fraction of the fluorophilic compound is about three-fold less than the mole fraction of the
15 second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is
about four-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments,
the mole fraction of the fluorophilic compound is about five-fold less than the mole fraction of
the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound
is about six-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments,
20 the mole fraction of the fluorophilic compound is about seven-fold less than the mole fraction of
the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound
is about eight-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments,
the mole fraction of the fluorophilic compound is about nine-fold less than the mole fraction of
the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound
25 is about ten-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments,
the mole fraction of the fluorophilic compound is about twenty-fold less than the mole fraction
of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic
compound is about fifty-fold less than the mole fraction of the second hydrofluorocarbon. In
embodiments, the mole fraction of the fluorophilic compound is about seventy five-fold less than
30 the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the
fluorophilic compound is about one hundred-fold less than the mole fraction of the second

hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is 1.1-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is 1.2-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is 1.3-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is 1.4-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is 1.5-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is two-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is three-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is four-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is five-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is six-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is seven-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is eight-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is nine-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is ten-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is twenty-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is fifty-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is seventy five-fold less than the mole fraction of the second hydrofluorocarbon. In embodiments, the mole fraction of the fluorophilic compound is one hundred-fold less than the mole fraction of the second hydrofluorocarbon.

[0242] In embodiments, the mole fraction of dimethyl ether is at least equal to or greater (e.g., 1.1-fold greater, 1.2-fold greater, 1.3-fold greater, 1.4-fold greater, 1.5-fold greater, two-fold greater, three-fold greater, four fold greater, five-fold greater, six-fold greater, seven-fold greater,

eight-fold greater, nine-fold greater, ten-fold greater, twenty-fold greater, fifty-fold greater, seventy five-fold greater, or one hundred-fold greater) than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least equal to the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least 1.1-fold greater than the mole fraction of the chlorodifluoromethane. In
5 embodiments, the mole fraction of dimethyl ether is at least 1.2-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least 1.3-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least 1.4-fold greater than the mole fraction of the
10 chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least 1.5-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least two-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least three-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is
15 at least four-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least five-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least six-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least seven-fold greater than the mole fraction of the
20 chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least eight-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least nine-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least ten-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction
25 of dimethyl ether is at least twenty-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least fifty-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least seventy five-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least one
30 hundred-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about equal to the mole fraction of the chlorodifluoromethane.

In embodiments, the mole fraction of dimethyl ether is about 1.1-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about 1.2-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about 1.3-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about 1.4-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about 1.5-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about two-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about three-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about four-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about five-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about six-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about seven-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about eight-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about nine-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about ten-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about twenty-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about fifty-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about seventy five-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about one hundred-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is equal to the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is 1.1-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is 1.2-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is 1.3-fold greater than the mole fraction of the chlorodifluoromethane. In

embodiments, the mole fraction of dimethyl ether is 1.4-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is 1.5-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is two-fold greater than the mole fraction of the chlorodifluoromethane. In
5 embodiments, the mole fraction of dimethyl ether is three-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is four-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is five-fold greater than the mole fraction of the chlorodifluoromethane. In
10 embodiments, the mole fraction of dimethyl ether is six-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is seven-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is eight-fold greater than the mole fraction of the chlorodifluoromethane. In
15 embodiments, the mole fraction of dimethyl ether is nine-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is ten-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is twenty-fold greater than the mole fraction of the chlorodifluoromethane. In
embodiments, the mole fraction of dimethyl ether is fifty-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is seventy five-fold greater than the mole fraction of the chlorodifluoromethane. In embodiments, the mole
20 fraction of dimethyl ether is one hundred-fold greater than the mole fraction of the chlorodifluoromethane.

[0243] In embodiments, the mole fraction of dimethyl ether is less (e.g., 1.1-fold less, 1.2-fold less, 1.3-fold less, 1.4-fold less, 1.5-fold less, two-fold less, three-fold less, four fold less, five-fold less, six fold less, seven fold less, eight fold less, nine fold less, ten-fold less, twenty fold
25 less, fifty fold less, seventy five-fold less, or one hundred fold less) than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least 1.1-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least 1.2-fold less than the mole fraction of the chlorodifluoromethane. In
embodiments, the mole fraction of dimethyl ether is at least 1.3-fold less than the mole fraction
30 of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least 1.4-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole

fraction of dimethyl ether is at least 1.5-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least two-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least three-fold less than the mole fraction of the chlorodifluoromethane. In
5 embodiments, the mole fraction of dimethyl ether is at least four-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least five-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least six-fold less than the mole fraction of the
10 chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least seven-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least eight-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least nine-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least ten-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the
15 mole fraction of dimethyl ether is at least twenty-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least fifty-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least seventy five-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is at least one
20 hundred-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about 1.1-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about 1.2-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about 1.3-fold less than the mole fraction of the chlorodifluoromethane. In
25 embodiments, the mole fraction of dimethyl ether is about 1.4-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about 1.5-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about two-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about three-fold less than the mole fraction
30 of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about four-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole

fraction of dimethyl ether is about five-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about six-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about seven-fold less than the mole fraction of the chlorodifluoromethane. In
5 embodiments, the mole fraction of dimethyl ether is about eight-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about nine-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about ten-fold less than the mole fraction of the
10 chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about twenty-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about fifty-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is about seventy five-fold less than the mole fraction of the chlorodifluoromethane. In
15 embodiments, the mole fraction of dimethyl ether is about one hundred-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is 1.1-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is 1.2-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl
20 ether is 1.3-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is 1.4-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is 1.5-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl
25 ether is two-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is three-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is four-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of
30 dimethyl ether is five-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is six-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is seven-fold less than the mole fraction of the chlorodifluoromethane. In
embodiments, the mole fraction of dimethyl ether is eight-fold less than the mole fraction of the chlorodifluoromethane. In
embodiments, the mole fraction of dimethyl ether is nine-fold less than the mole fraction of the

chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is ten-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is twenty-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is fifty-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is seventy five-fold less than the mole fraction of the chlorodifluoromethane. In embodiments, the mole fraction of dimethyl ether is one hundred-fold less than the mole fraction of the chlorodifluoromethane.

[0244] In embodiments, the mole fraction of dimethyl ether is at least equal to or greater (e.g., 1.1-fold greater, 1.2-fold greater, 1.3-fold greater, 1.4-fold greater, 1.5-fold greater, two-fold greater, three-fold greater, four fold greater, five-fold greater, six-fold greater, seven-fold greater, eight-fold greater, nine-fold greater, ten-fold greater, twenty-fold greater, fifty-fold greater, seventy five-fold greater, or one hundred-fold greater) than the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least equal to the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least 1.1-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least 1.2-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least 1.3-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least 1.4-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least 1.5-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least two-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least three-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least four-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least five-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least six-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least seven-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least eight-fold greater than the mole fraction of the 1,1,1,2-

tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least nine-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least ten-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least twenty-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least fifty-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least seventy five-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least one hundred-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about equal to the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about 1.1-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about 1.2-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about 1.3-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about 1.4-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about 1.5-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about two-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about three-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about four-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about five-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about six-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about seven-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about eight-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about nine-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about ten-fold greater than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of

dimethyl ether is about twenty-fold greater than the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about fifty-fold greater than the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about seventy five-fold greater than the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about one hundred-fold greater than the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is equal to the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is 1.1-fold greater than the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is 1.2-fold greater than the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is 1.3-fold greater than the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is 1.4-fold greater than the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is 1.5-fold greater than the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is two-fold greater than the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is three-fold greater than the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is four-fold greater than the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is five-fold greater than the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is six-fold greater than the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is seven-fold greater than the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is eight-fold greater than the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is nine-fold greater than the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is ten-fold greater than the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is twenty-fold greater than the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is fifty-fold greater than the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is seventy five-fold greater than the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the

mole fraction of dimethyl ether is one hundred-fold greater than the mole fraction of the 1,1,1,2-tetrafluoroethane.

[0245] In embodiments, the mole fraction of dimethyl ether is less (e.g., 1.1-fold less, 1.2-fold less, 1.3-fold less, 1.4-fold less, 1.5-fold less, two-fold less, three-fold less, four fold less, five-fold less, six fold less, seven fold less, eight fold less, nine fold less, ten-fold less, twenty fold less, fifty fold less, seventy five-fold less, or one hundred fold less) than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least 1.1-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least 1.2-fold less than the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least 1.3-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least 1.4-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least 1.5-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least two-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least three-fold less than the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least four-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least five-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least six-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least seven-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least eight-fold less than the mole fraction of the 1,1,1,2-tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least nine-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least ten-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least twenty-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least fifty-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least seventy five-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is at least one

hundred-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about 1.1-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about 1.2-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about 1.3-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In
5 embodiments, the mole fraction of dimethyl ether is about 1.4-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about 1.5-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about two-fold less than the mole fraction of the 1,1,1,2-
10 tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about three-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about four-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about five-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about six-
15 fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about seven-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about eight-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about nine-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In
20 embodiments, the mole fraction of dimethyl ether is about ten-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about twenty-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about fifty-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about seventy five-fold
25 less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is about one hundred-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is 1.1-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is 1.2-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments,
30 the mole fraction of dimethyl ether is 1.3-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is 1.4-fold less than the

mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is 1.5-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is two-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is three-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is four-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is five-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is six-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is seven-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is eight-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is nine-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is ten-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is twenty-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is fifty-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is seventy five-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane. In embodiments, the mole fraction of dimethyl ether is one hundred-fold less than the mole fraction of the 1,1,1,2- tetrafluoroethane.

[0246] In embodiments, the mole fraction of dimethyl ether is at least equal to or greater (e.g., 1.1-fold greater, 1.2-fold greater, 1.3-fold greater, 1.4-fold greater, 1.5-fold greater, two-fold greater, three-fold greater, four fold greater, five-fold greater, six-fold greater, seven-fold greater, eight-fold greater, nine-fold greater, ten-fold greater, twenty-fold greater, fifty-fold greater, seventy five-fold greater, or one hundred-fold greater) than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least equal to the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least 1.1-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least 1.2-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the

chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least 1.3-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least 1.4-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least 1.5-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least two-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least three-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least four-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least five-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least six-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least seven-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least eight-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least nine-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least ten-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least twenty-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least fifty-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least seventy five-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at

least one hundred-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about equal to the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about 1.1-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about 1.2-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about 1.3-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about 1.4-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about 1.5-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about two-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about three-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about four-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about five-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about six-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about seven-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about eight-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about nine-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about ten-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the

chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about twenty-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about fifty-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about seventy five-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about one hundred-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is equal to the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is 1.1-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is 1.2-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is 1.3-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is 1.4-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is 1.5-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is two-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is three-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is four-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is five-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is six-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is seven-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the

chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is eight-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is nine-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is ten-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is twenty-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is fifty-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is seventy five-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is one hundred-fold greater than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined..

[0247] In embodiments, the mole fraction of dimethyl ether is less (e.g., 1.1-fold less, 1.2-fold less, 1.3-fold less, 1.4-fold less, 1.5-fold less, two-fold less, three-fold less, four fold less, five-fold less, six fold less, seven fold less, eight fold less, nine fold less, ten-fold less, twenty fold less, fifty fold less, seventy five-fold less, or one hundred fold less) than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least 1.1-fold less than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least 1.2-fold less than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least 1.3-fold less than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least 1.4-fold less than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least 1.5-fold less than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least two-fold less than the total mole fraction of the 1,1,1,2-

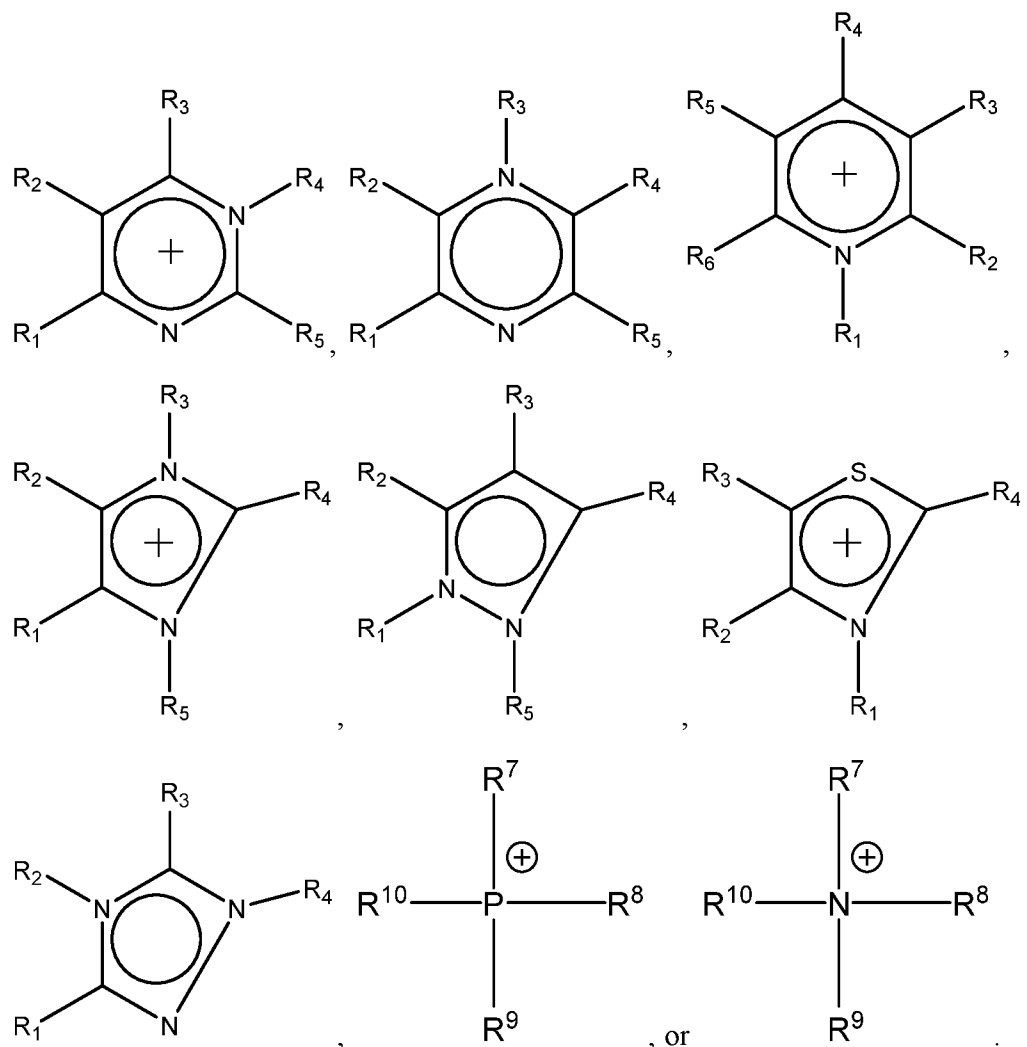
tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least three-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least four-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least five-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least six-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least seven-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least eight-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least nine-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least ten-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least twenty-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least fifty-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least seventy five-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is at least one hundred-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about 1.1-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about 1.2-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about 1.3-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction

of dimethyl ether is about 1.4-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about 1.5-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about two-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about three-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about four-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about five-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about six-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about seven-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about eight-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about nine-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about ten-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about twenty-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about fifty-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about seventy five-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is about one hundred-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is 1.1-fold less than the total mole fraction of the 1,1,1,2-tetrafluoroethane and

the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is 1.2-fold less than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is 1.3-fold less than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is 1.4-fold less than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is 1.5-fold less than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is two-fold less than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is three-fold less than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is four-fold less than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is five-fold less than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is six-fold less than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is seven-fold less than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is eight-fold less than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is nine-fold less than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is ten-fold less than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is twenty-fold less than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is fifty-fold less than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is

seventy five-fold less than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined.. In embodiments, the mole fraction of dimethyl ether is one hundred-fold less than the total mole fraction of the 1,1,1,2- tetrafluoroethane and the chlorodifluoromethane combined..

- 5 **[0248]** In embodiments, the extraction fluid is above about 15°C. In embodiments, the extraction fluid is above about 20°C. In embodiments, the extraction fluid is from about 15°C to about 35°C. In embodiments, the extraction fluid is from about 20°C to about 30°C. In embodiments, the extraction fluid is above about 15°C, 16°C, 17°C, 18°C, 19°C, 20°C, 21°C, 22°C, 23°C, 24°C, 25°C, 26°C, 27°C, 28°C, 29°C, 30°C, 31°C, 32°C, 33°C, 34°C, or 35°C. In
- 10 some embodiments, the extraction fluid is above 15°C. In embodiments, the extraction fluid is above 20°C. In embodiments, the extraction fluid is from 15°C to 35°C. In embodiments, the extraction fluid is from 20°C to 30°C. In embodiments, the extraction fluid is above 15°C, 16°C, 17°C, 18°C, 19°C, 20°C, 21°C, 22°C, 23°C, 24°C, 25°C, 26°C, 27°C, 28°C, 29°C, 30°C, 31°C, 32°C, 33°C, 34°C, or 35°C.
- 15 **[0249]** In embodiments, an ionic liquid includes a cation described by one or more of the following formulae:



R₁, R₂, R₃, R₄, R₅, R₆, R⁷, R⁸, R⁹, and R¹⁰ are independently hydrogen, halogen, -CX₃, -CHX₂,
5 -CH₂X, -CN, -OH, -NH₂, -COOH, -CONH₂, -NO₂, -SH, -SO₃H, -SO₄H, -SO₂NH₂, -NHNH₂,
-ONH₂, -NHC=(O)NHNH₂, -NHC=(O)NH₂, -NHSO₂H, -NHC=(O)H, -NHC(O)-OH,
-NHOH, -OCX₃, -OCHX₂, -OCH₂X, substituted or unsubstituted alkyl, substituted or
unsubstituted heteroalkyl, substituted or unsubstituted cycloalkyl, substituted or unsubstituted
heterocycloalkyl, substituted or unsubstituted aryl, substituted or unsubstituted heteroaryl. Two
10 of R₁, R₂, R₃, R₄, R₅, R₆, R⁷, R⁸, R⁹, and R¹⁰ may independently optionally be joined to form a
substituted or unsubstituted cycloalkyl, substituted or unsubstituted heterocycloalkyl, substituted
or unsubstituted aryl, substituted or unsubstituted heteroaryl. In embodiments, R₁, R₂, R₃, R₄, R₅,
R₆, R⁷, R⁸, R⁹, and R¹⁰ are independently halogen, -CX₃, -CHX₂, -CH₂X, -CN, -OH, -NH₂,
-COOH, -CONH₂, -NO₂, -SH, -SO₃H, -SO₄H, -SO₂NH₂, -NHNH₂, -ONH₂, -NHC=(O)NHNH₂,

-NHC=(O)NH₂, -NHSO₂H, -NHC=(O)H, -NHC(O)-OH, -NHOH, -OCX₃, -OCHX₂, -OCH₂X, substituted or unsubstituted alkyl, substituted or unsubstituted heteroalkyl, substituted or unsubstituted cycloalkyl, substituted or unsubstituted heterocycloalkyl, substituted or unsubstituted aryl, substituted or unsubstituted heteroaryl. Two of R₁, R₂, R₃, R₄, R₅, R₆, R⁷, R⁸, R⁹, and R¹⁰ may independently optionally be joined to form a substituted or unsubstituted cycloalkyl, substituted or unsubstituted heterocycloalkyl, substituted or unsubstituted aryl, substituted or unsubstituted heteroaryl. In embodiments, R₁, R₂, R₃, R₄, R₅, R₆, R⁷, R⁸, R⁹, and R¹⁰ are independently hydrogen.

[0250] In embodiments, R₁, R₂, R₃, R₄, R₅, R₆, R⁷, R⁸, R⁹, and R¹⁰ are independently substituted (e.g., substituted with a substituent group, a size-limited substituent group, or lower substituent group) or unsubstituted alkyl, substituted (e.g., substituted with a substituent group, a size-limited substituent group, or lower substituent group) or unsubstituted heteroalkyl, substituted (e.g., substituted with a substituent group, a size-limited substituent group, or lower substituent group) or unsubstituted cycloalkyl, substituted (e.g., substituted with a substituent group, a size-limited substituent group, or lower substituent group) or unsubstituted heterocycloalkyl, substituted (e.g., substituted with a substituent group, a size-limited substituent group, or lower substituent group) or unsubstituted aryl, or substituted (e.g., substituted with a substituent group, a size-limited substituent group, or lower substituent group) or unsubstituted heteroaryl. In embodiments, two of R₁, R₂, R₃, R₄, R₅, R₆, R⁷, R⁸, R⁹, and R¹⁰ may independently optionally be joined to form a substituted (e.g., substituted with a substituent group, a size-limited substituent group, or lower substituent group) or unsubstituted cycloalkyl, substituted (e.g., substituted with a substituent group, a size-limited substituent group, or lower substituent group) or unsubstituted heterocycloalkyl, substituted (e.g., substituted with a substituent group, a size-limited substituent group, or lower substituent group) or unsubstituted aryl, or substituted (e.g., substituted with a substituent group, a size-limited substituent group, or lower substituent group) or unsubstituted heteroaryl. In embodiments, wherein R₁, R₂, R₃, R₄, R₅, and R₆, are each independently selected from the group consisting of: (i) H; (ii) halogen; (iii) -CH₃, -C₂H₅, or C₃ to C₂₅ straight-chain, branched or cyclic alkane or alkene, optionally substituted with at least one member selected from the group consisting of Cl, Br, F, I, OH, NH₂ and SH; (iv) -CH₃, -C₂H₅, or C₃ to C₂₅ straight-chain, branched or cyclic alkane or alkene comprising one to three heteroatoms selected from the group consisting of O, N, Si and S, and optionally substituted with

at least one member selected from the group consisting of Cl, Br, F, I, OH, NH₂ and SH; (v) C₆ to C₂₀ unsubstituted aryl, or C₃ to C₂₅ unsubstituted heteroaryl having one to three heteroatoms independently selected from the group consisting of O, N, Si and S; and (vi) C₆ to C₂₅ substituted aryl, or C₃ to C₂₅ substituted heteroaryl having one to three heteroatoms independently selected from the group consisting of O, N, Si and S; wherein said substituted aryl or substituted heteroaryl has one to three substituents independently selected from the group consisting of: 1. -CH₃, -C₂H₅, or C₃ to C₂₅ straight-chain, branched or cyclic alkane or alkene, optionally substituted with at least one member selected from the group consisting of Cl, Br, F, I, OH, NH₂ and SH, 2. OH, 3. NH₂, and 4. SH. In embodiments, R⁷, R⁸, R⁹, and R¹⁰ are each independently selected from the group consisting of: (vii) -CH₃, -C₂H₅, or C₃ to C₂₅ straight-chain, branched or cyclic alkane or alkene, optionally substituted with at least one member selected from the group consisting of Cl, Br, F, I, OH, NH₂ and SH; (viii) -CH₃, -C₂H₅, or C₃ to C₂₅ straight-chain, branched or cyclic alkane or alkene comprising one to three heteroatoms selected from the group consisting of O, N, Si and S, and optionally substituted with at least one member selected from the group consisting of Cl, Br, F, I, OH, NH₂ and SH; (ix) C₆ to C₂₅ unsubstituted aryl, or C₃ to C₂₅ unsubstituted heteroaryl having one to three heteroatoms independently selected from the group consisting of O, N, Si and S; and (x) C₆ to C₂₅ substituted aryl, or C₃ to C₂₅ substituted heteroaryl having one to three heteroatoms independently selected from the group consisting of O, N, Si and S; wherein said substituted aryl or substituted heteroaryl has one to three substituents independently selected from the group consisting of: (1) -CH₃, -C₂H₅, or C₃ to C₂₅ straight-chain, branched or cyclic alkane or alkene, optionally substituted with at least one member selected from the group consisting of Cl, Br, F, I, OH, NH₂ and SH, (2) OH, (3) NH₂, and (4) SH; and wherein optionally at least two of R₁, R₂, R₃, R₄, R₅, R₆, R⁷, R⁸, R⁹, and R¹⁰ can together form a cyclic or bicyclic alkanyl or alkenyl group. In embodiments, an ionic liquid includes fluorinated cations wherein at least one member selected from R₁, R₂, R₃, R₄, R₅, R₆, R⁷, R⁸, R⁹, and R¹⁰, as described above, includes F.

[0251] In embodiments is included the extraction of medicinally, pharmaceutically, or other economically valuable organic compounds, including but not limited to terpenes, alkaloids, aromatic oils, and essential oils (e.g., for preparation of flavors and fragrances). In embodiments, the extraction includes use of two different fluorophilic compounds, specifically a fluorocarbon and a hydrofluorocarbon. In embodiments, is included the extraction of

medicinally, pharmaceutically, or other economically valuable organic compounds, including but not limited to terpenes, alkaloids, and essential oils (e.g., for preparation of flavors and fragrances). In embodiments, the extraction includes use of three different chemical compounds, including two different fluorophilic compounds (e.g., a fluorocarbon and a hydrofluorocarbon), and an alkane. In embodiments, the extraction includes use of three different fluorophilic chemical compounds, including two different fluorophilic compounds (e.g., a fluorocarbon and a hydrofluorocarbon), and a fluorinated ether. In embodiments, the mixture is a fluorocarbon and an ionic liquid.

[0252] In embodiments, a natural organic compound is extracted from a natural material (e.g., plant, animal, fungi, bacteria, or virus). In embodiments, the natural material is a plant. In embodiments, the plant is *Piper methysticum*, *Cannabis spp.*, *Salvia spp.*, *Banisteriopsis caapi*, *Psychotria viridis (chacrana)*, *Diplopterys cabrerana*, *Peganum harmala*, *Humulus lupulus* or mixtures thereof. In embodiments, the plant is *Piper methysticum*. In embodiments, the plant is *Cannabis spp.* In embodiments, the plant is *Salvia spp.* In embodiments, the plant is *Banisteriopsis caapi*. In embodiments, the plant is *Psychotria viridis (chacrana)*. In embodiments, the plant is *Diplopterys cabrerana*. In embodiments, the plant is *Peganum harmala*. In embodiments, the plant is *Humulus lupulus*.

[0253] In embodiments, are methods of extracting natural organic compounds from natural materials. In embodiments, natural organic compound includes biologically active organic compound. In embodiments, the natural organic compound includes aromatic oil and/or essential oil. In embodiments, the natural organic compound includes aromatic oil. In embodiments, the natural organic compound includes essential oil. In embodiments, the natural organic compound is in an aromatic oil and/or essential oil. In embodiments, the natural organic compound is an aromatic oil. In embodiments, the natural organic compound is an essential oil. In embodiments, the natural organic compound is caffeine, terpene, a humulone, a lupulone, a myrcene, a humulene, a caryophyllene, an alkaloid, a flavonoid, a cannabinoid, menthol, capsaicin, anise, camphor, xanthohumol, 8-prenylnaringenin, isoxanthohumol, prenylflavonoid, kavalactone, or a salvorin. In embodiments, the natural organic compound is caffeine. In embodiments, the natural organic compound is terpene. In embodiments, the natural organic compound is a humulone. In embodiments, the natural organic compound is a lupulone. In

embodiments, the natural organic compound is a myrcene. In embodiments, the natural organic compound is a humulene. In embodiments, the natural organic compound is a caryophyllene. In embodiments, the natural organic compound is an alkaloid. In embodiments, the natural organic compound is a flavonoid. In embodiments, the natural organic compound is a cannabinoid. In
5 embodiments, the natural organic compound is menthol. In embodiments, the natural organic compound is capsaicin. In embodiments, the natural organic compound is anise. In embodiments, the natural organic compound is camphor. In embodiments, the natural organic compound is xanthohumol. In embodiments, the natural organic compound is 8-prenylnaringenin. In embodiments, the natural organic compound is isoxanthohumol. In
10 embodiments, the natural organic compound is prenylflavonoid. In embodiments, the natural organic compound is kavalactone. In embodiments, the natural organic compound is a salvorin. In embodiments, the natural organic compound is cannabinoid. In embodiments, the cannabinoid is tetrahydrocannabinol, cannabidiol, or cannabinol. In embodiments, the cannabinoid is cannabidiol. In embodiments, the cannabinoid is cannabinol. In embodiments,
15 the natural organic compound is tetrahydrocannabinol.

[0254] In embodiments, the plant, animal, fungi, bacteria, or virus material used is cannabis. Multiple medicinal uses have been found for the active ingredients of cannabis, either *Cannabis spp.* but most commonly *Cannabis sativa*. Other plants than *Cannabis spp.* may contain useful cannabinoid activity, or may possess compounds, typically terpeneoid in character, which
20 possess micromolar or higher affinity for the CB₁ or CB₂ cannabinoid receptors present in a man, animal, or bird.

[0255] Cannabinoids present in cannabis include the ingredients tetrahydrocannabinol, cannabinol, cannabidiol, and cannabichromene. The medicinal uses of cannabis include but are not limited to: epilepsy ((Porter, Brenda E., and Catherine Jacobson. "Report of a parent survey of cannabidiol-enriched cannabis use in pediatric treatment-resistant epilepsy." *Epilepsy & Behavior* 29, no. 3 (2013): 574-577, which is incorporated herein by reference for all purposes));
25 pain ((Cooper, Ziva D., Sandra D. Comer, and Margaret Haney. "Comparison of the analgesic effects of dronabinol and smoked marijuana in daily marijuana smokers." *Neuropsychopharmacology* 38, no. 10 (2013): 1984-1992; Kahan, Meldon, Anita
30 Srivastava, Sheryl Spithoff, and Lisa Bromley. "Prescribing smoked cannabis for chronic

noncancer pain Preliminary recommendations.” *Canadian Family Physician* 60, no. 12 (2014): 1083-1090; Wilsey, Barth, Thomas Marcotte, Reena Deutsch, Ben Gouaux, Staci Sakai, and Haylee Donaghe. “Low-dose vaporized cannabis significantly improves neuropathic pain.” *The Journal of Pain* 14, no. 2 (2013): 136-148, which are incorporated herein by reference for all purposes)), specifically as evidenced in the treatment of nausea and pain associated with cancer and chemotherapy ((United States Patent Document US 8,119,697, Anti-Nausea and Anti Vomiting Activity of Cannabadiol Compounds, which is incorporated herein by reference for all purposes)); viral infection ((Molina, Patricia E., Peter Winsauer, Ping Zhang, Edith Walker, Leslie Birke, Angela Amedee, Curtis Vande Stouwe et al. “Cannabinoid administration attenuates the progression of simian immunodeficiency virus.” *AIDS research and human retroviruses* 27, no. 6 (2011): 585-592, which is incorporated herein by reference for all purposes)); AIDS-related pain and Wasting; multiple sclerosis ((Svendsen, Kristina B., Troels S. Jensen, and Flemming W. Bach. “Does the cannabinoid dronabinol reduce central pain in multiple sclerosis? Randomized double blind placebo controlled crossover trial.” *Bmj* 329, no. 7460 (2004): 253, which is incorporated herein by reference for all purposes)) arthritis; rheumatism; glaucoma ((Hingorani, Tushar, Waseem Gul, Mahmoud Elsohly, Michael A. Repka, and Soumyajit Majumdar. “Effect of ion pairing on in vitro transcorneal permeability of a Δ^9 -tetrahydrocannabinol prodrug: Potential in glaucoma therapy.” *Journal of pharmaceutical sciences* 101, no. 2 (2012): 616-626, which is incorporated herein by reference for all purposes)); migraines; muscle spasticity; chemical dependency. Research studies further suggest that cannabis and its components have utility in oncology ((Chakravarti, Bandana, Janani Ravi, and Ramesh K. Ganju. “Cannabinoids as therapeutic agents in cancer: current status and future implications.” *Oncotarget* 5, no. 15 (2014): 5852), Parkinson’s disease (see, for example, More, Sandeep Vasant, and Dong-Kug Choi. “Promising cannabinoid-based therapies for Parkinson’s disease: motor symptoms to neuroprotection.” *Molecular neurodegeneration* 10, no. 1 (2015): 1-26, which is incorporated herein by reference for all purposes), In embodiments, extracted material is used as a composition to treat post-herpetic neuralgia, shingles, burns, actinic keratosis, oral cavity sores, oral ulcers, post-episiotomy pain, psoriasis, pruritus, contact dermatitis, eczema, bullous dermatitis herpetiformis, exfoliative dermatitis, mycosis fungoides, pemphigus, severe erythema multiforme, seborrheic dermatitis, psoriatic arthritis, diabetic neuropathy, ankylosing spondylitis, Reiter’s syndrome, gout, chondrocalcinosis, joint pain

secondary to dysmenorrhea, fibromyalgia (Fiz, Jimena, Marta Durán, Dolors Capellà, Jordi Carbonell, and Magí Farré. “Cannabis use in patients with fibromyalgia: effect on symptoms relief and health-related quality of life.” (2011): e18440, which is incorporated herein by reference for all purposes), musculoskeletal pain, neuropathic-postoperative complications, polymyositis, acute nonspecific tenosynovitis, bursitis, epicondylitis, post-traumatic osteoarthritis, synovitis, juvenile rheumatoid arthritis, contact eczema, allergies (not otherwise specified), phototoxic reactions, inflammatory and itching dermatoses, rosacea, perioral dermatitis, acne, acne, psoriasis, mosquito and other insect bites, skin atrophy, allergic rhinitis, conjunctivitis, otitis, bronchial asthma, Crohn’s disease, ulcerative colitis, sarcoidosis, inflammatory-rheumatic diseases of the soft tissue or joints, mycoses, or combinations thereof.

[0256] In embodiments, the plant is *Cannabis spp.* In embodiments, the apparatus, method, or composition includes Freon ^(TM) 134a (1,1,1,2-Tetrafluoroethane). In embodiments, the apparatus, method, or composition includes Freon ^(TM) 134a (1,1,1,2-Tetrafluoroethane) and optionally one or more of carbon dioxide, nitrous oxide, sulfur hexafluoride, trifluoromethane, trifluoromethyl iodide, or tetrafluoromethane. The apparatus, method, or composition may include two extraction components, one component used in the extraction is Freon ^(TM) 134a (1,1,1,2-Tetrafluoroethane) and another is selected from the optional group of gases carbon dioxide, nitrous oxide, sulfur hexafluoride, trifluoromethane, trifluoromethyl iodide, or tetrafluoromethane. In embodiments, one component used in the extraction is Freon ^(TM) 134a (1,1,1,2-Tetrafluoroethane) within the range of 20 mol-% to 99 mol-% and another is selected from the optional group of gases consisting of carbon dioxide, nitrous oxide, sulfur hexafluoride, trifluoromethane, trifluoromethyl iodide, or tetrafluoromethane in the range independently from 80 mol-% to 1 mol-%. In embodiments, one component used in the extraction is Freon ^(TM) 134a (1,1,1,2-Tetrafluoroethane) within the range of 80 mol-% to 90 mol-% and another is selected from the optional group of gases consisting of carbon dioxide, nitrous oxide, sulfur hexafluoride, trifluoromethane, trifluoromethyl iodide, or tetrafluoromethane in the range independently from 10 mol-% to 20 mol-%. In embodiments, one component used in the extraction consists of Freon ^(TM) 134a (1,1,1,2-Tetrafluoroethane) within the range of 80 mol-% to 90 mol-% and another is selected from the optional group of gases consisting of carbon dioxide, nitrous oxide, sulfur hexafluoride, trifluoromethane, trifluoromethyl iodide, or tetrafluoromethane in the range

independently from 9 mol-% to 19 mol-% where ethanol is present in the range from 1 mol-% to 10 mol-%).

[0257] In embodiments, the plant material used is *Salvia spp.* Multiple medicinal uses have been found for the active ingredients of *Salvia spp.* in particular achieving sedation and tranquilization in psychiatric and neurological disorders and treatment of insomnia (see for example Perron, Brian E., Brian K. Ahmedani, Michael G. Vaughn, Joseph E. Glass, Arnelyn Abdon, and Li-Tzy Wu. "Use of *Salvia divinorum* in a nationally representative sample." *The American journal of drug and alcohol abuse* 38, no. 1 (2012): 108-113.; Potter, David N., Diane Damez-Werno, William A. Carlezon, Bruce M. Cohen, and Elena H. Chartoff. "Repeated exposure to the κ -opioid receptor agonist salvinorin A modulates extracellular signal-regulated kinase and reward sensitivity." *Biological psychiatry* 70, no. 8 (2011): 744-753; Teksin, Zeynep S., Insong J. Lee, Noble N. Nemieboka, Ahmed A. Othman, Vijay V. Upreti, Hazem E. Hassan, Shariq S. Syed, Thomas E. Prisinzano, and Natalie D. Eddington. "Evaluation of the transport, in vitro metabolism and pharmacokinetics of Salvinorin A, a potent hallucinogen." *European Journal of Pharmaceutics and Biopharmaceutics* 72, no. 2 (2009): 471-477, which are incorporated herein by reference for all purposes). Salvinorin A and other closely related salvinorins have substantial activity at the nanomolar level on kappa-type opioid receptors, which are involved, among other things, in analgesia. Accordingly, the extracts obtained from *Salvia spp.* are of utility of the treatment and amelioration of the disease process as well as the symptomatology of a variety diseases and pathological conditions, such as pain, especially neuropathic pain and cancer-breakthrough pain, which would normally be responsive to opioids.

[0258] In embodiments, the plant is *Salvia spp.* In embodiments, the apparatus, method, or composition includes Freon^(TM) 134a (1,1,1,2-Tetrafluoroethane). In embodiments, the apparatus, method, or composition includes Freon^(TM) 134a (1,1,1,2-Tetrafluoroethane) and optionally one or more of carbon dioxide, nitrous oxide, sulfur hexafluoride, trifluoromethane, trifluoromethyl iodide, or tetrafluoromethane. The apparatus, method, or composition may include two extraction components, one component used in the extraction is Freon^(TM) 134a (1,1,1,2-Tetrafluoroethane) and another is selected from the optional group of gases consisting of carbon dioxide, nitrous oxide, sulfur hexafluoride, trifluoromethane, trifluoromethyl iodide, or tetrafluoromethane. In embodiments, one component used in the extraction is Freon^(TM) 134a

(1,1,1,2-Tetrafluoroethane) within the range of 20 mol-% to 99 mol-% and another is selected from the optional group of gases consisting of carbon dioxide, nitrous oxide, sulfur hexafluoride, trifluoromethane, trifluoromethyl iodide, or tetrafluoromethane in the range independently from 80 mol-% to 1 mol-%. In embodiments, one component used in the extraction is Freon ^(TM)

5 134a (1,1,1,2-Tetrafluoroethane) within the range of 80 mol-% to 90 mol-% and another is selected from the optional group of gases consisting of carbon dioxide, nitrous oxide, sulfur hexafluoride, trifluoromethane, trifluoromethyl iodide, or tetrafluoromethane in the range independently from 10 mol-% to 20 mol-%. In embodiments, one component used in the extraction is Freon ^(TM) 134a (1,1,1,2-Tetrafluoroethane) within the range of 80 mol-% to 90
10 mol-% and another is selected from the optional group of gases consisting of carbon dioxide, nitrous oxide, sulfur hexafluoride, trifluoromethane, trifluoromethyl iodide, or tetrafluoromethane in the range independently from 9 mol-% to 19 mol-% where ethanol is present in the range from 1 mol-% to 10 mol-%.

[0259] In embodiments, the plant material used is *Banisteriopsis caapi*, *Psychotria viridis*
15 (*chacrana*), *Diplopterys cabrerana* (also known as chaliponga and chagropanga), *Peganum harmala*, or any mixture thereof. Multiple medicinal uses have been found for the active ingredients of *Banisteriopsis caapi*, *Psychotria viridis* (*chacrana*), *Diplopterys cabrerana* (also known as chaliponga and chagropanga), *Peganum harmala*, or any mixture thereof, in particular achieving sedation and tranquilization in psychiatric and neurological disorders and treatment of
20 insomnia. See, for example, Riba, Jordi, Marta Valle, Gloria Urbano, Mercedes Yritia, Adelaida Morte, and Manel J. Barbanoj. "Human pharmacology of ayahuasca: subjective and cardiovascular effects, monoamine metabolite excretion, and pharmacokinetics." *Journal of Pharmacology and Experimental Therapeutics* 306, no. 1 (2003): 73-83; Rivier, Laurent, and Jan-Erik Lindgren. "'Ayahuasca,' the South American hallucinogenic drink: An ethnobotanical
25 and chemical investigation." *Economic Botany* 26, no. 2 (1972): 101-129, which are incorporated herein by reference for all purposes. Accordingly, the extracts obtained from *Banisteriopsis caapi*, *Psychotria viridis* (*chacrana*), *Diplopterys cabrerana* (also known as chaliponga and chagropanga), *Peganum harmala*, or any mixture thereof. Such mixtures are of utility of the treatment and amelioration of the disease process as well as the symptomatology of
30 the diseases and pathological conditions, especially in the treatment of psychiatric disorders, such as depression.

[0260] In embodiments, the plant is *Banisteriopsis caapi*, *Psychotria viridis* (chacrana), *Diplopterys cabrerana* (also known as chaliponga and chagropanga), *Peganum harmala*, or any mixture thereof. In embodiments, the plant is *Banisteriopsis caapi*. In embodiments, the plant is *Psychotria viridis* (chacrana). In embodiments, the plant is *Diplopterys cabrerana* (also known as chaliponga and chagropanga). In embodiments, the plant is *Peganum harmala*. In 5 embodiments, the apparatus, method, or composition includes Freon ^(TM) 134a (1,1,1,2-Tetrafluoroethane). In embodiments, the apparatus, method, or composition includes Freon ^(TM) 134a (1,1,1,2-Tetrafluoroethane) and optionally one or more of carbon dioxide, nitrous oxide, sulfur hexafluoride, trifluoromethane, trifluoromethyl iodide, or tetrafluoromethane. The 10 apparatus, method, or composition may include two extraction components, one component used in the extraction is Freon ^(TM) 134a (1,1,1,2-Tetrafluoroethane) and another is selected from the optional group of gases consisting of carbon dioxide, nitrous oxide, sulfur hexafluoride, trifluoromethane, trifluoromethyl iodide, or tetrafluoromethane. In embodiments, one component used in the extraction is Freon ^(TM) 134a (1,1,1,2-Tetrafluoroethane) within the range of 20 mol- 15 % to 99 mol-% and another is selected from the optional group of gases consisting of carbon dioxide, nitrous oxide, sulfur hexafluoride, trifluoromethane, trifluoromethyl iodide, or tetrafluoromethane in the range independently from 80 mol-% to 1 mol-%. In embodiments, one component used in the extraction is Freon ^(TM) 134a (1,1,1,2-Tetrafluoroethane) within the range of 80 mol-% to 90 mol-% and another is selected from the optional group of gases consisting of 20 carbon dioxide, nitrous oxide, sulfur hexafluoride, trifluoromethane, trifluoromethyl iodide, or tetrafluoromethane in the range independently from 10 mol-% to 20 mol-%. In embodiments, one component used in the extraction is Freon ^(TM) 134a (1,1,1,2-Tetrafluoroethane) within the range of 80 mol-% to 90 mol-% and another is selected from the optional group of gases consisting of carbon dioxide, nitrous oxide, sulfur hexafluoride, trifluoromethane, 25 trifluoromethyl iodide, or tetrafluoromethane in the range independently from 9 mol-% to 19 mol-% where ethanol is present in the range from 1 mol-% to 10 mol-%.

[0261] In embodiments, the plant material used is kava (*Piper myristicum*). Multiple medicinal uses have been found for the active ingredients of kava (*Piper myristicum*), in particular achieving sedation and tranquilization in psychiatric and neurological disorders and treatment of 30 insomnia and anxiety. See, for example, Volz, Hans-Peter, and M. Kieser. "Kava-kava extract WS 1490 versus placebo in anxiety disorders: A randomized placebo-controlled 25-week

outpatient trial.” *Pharmacopsychiatry* (1997). Sarris, J., D. J. Kavanagh, G. Byrne, K. M. Bone, J. Adams, and G. Deed. “The Kava Anxiety Depression Spectrum Study (KADSS): a randomized, placebo-controlled crossover trial using an aqueous extract of *Piper methysticum*.” *Psychopharmacology* 205, no. 3 (2009): 399-407, which are incorporated herein by reference for all purposes. However, there have been reports of hepatotoxicity due to Kava (Clouatre, Dallas L. “Kava: examining new reports of toxicity.” *Toxicology letters* 150, no. 1 (2004): 85-96, which is incorporated herein by reference for all purposes); better extraction procedures could offer the promise of ameliorating these difficulties if only the active kavalactones, which account for much of the biological activity, could be extracted in a substantially purer form. The extracts obtained from kava are of utility of the treatment and amelioration of the disease process as well as the symptomatology of the diseases and pathological conditions.

[0262] In embodiments, the plant is *Piper methysticum* (Kava). In embodiments, the apparatus, method, or composition includes Freon ^(TM) 134a (1,1,1,2-Tetrafluoroethane). In embodiments, the apparatus, method, or composition includes Freon ^(TM) 134a (1,1,1,2-Tetrafluoroethane) and optionally one or more of carbon dioxide, nitrous oxide, sulfur hexafluoride, trifluoromethane, trifluoromethyl iodide, or tetrafluoromethane. The apparatus, method, or composition may include two extraction components (e.g., one component used in the extraction is Freon ^(TM) 134a (1,1,1,2-Tetrafluoroethane) and another is selected from the optional group of gases consisting of carbon dioxide, nitrous oxide, sulfur hexafluoride, trifluoromethane, trifluoromethyl iodide, or tetrafluoromethane. In embodiments, one component used in the extraction consists of Freon ^(TM) 134a (1,1,1,2-Tetrafluoroethane) within the range of 20 mol-% to 99 mol-% and another is selected from the optional group of gases consisting of carbon dioxide, nitrous oxide, sulfur hexafluoride, trifluoromethane, trifluoromethyl iodide, or tetrafluoromethane in the range independently from 80 mol-% to 1 mol-%. In embodiments, one component used in the extraction is Freon ^(TM) 134a (1,1,1,2-Tetrafluoroethane) within the range of 80 mol-% to 90 mol-% and another is selected from the optional group of gases consisting of carbon dioxide, nitrous oxide, sulfur hexafluoride, trifluoromethane, trifluoromethyl iodide, or tetrafluoromethane in the range independently from 10 mol-% to 20 mol-%.

III. Examples

[0263] The following examples illustrate certain specific embodiments of the invention and are not meant to limit the scope of the invention.

[0264] Embodiments herein are further illustrated by the following examples and detailed protocols. However, the examples are merely intended to illustrate embodiments and are not to be construed to limit the scope herein. The contents of all references and published patents and patent applications cited throughout this application are hereby incorporated by reference.

[0265] A problem in pharmaceutical chemistry relates to extraction of useful substances from plants or animals where such useful substances are employed for the formulation of a pharmaceutical or a nutraceutical. For example, morphine is a pharmaceutically highly useful material. All morphine used today originates in natural opium, which is obtained exclusively by extraction from *Papaver somniferum* (opium poppies), which is supplied primarily from India, Afghanistan, and Turkey where the poppies contain up to 20% of morphine in their latex. There are many total synthetic pathways to morphine but to date there is no reported synthesis of the alkaloid that would show much promise for a large-scale manufacturing (Zezula, Josef, and Tomas Hudlicky. "Recent progress in the synthesis of morphine alkaloids." *Synlett* 3 (2005): 388-405, which is incorporated herein by reference for all purposes). Thus the supply of morphine remains dependent upon extraction of plant material.

[0266] Alternatively, the extracted useful substance may be employed as a synthetic intermediate in the manufacture of other drugs which are formulated as a pharmaceutical dosage form or a nutraceutical. As an example, thebaine is an opium alkaloid which is also extracted from opium poppies which itself is somewhat toxic and convulsant and when administered as a drug has no medical value. However, thebaine is used as the key intermediate for the synthesis of most of the non-natural opiates used in clinical practice. See, for example, Schiff, Paul L. "Opium and its alkaloids." *American Journal of Pharmaceutical Education* 66.2 (2002): 188-196 ; Tolstikova, TG. AV Bolkunov, EA Morozova, and SE Tolstikov. "Thebaine as a Precursor of Opioid Analgesic Agents." *Chemistry for Sustainable Development* 17 (2009) 109-126, which are incorporated herein by reference for all purposes.

[0267] Plants may be shrubs, trees, roots, berries, or other components of normal terrestrial plants, or they can be plants present in freshwater aquatic or marine environments. For examples of the latter, see Rocha, Fabíola Dutra, Angélica Ribeiro Soares, Peter John Houghton, Renato Crespo Pereira, Maria Auxiliadora Coelho Kaplan, and Valéria Laneuville Teixeira. “Potential cytotoxic activity of some Brazilian seaweeds on human melanoma cells.” *Phytotherapy Research* 21, no. 2 (2007): 170-175, which is incorporated herein by reference for all purposes.

[0268] Although in many cases plants represent the major source of naturally occurring compounds which are useful in the prevention and treatment of diseases in humans and animals other natural sources can be important as a source of these materials. For example, many drugs have been derived from marine natural products (Jha, Rajeev Kumar, and Xu Zi-rong. “Biomedical compounds from marine organisms.” *Marine drugs* 2.3 (2004): 123-146, which is incorporated herein by reference for all purposes).

[0269] Also, many marine drugs are extracted from organisms. See, for example, Thornburg, Christopher C., T. Mark Zabriskie, and Kerry L. McPhail. “Deep-Sea Hydrothermal Vents: Potential Hot Spots for Natural Products Discovery?” *Journal of natural products* 73, no. 3 (2010): 489-499, Pettit, George R., Jun-ping Xu, Zbigniew A. Cichacz, Michael D. Williams, Ann-Christine Dorsaz, Daniel C. Brune, Michael R. Boyd, and Ronald L. Cerny. “Antineoplastic agents 315. Isolation and structure of the marine sponge cancer cell growth inhibitor phakellistatin 5.” *Bioorganic & Medicinal Chemistry Letters* 4, no. 17 (1994): 2091-2096. ; Yosief, Tesfamariam, Amira Rudi, and Yoel Kashman. “Asmarines AF, novel cytotoxic compounds from the marine sponge *Raspailia* species.” *Journal of natural products* 63, no. 3 (2000): 299-304. Numata, Atsushi, Taro Amagata, Katsuhiko Minoura, and Tadayoshi Ito. “Gymnastatins, novel cytotoxic metabolites produced by a fungal strain from a sponge.” *Tetrahedron letters* 38, no. 32 (1997): 5675-5678.; Kobayashi, Jun'ichi, Shinji Takeuchi, Masami Ishibashi, Hideyuki Shigemori, and Takuma Sasaki. “Plakotenin, a new cytotoxic carboxylic acid from the okinawan marine sponge *plakortis* Sp.” *Tetrahedron letters* 33, no. 18 (1992): 2579-2580. ; Washida, Kazuto, Tomoyuki Koyama, Kaoru Yamada, Masaki Kita, and Daisuke Uemura. “Karatungiols A and B, two novel antimicrobial polyol compounds, from the symbiotic marine dinoflagellate *Amphidinium* sp.” *Tetrahedron letters* 47, no. 15 (2006): 2521-2525, Kwon, Hak Cheol, Christopher A. Kauffman, Paul R. Jensen, and William Fenical.

“Marinomycins AD, antitumor-antibiotics of a new structure class from a marine actinomycete of the recently discovered genus ‘Marinisporea’.” *Journal of the American Chemical Society* 128, no. 5 (2006): 1622-1632, which are incorporated herein by reference for all purposes. Drugs may extracted from many sources. See, for example, Yan, Yong-Ming, Jun Ai, Yan-Ni Shi, Zhi-Li Zuo, Bo Hou, Jie Luo, and Yong-Xian Cheng. “(±)-Aspongamide A, an N-Acetyldopamine Trimer Isolated from the Insect *Aspongopus chinensis*, Is an Inhibitor of p-Smad3.” *Organic letters* 16, no. 2 (2014): 532-535, Whitehouse, M. W., A. G. Turner, C. K. C. Davis, and M. S. Roberts. “Emu oil (s): a source of non-toxic transdermal anti-inflammatory agents in aboriginal medicine.” *Inflammopharmacology* 6, no. 1 (1998): 1-8, which are incorporated herein by reference for all purposes.

[0270] It should further be noted that typically natural products, including but not limited to marine natural products, and natural products from terrestrial plants, may contain multiple chiral centers which manifest optical activity. In general, this complicates the total synthesis of these natural products from commercially available achiral molecules. Although many methods exist in modern organic chemistry to perform enantioselective or chiral synthetic steps in high yield as well as to form multiple chiral centers in the correct stereochemical relation to each other in a single chemical step, many of these procedures are not well scalable from milligram scale in the laboratory to kilogram scale in production. Accordingly, semisynthesis is commonly employed. For example although there are many total syntheses of Paclitaxel, an important cancer drug, it is still produced from cells maintained in plant tissue culture derived from the pacific yew tree, *Taxus brevifolia* as none of the total syntheses are practical at large scale and there is not much possibility that they will ever be.

[0271] Many methods have been developed for extraction of natural products most particularly from plant, animal, fungi, bacteria, or viruses, where this has been historically important long before the advent of modern medicine in the preparation of materials required for the fragrance industry, such as the formulation of perfumes. These have been reviewed. See, for example, Wang, Lijun, and Curtis L. Weller. “Recent advances in extraction of nutraceuticals from plants.” *Trends in Food Science & Technology* 17, no. 6 (2006): 300-312, which is incorporated herein by reference for all purposes. The oldest methods, which are still used, involve steam distillation, co-distillation with a solvent, typically ethanol, or Soxhlet extraction with an organic

solvent. In these processes, the water, ethanol or organic solvent which co-distills with the desired mixture of natural products is removed, leaving the final product, typically as an oil, which may in its impure state may still be highly desired in the fragrance industry. For example Otto of roses is produced by steam distillation of rose (*Rosa damascene*) petals and is an important item of commerce in the perfume industry. However, steam distillation is an extremely inefficient and laborious process in practice, and it cannot be applied effectively to molecules which are somewhat polar in aqueous solution, as is, for example, the case with most alkaloids.

[0272] Extraction with organic solvents has been used for obtaining desired valuable substances from natural product plant, animal, fungi, bacteria, or virus material. This could involve Soxhlet extraction (De Castro, MD Luque, and F. Priego-Capote. "Soxhlet extraction: Past and present panacea." Journal of Chromatography A 1217, no. 16 (2010): 2383-2389, which is incorporated herein by reference for all purposes) whereby solvent is heated under reflux and the refluxed solvent is passed over a porous thimble containing the natural product. The natural product material is continually washed with fresh solvent in this approach, allowing the removal of much more product than would otherwise be possible because the amount in solution is not limited by equilibrium solubility of the solute in the solvent. While this approach is useful with highly soluble material, especially at the laboratory scale it becomes physically inefficient from the point of view of solvent and material handling at greater than a kilo scale. To some this can be addressed by using a different design, such as a fluidized bed extractor.

[0273] Extraction with hydrocarbon gases is also a useful technique, especially for the isolation of extremely hydrophobic materials such as waxes and oils (US5405633, Process for the extraction of fats and oils; European Patent Office Document EP0711508A1, Verfahren zur Extraktion von natürlichen Aromen aus fett- und ölhaltigen Naturstoffen.; Nobre, Beatriz P., Luisa Gouveia, Patricia GS Matos, Ana F. Cristino, António F. Palavra, and Rui L. Mendes. "Supercritical extraction of lycopene from tomato industrial wastes with ethane." Molecules 17, no. 7 (2012): 8397-8407); which are incorporated herein by reference. Propane versus supercritical CO₂, is ten times more efficient at extracting carotenoids from pepper. See, for example, Daood, H. G., V. Illés, M. H. Gnayfeed, B. Mészáros, G. Horváth, and P. A. Biacs. "Extraction of pungent spice paprika by supercritical carbon dioxide and subcritical propane."

The Journal of supercritical fluids 23, no. 2 (2002): 143-152, which is incorporated herein by reference for all purposes. However, these processes which employ ethane, propane, or butane although they can be worked safely still present a prima facie serious risk of fire or explosion, and great care must be taken on an industrial scale to avoid this. In “backyard” extraction of cannabis by this approach, many serious fires and explosions have occurred. See, for example, Downs, D. “Don't Try This At Home: Butane Hash Oil Penalties Stiffen”, East Bay Express August 11, 2015, which is incorporated herein by reference for all purposes. Also, although solvent extraction processes are used on a commercial scale, the extraction solvents which are currently used in these processes are not wholly satisfactory. Thus, when solvents such as hexane are used to extract aromatic oils, such as are used in the food and cosmetic industries, from plant matter containing those oils, unwanted materials contained in the plant, animal, fungi, bacteria, or virus, e.g. high molecular weight waxes, tend to be eluted along with the desired oil. This then can necessitate a further costly purification step [US2467403, Solvent extraction of castor oils, which is incorporated herein by reference for all purposes].

[0274] Halogenated solvents, such as dichloromethane or bromomethane, have been used for extraction of natural products (US2294811 Crystallized glucoside from red squill; US2472121, Decaffeinated soluble coffee; US 2010/0314240, Process of extracting aromatic compounds from plants using bromomethane as a solvent, which are incorporated herein by reference for all purposes). By the use of a phase transfer catalyst even relatively polar alkaloids can be efficiently extracted (US 4818533, Production of high purity alkaloids, which is incorporated herein by reference for all purposes). However, the use of these halogenated solvents has been diminished greatly in recent years for substances of pharmaceutical or nutraceutical activity due to concerns about solvent residues, even at the parts-per-million levels, in the final product, since these halogenated solvents are known to be toxic and some such as chloroform and bromomethane to be putative carcinogens.

[0275] More recently, steam distillation, co-distillation with a solvent, typically ethanol, or Soxhlet extraction have been substantially superseded except in “niche” applications by a method employing extraction with supercritical gases, most particularly supercritical carbon dioxide (CO₂). This method employs CO₂ under substantial temperature and pressure, typically greater than 200 atmospheres and at a temperature between 40°C and 80°C. This has recently

been reviewed. See, for example, De Melo, M. M. R., A. J. D. Silvestre, and C. M. Silva.

“Supercritical fluid extraction of vegetable matrices: applications, trends and future perspectives of a convincing green technology.” *The Journal of Supercritical Fluids* 92 (2014): 115-176, which is incorporated herein by reference for all purposes. Originally, this methodology was adopted on an industrial scale for decaffeination of coffee, when it was recognized that it was highly undesirable to utilize chlorinated solvents, such as dichloromethane, which leave trace solvent residues. See US2472121, Decaffeinated soluble coffee, which is incorporated herein by reference for all purposes. The methodology is described in US4820537 Method for decaffeinating coffee with a supercritical fluid; US5288511 Supercritical carbon dioxide decaffeination of acidified coffee, which are incorporated herein by reference for all purposes. The caffeine may be economically recovered (US4996317 Caffeine recovery from supercritical carbon dioxide, which is incorporated herein by reference for all purposes).

[0276] Though this approach has become widely used for extraction of plants, it suffers from a number of important deficiencies. In the first place, the temperatures and pressures which are required result in the need for specialized pressure vessels and high pressure pumps, and although such equipment is commercially available, it can become extremely expensive if a large scale (hundreds of kilograms of plant, animal, fungi, bacteria, or virus material per batch) is required. Since many natural products are present at concentrations in the plant, animal, fungi, bacteria, or virus which are relatively low, in many cases a few percent by weight or less, multiple large batches of raw plant, animal, fungi, bacteria, or virus material frequently need to be processed if a few to tens of kilo/day quantities of extract are required. In many cases, economic requirements dictate hundreds of kilos per day to be produced of extract in order for the extractive process to be run in a manner which is profitable. At this scale, supercritical CO₂ extraction becomes extremely expensive in terms of capital requirements for plant, animal, fungi, bacteria, or virus construction. Furthermore, because CO₂'s vapor pressure at room temperature is greater than sixty times normal atmospheric pressure, the use of CO₂ in a process creates a potential safety hazard relative to the same process operated at one atmosphere operation. Clearly, there is a need for processes which can be run in more conventional equipment at significantly lower pressures and temperatures.

[0277] Many extraction processes which are generically termed “supercritical” in nature with regard to CO₂ pressures and temperatures are actually not carried out at temperatures above the critical temperature and critical pressure of the gas, but are actually carried out at temperatures slightly to substantially below these pressures and temperatures. However, below the critical point temperature and pressure the efficiency of extraction of valuable natural products by CO₂ is markedly reduced. It is therefore commonly the case that so-called “supercritical” CO₂ extraction is not as efficient as would be the case if it were truly carried out under supercritical conditions. This limitation, which is not solely a semantic one, also contributes to a deficiency of the CO₂ extraction procedure which must be recognized. An advantage of CO₂ under subcritical conditions is that the solubility of undesired waxes is substantially lower at slightly reduced pressures (Jha, Sujit Kumar, and Giridhar Madras. “Modeling the solubilities of high molecular weight n-alkanes in supercritical carbon dioxide.” *Fluid phase equilibria* 225 (2004): 59-62, which is incorporated herein by reference for all purposes).

[0278] It is generally recognized that liquid CO₂, regardless of whether it is used as the extracting fluid at fully supercritical conditions or at lower pressures and temperatures, is not a completely inert solvent. Carbon dioxide is relatively inert towards reactive compounds, but CO₂’s relative inertness should not be confused with complete inertness. For example, an attempt to conduct a hydrogenation in CO₂ over a platinum catalyst at 303 K will lead to the production of carbon monoxide CO, which itself could be quite reactive under the conditions of supercritical CO₂ extraction. Simple salts such as NaCl, KCl, and LiCl which are invariably present in plant material, especially if the said plant material has been heated, will serve efficiently to catalyze the addition of CO₂ to activated systems at one atmosphere. See, for example, Kihara, Nobuhiro, Nobutaka Hara, and Takeshi Endo. “Catalytic activity of various salts in the reaction of 2, 3-epoxypropyl phenyl ether and carbon dioxide under atmospheric pressure.” *The Journal of Organic Chemistry* 58, no. 23 (1993): 6198-6202, which is incorporated herein by reference for all purposes. Although it might be suggested that it is improbable that plant material would contain epoxides, this is not true as many terpenes will oxidize to produce epoxides; this could in fact be accelerated under supercritical CO₂ conditions if care is not taken to exclude O₂ from the system prior to pressurizing with CO₂. In the presence of simple inorganic catalysts such as zeolites, terpenes such as limonene are efficiently converted to epoxides by oxygen. See, for example, Bhattacharjee, Samiran, and James A. Anderson. “Epoxidation by Layered Double

Hydroxide-Hosted Catalysts. Catalyst Synthesis and Use in the Epoxidation of R-(+)-Limonene and (-)- α -Pinene Using Molecular Oxygen.” *Catalysis letters* 95, no. 3-4 (2004): 119-125, which is incorporated herein by reference for all purposes. Other materials that possess catalytic activity similar to the zeolites, such as clays, which could be present to some degree in plant material
5 could serve as catalysts in a similar manner.

[0279] It should be however recognized that even a small amount of addition of CO₂ to a reactive moiety could result in multiple reactions under the conditions of supercritical extraction of a nature which would yield some amount of polymeric tarry material of indefinite character. Indeed, such tars do, to some degree, invariably occur in the course of supercritical CO₂
10 extraction. Supercritical CO₂ is, in fact, generally recognized as an excellent solvent in which to perform polymerization reactions (Kendall, Jonathan L., Dorian A. Canelas, Jennifer L. Young, and Joseph M. DeSimone. “Polymerizations in supercritical carbon dioxide.” *Chemical Reviews* 99, no. 2 (1999): 543-564, which is incorporated herein by reference for all purposes). The presence of such tars and their removal represents a serious deficiency in supercritical CO₂
15 extraction of natural products, as commonly it is necessary to employ a secondary purification process following the extraction to remove them. Typically, this is realized by a method such as high vacuum fractional distillation, molecular distillation, or flash chromatography (Still, W. Clark, Michael Kahn, and Abhijit Mitra. “Rapid chromatographic technique for preparative separations with moderate resolution.” *The Journal of Organic Chemistry* 43, no. 14 (1978):
20 2923-2925, which is incorporated herein by reference for all purposes). These processes are expensive and furthermore result invariably in some measure of loss of the desired product. For example, aromatic oils contained in certain plants are complex substances containing a large number of individual compounds some of which are relatively volatile or relatively thermally unstable. Consequently, high distillation temperatures can tend to result in a loss of product
25 either through evaporation of the more volatile compounds or thermal degradation of the more thermally unstable compounds. It would therefore be highly desirable to have a process which did not yield such undesired polymeric tarry materials.

[0280] Carbon dioxide will add to olefins at 1 atmosphere and 60°C in the presence of a free radical initiator and a strong base; under conditions of elevated pressure this could be expected to
30 occur in the presence of weaker bases (e.g. Potassium carbonates and hydroxides) which could

be present in plant derived material, especially if it has been heated (Eghbali, Nicolas, and Chao-Jun Li. "Conversion of carbon dioxide and olefins into cyclic carbonates in water." *Green Chem.* 9, no. 3 (2007): 213-215, which is incorporated herein by reference for all purposes). CO₂ will add to heterocyclic systems in the presence of catalytic amounts of copper halides at 1
5 atmospheres pressure and a temperature of 80°C (Zhang, Liang, Jianhua Cheng, Takeshi Ohishi, and Zhaomin Hou. "Copper-Catalyzed Direct Carboxylation of C-H Bonds with Carbon Dioxide." *Angewandte Chemie* 122, no. 46 (2010): 8852-8855, which is incorporated herein by reference for all purposes).

[0281] All plant, animal, fungi, bacteria, or virus materials which serve as the raw feedstock
10 for extraction contain a significant amount of water. Even if these materials are dried *in vacuo*, they nonetheless inherently possess some water which is only released at the elevated temperatures and pressures which are required to carry out the supercritical CO₂ extraction process. In completely pure CO₂, water has substantial solubility: at pressures and temperatures just below the critical point the mole fraction of water in CO₂ is about 0.02 (King Jr, Allen
15 Dupree, and C. R. Coan. "Solubility of water in compressed carbon dioxide, nitrous oxide, and ethane. Evidence for hydration of carbon dioxide and nitrous oxide in the gas phase." *Journal of the American Chemical Society* 93, no. 8 (1971): 1857-1862, which is incorporated herein by reference for all purposes). This paper further teaches that the water in the liquid CO₂ medium is almost completely solvated and is in the form of carbonic acid. Carbonic acid has a pKa of 3.45
20 (Adamczyk, Katrin, Mirabelle Prémont-Schwarz, Dina Pines, Ehud Pines, and Erik TJ Nibbering. "Real-time observation of carbonic acid formation in aqueous solution." *Science* 326, no. 5960 (2009): 1690-1694, which is incorporated herein by reference for all purposes) and in a nonaqueous system such as liquid CO₂ it probably exists substantially in the form of the gas-phase dimer (Bernard, Jürgen, Markus Seidl, Ingrid Kohl, Klaus R. Liedl, Erwin Mayer, Óscar Gálvez, Hinrich Grothe, and Thomas Loerting. "Spectroscopic Observation of Matrix-Isolated Carbonic Acid Trapped from the Gas Phase." *Angewandte Chemie International Edition* 50, no. 8 (2011): 1939-1943, which is incorporated herein by reference for all purposes) in which it will effectively possess greater acidic character. Carbonic acid in this medium at elevated pressures and temperatures possesses substantial reactivity.

[0282] The critical pressure of CO₂ is significantly higher than that for alkanes or fluorocarbons. This anomalously high critical pressure is due to the fact that CO₂ has a high quadrupole moment. It has been suggested that CO₂ may prove to be a solvent whose strength would rival or surpass that of alkanes and ketones. Because early models employed to calculate CO₂'s solvent power relied on a direct relationship between the Hildebrandt solubility parameter (δ) and the square root of the critical pressure the solubility parameter of CO₂ was over-predicted by 20–100%, leading to early inflated claims as to its potential.

[0283] Supercritical CO₂ processes can benefit, in many cases, from the addition of various cosolvents. For example, addition of a few percent of methanol to CO₂ will result in dramatic increases in solubility of slightly polar materials, such as for example acridine (Brennecke, Joan F., and Charles A. Eckert. "Phase equilibria for supercritical fluid process design." *AIChE Journal* 35, no. 9 (1989): 1409-1427, which is incorporated herein by reference for all purposes). The addition of a small amount of isopropanol to the supercritical CO₂ system has been carefully shown to dramatically increase the recovery of the sugar tagatose (Montañés, Fernando, Tiziana Fornari, Pedro J. Martín-Álvarez, Nieves Corzo, Agustin Olano, and Elena Ibáñez. "Selective recovery of tagatose from mixtures with galactose by direct extraction with supercritical CO₂ and different cosolvents." *Journal of agricultural and food chemistry* 54, no. 21 (2006): 8340-8345, which is incorporated herein by reference for all purposes). While this approach is of principal utility with regard to the extraction of substances of intermediate hydrophobicity, it can be used, to advantage for very hydrophobic systems. For example, it has been reported that different very hydrophobic fractions containing useful antioxidant activity can be obtained from a bark extract by varying small amounts of ethanol which are added to the supercritical extraction (Braga, Mara EM, Rosa MS Santos, Inês J. Seabra, Roselaine Facanali, Márcia OM Marques, and Hermínio C. de Sousa. "Fractioned SFE of antioxidants from maritime pine bark." *The Journal of Supercritical Fluids* 47, no. 1 (2008): 37-48, which is incorporated herein by reference for all purposes).

[0284] One approach to improvement of certain of the deficiencies of the supercritical CO₂ extraction system is to utilize a different supercritical gas. Unfortunately, many other gases have inconvenient critical properties. For example Argon has a critical pressure of 705 psi which can be attained easily but a critical temperature of only 151°K, which is so cold that it will not be a

very effective solvent. Xenon would be an extremely good solvent but it is prohibitively expensive although its critical pressure is high (847 psi) although its critical temperature is close to room temperature. Nitrous oxide is attractive because its critical temperature is just above room temperature (36°C) although its critical pressure is rather high (1044 psi).

- 5 Furthermore, nitrous oxide is potentially reactive to sensitive organic material in the presence of water, and the limited literature data suggest that it generally it is not as good a solvent in practice as CO₂.

[0285] Fluorocarbons are a chemical class selected from the field of fluorophilic compounds that are clear, colorless, odorless, nonflammable liquids that are essentially insoluble in water. In
10 addition, fluorocarbon liquids are denser than water and soft tissue, have low surface tension and, for the most part, low viscosity.

[0286] Fluorocarbons have been used as solvents (US2410101, US2449671). Chlorofluorocarbon Freon^(TM) gases have been used in the extraction of perfume components (US3150050). Chlorofluorocarbons have been used in the extraction of caffeine in coffee
15 (US3669679). However, this process employed a single class of fluorocarbon and no examples of mixtures of gases are therein cited.

[0287] Combinations of supercritical CO₂ and Freon^(TM) solvents have been used for spice extraction of active materials (US4490398). U.S. Patents US6455087 and US6649205 also describe potential uses of fluorocarbons in solvent extraction methods.

20 [0288] Dielectric constant is not an important parameter in determining the interaction of hydrofluorocarbons and fluorocarbons in the extraction process and its sole use in the selection of cosolvents is not supported by the present scientific literature (see supra). For example, for fluoroethanes the Kamlet-Taft parameters, which do depend upon the dielectric constant, albeit not in a simple, monotonic manner, do not appear to be strongly predictive of the microscopic
25 thermodynamic behavior of the system (Lagalante, Anthony F., Robert L. Hall, and Thomas J. Bruno. "Kamlet-Taft solvatochromic parameters of the sub-and supercritical fluorinated ethane solvents." The Journal of Physical Chemistry B 102, no. 34 (1998): 6601-6604, which is incorporated herein by reference for all purposes). A much better choice of parameter would exemplified by one which is experimentally determined, such as the partial molal free energy of
30 mixing. This parameter which can be readily measured (for example see Duce, Celia, Maria

Tinë, L. Lepori, E. Matteoli, B. Marongiu, and Alessandra Piras. "A comparative study of thermodynamic properties of binary mixtures containing perfluoroalkanes." *Journal of Thermal Analysis and Calorimetry* 92, no. 1 (2008): 145-154, which is incorporated herein by reference for all purposes). The second virial coefficients of the solution, which were measured in the work of Scott supra, or most localized energetic calculations of the mixtures using a mixed approach of Monte Carlo dynamics and Kohn-Sham quantum calculations (DFT) incorporating explicit electron correlation. These studies show that aggregation behavior of hydrofluorocarbons in fluorocarbon binary (or tertiary) mixtures represents the most important component of the prediction of solubility of hydrophobic organic compounds in these mixtures. A useful way to think of this is that the solution of a component in a fluorophilic mixture is controlled by the clustering of a component (typically a hydrofluorocarbon) around the solute on the dynamic timescale of order-disorder in the fluid system (as described in Gerig, John T. "Selective solvent interactions in a fluorous reaction system." *Journal of the American Chemical Society* 127, no. 25 (2005): 9277-9284, which is incorporated herein by reference for all purposes). This can also be approached experimentally (Binks, B. P., P. D. I. Fletcher, S. N. Kotsev, and R. L. Thompson. "Adsorption and aggregation of semifluorinated alkanes in binary and ternary mixtures with hydrocarbon and fluorocarbon solvents." *Langmuir* 13, no. 25 (1997): 6669-6682. ; Ruckenstein, E., and I. Shulgin. "Aggregation in binary solutions containing hexafluorobenzene." *The Journal of Physical Chemistry B* 103, no. 46 (1999): 10266-10271, which are incorporated herein by reference for all purposes) or spectroscopically, for example, with the use of small angle X-ray scattering (Brady, George W. "Cluster Formation in Perfluoroheptane-iso-Octane Systems near the Consolute Temperature." *The Journal of Chemical Physics* 32, no. 1 (1960): 45-51, which is incorporated herein by reference for all purposes), or even through surface tension measurements (McLure, I. A., B. Edmonds, and M. Lal. "Extremes in surface tension of fluorocarbon+ hydrocarbon mixtures." *Nature* 241, no. 107 (1973): 71-71, which is incorporated herein by reference for all purposes). Hydrogen bond donation is important, yet dielectric constant in a non-hydrogen bonding solvent has little to do with this critical parameter (Williams, Thomas D., Michael Jay, Hans-Joachim Lehmmler, Michael E. Clark, Dennis J. Stalker, and Paul M. Bummer. "Solubility enhancement of phenol and phenol derivatives in perfluorooctyl bromide." *Journal of pharmaceutical sciences* 87, no. 12 (1998): 1585-1589, which is incorporated herein by reference for all purposes). In a highly polar system

as in water one can build a model for a dielectric constant based upon a hydrogen bound network (see for example Suresh, S. J., and V. M. Naik. "Hydrogen bond thermodynamic properties of water from dielectric constant data." *The Journal of Chemical Physics* 113, no. 21 (2000): 9727-9732, which is incorporated herein by reference for all purposes). Using a classical approach (Oster, Gerald, and John G. Kirkwood. "The influence of hindered molecular rotation on the dielectric constants of water, alcohols, and other polar liquids." *The Journal of Chemical Physics* 11, no. 4 (1943): 175-178, which is incorporated herein by reference for all purposes). Furthermore, the fact that CO₂ does not possess a dipole moment (although it has a quadrupole moment) reinforces the lack of utility of the bulk dielectric constant as a metric within the context of the present invention.

[0289] While the processes described in the aforementioned documents are advantageous in some circumstances, there is a limit to the types of materials that can be extracted. Deficiencies are present in the use of steam, alcohols, supercritical or subcritical CO₂, or pure fluorocarbons to extracted valuable material from plant sources.

[0290] Surprisingly it has been found that mixtures of fluorocarbons and hydrofluorocarbons at or very close to the point where the two components are immiscible, although while still remaining partially or approximately miscible, but usually within a range of pressures and temperatures well below the critical temperature and pressure of the individual components, possess dramatically altered and improved solvent properties as compared with the individual components, if the mixtures are of a binary nature, or of binary mixtures of the individual components if the mixtures are of a ternary nature. (For example, see also Shin, Jungin, Moon Sam Shin, Won Bae, Youn-Woo Lee, and Hwayong Kim. "High-pressure phase behavior of carbon dioxide+ heptadecafluoro-1-decanol system." *The Journal of Supercritical Fluids* 44, no. 3 (2008): 260-265, Morgado, Pedro, Jana Black, J. Ben Lewis, Christopher R. Iacovella, Clare McCabe, Luís FG Martins, and Eduardo JM Filipe. "Viscosity of liquid systems involving hydrogenated and fluorinated substances: Liquid mixtures of (hexane+ perfluorohexane)." *Fluid Phase Equilibria* 358 (2013): 161-165, which is incorporated herein by reference for all purposes).

[0291] It has not previously been recognized that the extrema points of solutions of hydrofluorocarbons in fluorocarbons, and most particularly those hydrofluorocarbons and

fluorocarbons under which the desired conditions of pressure and temperature result in a barely miscible system, would possess the unique ability to tunably extract, e.g. to extract in a manner which is tunable the desired hydrophobic organic materials from complex natural product mixtures. Described herein are processes, methods, and compositions related to discovery of extraction of natural products from plant material employing pure fluorocarbon liquids or gases and optionally admixtures of fluorocarbon and non-fluorocarbon gases and liquids. Extraction may be carried out in a highly selective manner such that specific components consisting of pure compounds or defined mixtures thereof may be extracted from said plant or animal material without extracting undesired materials.

[0292] Example 1.

[0293] An extraction vessel is charged with 10 Kg. of *Cannabis Sativa* “trim”. This material is obtained when harvesting cannabis flower, all the non-flower material which does not contain many trichomes is essentially a “waste product” from the production of the flower. It is most commonly the material which is used for cannabinoid extraction. This botanical material is contained in a cloth bag, which is placed within the extraction vessel in order to contain the material from dispersion through the extraction system. The vessel is evacuated. Subsequently, a premixed liquid phase which contains chlorodifluoromethane (mole fraction 0.4), 1,1,1,2-tetrafluoroethane (0.2 mole fraction), dimethyl ether (0.3 mole fraction), ethanol (0.05 mole fraction) and isobutane (0.05 mole fraction) is circulated through the plant material. The pressure is increased to 1.3 Mpa and the temperature to 45° C and the circulation is continued for a 40-min period. At the end of this time, the liquid phase is pumped in the sealed system to a flash evaporator. The gases are removed and reprocessed through 3A molecular sieves ($2/3\text{K}_2\text{O} \cdot 1/3\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 9/2\text{H}_2\text{O}$) and are compressed using a Corkin compressor into a storage vessel. The product oil from the flash evaporator is collected and assayed for cannabinoid content on an Agilent 1200 series HPLC with diode array detector

[0294] Over a four-hour period while the extraction is carried out, the extraction fluid (e.g., Freon ^(TM); chlorodifluoromethane; 1,1,1,2- tetrafluoroethane) turns bright green due to chlorophyll and other pigments which it contains that have been extracted from it. At the end of the four hour period, the extraction fluid (e.g., Freon ^(TM); chlorodifluoromethane; 1,1,1,2-

tetrafluoroethane) is compressed and recovered in a storage tank. It is regenerated by passing through a column of 4A molecular sieves to remove water and terpenes which may be present.

[0295] The extracted material may be separated in the form of multiple components as a function of time during the extraction period. These multiple components contain different chemically distinct fractions, comprised of different approximate mixtures of compounds. Such mixtures may be precisely characterized in terms of composition and quantified in terms of concentration using analytical methodology well known to one normally skilled in the Art, such as Gas Chromatography, High Pressure Liquid Chromatography, Superfluid Critical Liquid Chromatography, Ultrahigh Resolution High Performance Liquid Chromatography, and the like. For the purposes of the present example the total amount of extracted material is quantified.

[0296] Data for Example 1.

Data:

Run Number	Oil Recovered	% tetrahydrocannabinol
1	1.72 kg	68
2	2.02	66
3	1.98	82.3
4	2.18	71.5
5	2.26	71.3
6	1.92	64
Mean	2.01	70.5

[0297] Example 2.

[0298] An extraction vessel is charged with 10 Kg. of *Cannabis Sativa* “trim”. This material is obtained when harvesting cannabis flower, all the non-flower material which does not contain many trichomes is essentially a “waste product” from the production of the flower. It is most commonly the material which is used for cannabinoid extraction. This botanical material is contained in a cloth bag, which is placed within the extraction vessel in order to contain the

material from dispersion through the extraction system. The vessel is evacuated. Subsequently, a premixed liquid phase which contains chlorodifluoromethane (mole fraction 0.6), 1,1,1,2-tetrafluoroethane (0.2 mole fraction), and dimethyl ether (0.2 mole fraction), is circulated through the plant material. The pressure is increased to 1.3 Mpa and the temperature to 45° C and the circulation is continued for a 40-min period. At the end of this time, the liquid phase is pumped in the sealed system to a flash evaporator. The gases are removed and reprocessed through 3A molecular sieves ($2/3K_2O \cdot 1/3Na_2O \cdot Al_2O_3 \cdot 2SiO_2 \cdot 9/2H_2O$) and are compressed using a Corkin compressor into a storage vessel. The product oil from the flash evaporator is collected and assayed for cannabinoid content on an Agilent 1200 series HPLC with diode array detector

[0299] Over a four-hour period while the extraction is carried out, the extraction fluid (e.g., Freon^(TM); chlorodifluoromethane; 1,1,1,2- tetrafluoroethane) turns bright green due to chlorophyll and other pigments which it contains that have been extracted from it. At the end of the four hour period, the extraction fluid (e.g., Freon^(TM); chlorodifluoromethane; 1,1,1,2-tetrafluoroethane) is compressed and recovered in a storage tank. It is regenerated by passing through a column of 4A molecular sieves to remove water and terpenes which may be present.

[0300] The extracted material may be separated in the form of multiple components as a function of time during the extraction period. These multiple components contain different chemically distinct fractions, comprised of different approximate mixtures of compounds. Such mixtures may be precisely characterized in terms of composition and quantified in terms of concentration using analytical methodology well known to one normally skilled in the Art, such as Gas Chromatography, High Pressure Liquid Chromatography, Superfluid Critical Liquid Chromatography, Ultrahigh Resolution High Performance Liquid Chromatography, and the like. For the purposes of the present example the total amount of extracted material is quantified.

Run Number	Oil Recovered	% tetrahydrocannabinol
1	2.2 Kg	68
2	2.4	72
3	2.1	76

4	2.0	62
Mean	2.175 Kg	69.5

Example 3

[0301] An extraction vessel is charged with about 50 Kg. of *Cannabis Sativa* “trim”. This material is obtained when harvesting cannabis flower, all the non-flower material which does not contain many trichomes is essentially a “waste product” from the production of the flower. It is most commonly the material which is used for cannabinoid extraction. This botanical material is contained in a cloth bag, which is placed within the extraction vessel in order to contain the material from dispersion through the extraction system. The vessel is evacuated. Subsequently, a premixed liquid phase which contains chlorodifluoromethane (mole fraction 0.4), 1,1,1,2-tetrafluoroethane (0.2 mole fraction) dimethyl ether (0.3 mole fraction), ethanol (0.05 mole fraction) and isobutane (0.05 mole fraction) is circulated through the plant material. The pressure is increased to 1.3 Mpa and the temperature to 45° C and the circulation is continued for a 40-min period. At the end of this time, the liquid phase is pumped in the sealed system to a flash evaporator. The gases are removed and reprocessed through 3A molecular sieves (2/3K₂O•1/3Na₂O•Al₂O₃• 2 SiO₂ • 9/2 H₂O) and are compressed using a Corkin compressor into a storage vessel. The product oil from the flash evaporator is collected and assayed for cannabinoid content on an Agilent 1200 series HPLC with diode array detector

[0302] Over a four-hour period while the extraction is carried out, the extraction fluid (e.g., Freon ^(TM); chlorodifluoromethane; 1,1,1,2- tetrafluoroethane) turns bright green due to chlorophyll and other pigments which it contains that have been extracted from it. At the end of the four hour period, the gas is compressed and recovered in a storage tank. It is regenerated by passing through a column of 3A molecular sieves to remove water and terpenes which may be present.

[0303] The extracted material may be separated in the form of multiple components as a function of time during the extraction period. These multiple components contain different chemically distinct fractions, comprised of different approximate mixtures of compounds. Such mixtures may be precisely characterized in terms of composition and quantified in terms of concentration using analytical methodology well known to one normally skilled in the Art, such

as Gas Chromatography, High Pressure Liquid Chromatography, Superfluid Critical Liquid Chromatography, Ultrahigh Resolution High Performance Liquid Chromatography, and the like. For the purposes of the present example the total amount of extracted material is quantified.

[0304] Run 1

5 [0305] Charge: 48.72 Kg

[0306] Extraction yields 7.82 Kg of oil, 68% by weight total cannabinoids

[0307] Run 2

[0308] Extraction yields 779 Kg of oil, 72% cannabinoids by weight

[0309] **Example 4.**

10 [0310] An extraction vessel is charged with 10 Kg. of *Cannabis Sativa* “flower”. This botanical material is contained in a cloth bag, which is placed within the extraction vessel in order to contain the material from dispersion through the extraction system. The vessel is evacuated. Subsequently, a premixed liquid phase which contains chlorodifluoromethane (mole fraction 0.4), 1,1,1,2- tetrafluoroethane (0.2 mole fraction), dimethyl ether (0.3 mole fraction),
15 ethanol (0.05 mole fraction) and isobutane (0.05 mole fraction) is circulated through the plant material. The pressure is increased to 1.3 Mpa and the temperature to 45° C and the circulation is continued for a 40-min period. At the end of this time, the liquid phase is pumped in the sealed system to a flash evaporator. The gases are removed and reprocessed through 3A molecular sieves ($2/3K_2O \cdot 1/3Na_2O \cdot Al_2O_3 \cdot 2SiO_2 \cdot 9/2H_2O$) and are compressed using a Corkin
20 compressor into a storage vessel. The product oil from the flash evaporator is collected and assayed for cannabinoid content on an Agilent 1200 series HPLC with diode array detector

[0311] Over a four-hour period while the extraction is carried out, the extraction fluid (e.g., Freon ^(TM); chlorodifluoromethane; 1,1,1,2- tetrafluoroethane) turns bright green due to chlorophyll and other pigments which it contains that have been extracted from it. At the end of
25 the four hour period, the gas is compressed and recovered in a storage tank. It is regenerated by passing through a column of 3A molecular sieves to remove water and terpenes which may be present.

[0312] The extracted material may be separated in the form of multiple components as a function of time during the extraction period. These multiple components contain different chemically distinct fractions, comprised of different approximate mixtures of compounds. Such mixtures may be precisely characterized in terms of composition and quantified in terms of concentration using analytical methodology well known to one normally skilled in the Art, such as Gas Chromatography, High Pressure Liquid Chromatography, Superfluid Critical Liquid Chromatography, Ultrahigh Resolution High Performance Liquid Chromatography, and the like. For the purposes of the present example the total amount of extracted material is quantified.

[0313] Run 1: 2.4 Kg of oil, 78% cannabinoids

[0314] Run 2: 2.2 Kg of oil, 82% cannabinoids

[0315] Run3: 2.6 Kg of oil, 79% cannabinoids

Example 5.

[0316] A stainless steel tube about 10" in length and 1.25" in diameter was equipped with sanitary flanges at each end, to which could be affixed a pressure transducer and a sight glass. A sample of amount 500 mg to 5 g was placed in the tube contained in an inert polypropylene mesh bag. The entire apparatus was placed on a toploading balance, and by means of a flexible hose gases could be added to the vessel. By means of the change in weight, different gases could be added in known ratios. The apparatus, after filling, could then be maintained in a constant temperature bath for any desired period of time, and at the end of this time the apparatus could be opened, the bag removed and the gas volatilized, and the extracted residue dissolved in a suitable solvent (generally acetone) in a quantitative manner. The acetone could then be transferred to a tared roundbottom flask, and solvent removed on a rotary evaporator under vacuum. The amount of the residue in the flask corresponds to the total soluble mass extracted, and this is then quantified by weighing the flask. After determining this weight, the gummy residue could be redissolved in a suitable solvent (generally methanol) in a volumetric flask and aliquots of this material analyzed by HPLC to determine the amounts of cannabinoids (eg. THC, CBD, THCA, and so forth). HPLC analysis is carried out using an Agilent 1100 Series Separation Module, with an Agilent diode array detector, using Agilent Chemstation Software. The column used is a Restek Raptor ARC-18 2.7 μ m, 4.6 x 150 mm column, equipped with a

Guard Cartridge (Restek Catalog# 9304A0252) or equivalent). Samples are injected and eluted with an isocratic solvent system A/B (25/75). Mobile phase A consists of 0.1% Trifluoroacetic acid (TFA) in H₂O (chromatography quality). Mobile phase B consists of 0.1% TFA in chromatography grade acetonitrile. The Detector Wavelength is 220 nm, Flow Rate is 1.5 mL/min, Injection Volume is 10 µL, and Column Temp is 45.0°C. Under these conditions the Run time is about 9 minutes. Typically, a standards calibration curve of THC of nine concentrations (5 – 200 ppm) is run daily.

[0317] Using these conditions, the efficiency of mixtures of chlorodifluoromethane (R22) and dimethyl ether (DME) to extract total cannabinoids in a single 30-minute extraction at 26 °C is shown in FIG. 1.

[0318] Using the same approach, the efficiency of the pure materials to extract cannabinoids in a single 30-minute procedure at 26 °C can be determined and this is shown in FIG. 2.

EMBODIMENTS

[0319] Embodiments contemplated herein include the following.

Embodiment 1

[0320] A method of extracting a natural organic compound from a natural material, said method comprising contacting said natural material with an extraction fluid thereby extracting said natural organic compound from said natural material into said extraction fluid to form an extracted fluid solution, wherein said extraction fluid comprises a fluorophilic compound and a hydrofluorocarbon.

Embodiment 2

[0321] The method of embodiment 1, wherein said extraction fluid is a non-ideal fluid.

Embodiment 3

[0322] The method of embodiments 1 or 2, wherein the natural material is a material derived from a plant, an animal, a fungi, a bacteria or a virus.

Embodiment 4

[0323] The method of one of embodiments 1-3, wherein the natural material is a material derived from a plant.

Embodiment 5

[0324] The method of one of embodiments 3 to 5, wherein the plant is *Piper methysticum*, *Cannabis spp.*, *Salvia spp.*, *Banisteriopsis caapi*, *Psychotria viridis (chacrana)*, *Diplopterys cabrerana*, *Peganum harmala*, *Humulus lupulus* or mixture thereof.

5 Embodiment 6

[0325] The method of one of embodiments 3 to 6, wherein the plant is *Cannabis Sativa*.

Embodiment 7

[0326] The method of one of embodiments 1 to 6, wherein the natural organic compound is a biologically active organic compound.

10 Embodiment 8

[0327] The method of one of embodiments 1 to 6, wherein the natural organic compound is an aromatic compound.

Embodiment 9

15 [0328] The method of one of embodiments 1 to 6, wherein the natural organic compound forms part of an aromatic oil or essential oil.

Embodiment 10

[0329] The method of one of embodiments 1 to 6, wherein the natural organic compound is caffeine.

Embodiment 11

20 [0330] The method of one of embodiments 1 to 6, wherein the natural organic compound is a terpene, a humulone, a lupulone, a myrcene, a humulene, a caryophyllene, an alkaloid, a flavonoid, a cannabinoid, menthol, capsaicin, anise or camphor.

Embodiment 12

25 [0331] The method of one of embodiments 1 to 6, wherein the natural organic compound is xanthohumol, 8-prenylnaringenin or isoxanthohumol.

Embodiment 13

[0332] The method of one of embodiments 1 to 6, wherein the natural organic compound is a prenylflavonoid.

Embodiment 14

[0333] The method of one of embodiments 1 to 6, wherein the natural organic compound is a kavalactone or a salvorin.

Embodiment 15

5 [0334] The method of one of embodiments 1 to 6, wherein the natural organic compound is a cannabinoid.

Embodiment 16

[0335] The method of one of embodiments 1 to 6, wherein the natural organic compound is tetrahydrocannabinol, cannabidiol or cannabinol.

10 Embodiment 17

[0336] The method of one of embodiments 1 to 6, wherein the natural organic compound is tetrahydrocannabinol.

Embodiment 18

15 [0337] The method of one of embodiments 1 to 17, wherein at least 5,000 g of said natural organic compound is present in said extracted fluid solution.

Embodiment 19

[0338] The method of one of embodiments 1 to 18, wherein said extraction fluid does not comprise supercritical CO₂.

Embodiment 20

20 [0339] The method of one of embodiments 1 to 18, wherein said extraction fluid does not comprise argon.

Embodiment 21

[0340] The method of one of embodiments 1 to 18, wherein said extraction fluid does not comprise xenon.

25 Embodiment 22

[0341] The method of one of embodiments 1 to 18, wherein said extraction fluid does not comprise nitrous oxide.

Embodiment 23

[0342] The method of one of embodiments 1 to 22, wherein said extraction fluid further comprises trifluorethanol or hexafluoroisopropanol.

Embodiment 24

5 [0343] The method of one of embodiments 1 to 23, wherein said extraction fluid is above about 15°C.

Embodiment 25

[0344] The method of one of embodiments 1 to 23, wherein said extraction fluid is above about 20°C.

Embodiment 26

10 [0345] The method of one of embodiments 1 to 23, wherein said extraction fluid is from about 15°C to about 35°C.

Embodiment 27

[0346] The method of one of embodiments 1 to 23, wherein said extraction fluid is from about 20°C to about 30°C.

15 Embodiment 28

[0347] The method of one of embodiments 1 to 27, wherein the hydrofluorocarbon is a hydrofluoroether, a hydrofluoroketone, a hydrofluoroaromatic or a hydrofluoroolefin.

Embodiment 29

20 [0348] The method of one of embodiments 1 to 27, wherein the hydrofluorocarbon is chlorodifluoromethane, methyl nonafluoroisobutyl ether, methyl nonafluorobutyl ether, ethyl nonafluoroisobutyl ether, ethyl nonafluorobutyl ether, 3-ethoxy-1, 1,1,2,3,4,4,5, 5,6,6,6-dodecafluoro-2-trifluoromethylhexane, trifluoromethane (HFC-23), difluoromethane (HFC-32), pentafluoroethane (HFC-125), 1,1,2,2-tetrafluoroethane (HFC-134), 1,1,1,2-tetrafluoroethane (HFC-134a), 1,1,1-trifluoroethane (HFC-143a), 1,1-difluoroethane (HFC-152a) or fluoroethane
25 (HFC-161).

Embodiment 30

[0349] The method of one of embodiments 1 to 29, wherein the fluorophilic compound is dimethyl ether.

Embodiment 31

[0350] The method of one of embodiments 1 to 30, wherein the extraction fluid is a liquid-gas mixture fluid.

Embodiment 32

- 5 [0351] The method of one of embodiments 1 to 31, further comprising, prior to said contacting, freezing the natural material at a temperature from about 0 °C to about -60 °C.

Embodiment 33

- [0352] The method of one of embodiments 1 to 32, wherein the mole fraction of the fluorophilic compound is at least four-fold greater than the mole fraction of the
10 hydrofluorocarbon.

Embodiment 34

[0353] The method of one of embodiments 1 to 33, further comprising separating said extraction fluid from said natural material by volatilizing said extraction fluid to form a volatilized extraction fluid.

- 15 Embodiment 35

[0354] The method of embodiment 34, further comprising chilling and compressing the volatilized extraction fluid to form a liquid extraction fluid.

Embodiment 36

- [0355] The method of embodiments 34 or 35, further comprising recirculating the liquid
20 extraction fluid to the natural material.

Embodiment 37

[0356] The method of one of embodiments 34 to 36, further comprising collecting separated fractions of the liquid extraction fluid.

Embodiment 38

- 25 [0357] A fluid comprising chlorodifluoromethane and dimethyl ether.

Embodiment 39

[0358] The fluid of embodiment 38, wherein said fluid is a non-ideal fluid.

Embodiment P1

[0359] A process for extraction of natural products of medicinal, pharmacological, or other value from plant, animal, fungi, bacteria, or virus mixtures consisting of

(a) freezing the plant, animal, fungi, bacteria, or virus material to a temperature between 0°C and -60°C by the use of a blast freezer or a compressed cryogenic gas

(b) passing a fluid over the plant, animal, fungi, bacteria, or virus material with the use of a recirculating pump, whereby the fluid consists of three components:

(i) a fluorophilic compound

(ii) a hydro fluorocarbon

(iii) a third component which is a fluorophilic amine, alcohol, or nonfluorinated alkanol

(iv) wherein the mole fraction of the fluorocarbon is at least four-fold greater than the mole fraction of the hydrofluorocarbon, and the mole fraction of the third component is four-fold less than the hydrofluorocarbon

(c) volatilizing the fluorophilic compound which has been passed over the plant, animal, fungi, bacteria, or virus material using a heated column, whereby the extracted plant, animal, fungi, bacteria, or virus material solubilized by the fluid remains at the bottom of the said column and the fluorophilic compound is extracted in a gaseous form at one end of said column

(d) chilling the volatilized fluorophilic compound with a heat exchanger and compressing the fluorophilic compound to the liquid state

(e) warming the liquefied fluorophilic compound in a controlled manner

(f) recirculating the liquefied warm fluorophilic compound back through the plant, animal, fungi, bacteria, or virus material in a continuous manner

(g) slowly increasing the temperature of the liquefied recirculated fluorophilic compound which flows back over the plant, animal, fungi, bacteria, or virus material, thereby increasing the temperature of the said plant, animal, fungi, bacteria, or virus material from the temperature range of freezing to a temperature range between 40°C and 80°C.

- (h) collecting separated fractions at the bottom of the volatilizing column as the temperature is thereby increased.

Embodiment P2

- [0360] A process according to embodiment P1, wherein said fluorocarbon is 1,1,1,2
5 tetrafluoroethane.

Embodiment P3

- [0361] A process according to embodiment P1, wherein said fluorocarbon is tetrafluoromethane.

Embodiment P4

- 10 [0362] A process according to embodiment P1, wherein said fluorocarbon is hexafluoroethane.

Embodiment P5

- [0363] A process according to embodiment P1, wherein said fluorocarbon is trifluoromethyl iodide.

Embodiment P6

- 15 [0364] A process according to embodiment P1, wherein said fluorocarbon is perfluorocyclobutane.

Embodiment P7

- [0365] A process according to embodiment P1, wherein said fluorocarbon is perfluorotributylamine.

- 20 Embodiment P8

- [0366] A process according to embodiment P1, wherein said fluorocarbon is perfluoro-n-propane.

Embodiment P9

- [0367] A process for extraction of natural products of medicinal, pharmacological, or other
25 value from plant, animal, fungi, bacteria, or virus mixtures consisting of

- (a) freezing the plant, animal, fungi, bacteria, or virus material to a temperature between 0°C and -60°C by the use of a blast freezer or a compressed cryogenic gas
- (b) passing a fluid over the plant, animal, fungi, bacteria, or virus material with the use of a recirculating pump, whereby the fluid consists of three components:
- (v) a fluorophilic compound
 - (vi) a hydrofluorocarbon
 - (vii) a third component which is an inert gas
- (c) volatilizing the fluorophilic compound which has been passed over the plant, animal, fungi, bacteria, or virus material using a heated column, whereby the extracted plant, animal, fungi, bacteria, or virus material solubilized by the fluid remains at the bottom of the said column and the fluorophilic compound is extracted in a gaseous form at one end of said column
- (d) chilling the volatilized fluorophilic compound with a heat exchanger and compressing the fluorophilic compound to the liquid state
- (e) warming the liquefied fluorophilic compound in a controlled manner
- (f) recirculating the liquefied warm fluorophilic compound back through the plant, animal, fungi, bacteria, or virus material in a continuous manner
- (g) slowly increasing the temperature of the liquefied recirculated fluorophilic compound which flows back over the plant, animal, fungi, bacteria, or virus material, thereby increasing the temperature of the said plant, animal, fungi, bacteria, or virus material from the temperature range of freezing to a temperature range between 40°C and 80°C.
- (h) collecting separated fractions at the bottom of the volatilizing column as the temperature is thereby increased.

Embodiment P10

[0368] A process according to embodiment P9, wherein said fluorocarbon is 1,1,1,2-tetrafluoroethane and the inert gas is SF₆.

Embodiment P11

[0369] A process according to embodiment P9, wherein said fluorocarbon is 1,1,1,2 tetrafluoroethane and the inert gas is CO₂.

Embodiment P12

[0370] A process according to embodiment P9, wherein said fluorocarbon is 1,1,1,2
5 tetrafluoroethane and the inert gas is N₂O.

Embodiment P13

[0371] A process according to embodiment P9, wherein said fluorocarbon is 1,1,1,2 tetrafluoroethane and the inert gas is CH₄.

Embodiment P14

10 [0372] A process according to embodiment P9, wherein said fluorocarbon is 1,1,1,2 tetrafluoroethane and the inert gas is C₂H₆.

Embodiment P15

[0373] A process according to embodiment P9, wherein said fluorocarbon is tetrafluoromethane and the inert gas is SF₆.

15 Embodiment P16

[0374] A process according to embodiment P9, wherein said fluorocarbon is tetrafluoromethane and the inert gas is CO₂.

Embodiment P17

[0375] A process according to embodiment P9, wherein said fluorocarbon is
20 tetrafluoromethane and the inert gas is N₂O.

Embodiment P18

[0376] A process according to embodiment P9, wherein said fluorocarbon is tetrafluoromethane and the inert gas is CH₄.

Embodiment P19

[0377] A process according to embodiment P9, wherein said fluorocarbon is tetrafluoromethane and the inert gas is C_2H_6 .

Embodiment P20

5 [0378] A process according to embodiment P9, wherein said fluorocarbon is perfluorocyclobutane and the inert gas is SF_6 .

Embodiment P21

[0379] A process according to embodiment P9, wherein said fluorocarbon is perfluorocyclobutane and the inert gas is CO_2 .

Embodiment P22

10 [0380] A process according to embodiment P9, wherein said fluorocarbon is perfluorocyclobutane and the inert gas is N_2O .

Embodiment P23

[0381] A process according to embodiment P9, wherein said fluorocarbon is perfluorocyclobutane and the inert gas is CH_4 .

15 Embodiment P24

[0382] A process according to embodiment P9, wherein said fluorocarbon is perfluorocyclobutane and the inert gas is C_2H_6 .

Embodiment P25

20 [0383] A process for extraction of natural products of medicinal, pharmacological, or other value from plant, animal, fungi, bacteria, or virus mixtures consisting of

(a) freezing the plant, animal, fungi, bacteria, or virus material to a temperature between $0^{\circ}C$ and $-60^{\circ}C$ by the use of a blast freezer or a compressed cryogenic gas

25 (b) passing a fluid over the plant, animal, fungi, bacteria, or virus material with the use of a recirculating pump, whereby the fluid consists of three components:

- (i) a fluorophilic compound
- (ii) a hydrofluorocarbon
- (iii) an ionic liquid

(c) volatilizing the fluorophilic compound which has been passed over the plant, animal, fungi, bacteria, or virus material using a heated column, whereby the extracted plant, animal, fungi, bacteria, or virus material solubilized by the fluid remains at the bottom of the said column and the fluorophilic compound is extracted in a gaseous form at the top of said column

(d) chilling the volatilized fluorophilic compound with a heat exchanger and compressing the fluorophilic compound to the liquid state

(e) warming the liquefied fluorophilic compound in a controlled manner

(f) recirculating the liquefied warm fluorophilic compound back through the plant, animal, fungi, bacteria, or virus material in a continuous manner

(g) slowly increasing the temperature of the liquefied recirculated fluorophilic compound which flows back over the plant, animal, fungi, bacteria, or virus material, thereby increasing the temperature of the said plant, animal, fungi, bacteria, or virus material from the temperature range of freezing to a temperature range between 40°C and 80°C.

(h) collecting separated fractions at the bottom of the volatilizing column as the temperature is thereby increased.

Embodiment U1

[0384] A method of extracting a natural organic compound from a natural material, said method comprising contacting said natural material with an extraction fluid thereby extracting said natural organic compound from said natural material into said extraction fluid to form an extracted fluid solution, wherein said extraction fluid comprises a fluorophilic compound and a hydrofluorocarbon.

Embodiment U2

[0385] The method of embodiment U1, wherein the natural material is a material derived from a plant, an animal, a fungi, a bacteria or a virus.

Embodiment U3

[0386] The method of embodiment U2, wherein the plant is *Piper methysticum*, *Cannabis* spp., *Salvia* spp., *Banisteriopsis caapi*, *Psychotria viridis* (chacruna), *Diplopterys cabrerana*, *Peganum harmala*, *Humulus lupulus* or mixture thereof.

5 Embodiment U4

[0387] The method of embodiment U2, wherein the plant is *Cannabis Sativa*.

Embodiment U5

[0388] The method of embodiment U1, wherein the natural organic compound is a biologically active organic compound, an aromatic compound, or forms part of an aromatic oil or essential
10 oil.

Embodiment U6

[0389] The method of embodiment U1, wherein the natural organic compound is caffeine, a terpene, a humulone, a lupulone, a myrcene, a humulene, a caryophyllene, an alkaloid, a flavonoid, a cannabinoid, menthol, capsaicin, anise, camphor, xanthohumol, 8-prenylnaringenin,
15 isoxanthohumol, a prenylflavonoid, a kavalactone, a salvorin, a cannabinoid, tetrahydrocannabinol, cannabidiol, or cannabinol.

Embodiment U7

[0390] The method of embodiment U1, wherein at least 5000g of said natural organic compound is present in said extracted fluid solution.

20 Embodiment U8

[0391] The method of embodiment U1, wherein said extraction fluid does not comprise supercritical CO₂.

Embodiment U9

[0392] The method of embodiment U1, wherein said extraction fluid does not comprise argon,
25 xenon, or nitrous oxide.

Embodiment U10

[0393] The method of embodiment U1, wherein said extraction fluid further comprises trifluorethanol or hexafluoroisopropanol.

Embodiment U11

[0394] The method of embodiment U1, wherein said extraction fluid is above about 15 °C.

5 Embodiment U12

[0395] The method of embodiment U1, wherein the hydrofluorocarbon is a hydrofluoroether, a hydrofluoroketone, a hydrofluoroaromatic or a hydrofluoroolefin.

Embodiment U13

[0396] The method of embodiment U1, wherein the hydrofluorocarbon is
10 chlorodifluoromethane, methyl nonafluoroisobutyl ether, methyl nonafluorobutyl ether, ethyl nonafluoroisobutyl ether, ethyl nonafluorobutyl ether, 3-ethoxy-1, 1,1,2,3,4,4,5, 5,6,6,6-dodecafluoro-2-trifluoromethylhexane, trifluoromethane (HFC-23), difluoromethane (HFC-32), pentafluoroethane (HFC-125), 1,1,2,2-tetrafluoroethane (HFC-134), 1,1,1,2-tetrafluoroethane (HFC-134a), 1,1,1-trifluoroethane (HFC-143a), 1,1-difluoroethane (HFC-152a), (1,1,1,3,3,3-
15 hexafluoro-2-(fluoromethoxy)propane, 1,2,2,2-tetrafluoroethyl difluoromethyl ether, 2-chloro-1,1,2-trifluoroethyl difluoromethyl ether, 1-chloro-2,2,2-trifluoroethyl difluoromethyl ether, 2,2-dichloro-1,1-difluoromethyl ether, or fluoroethane (HFC-161).

Embodiment U14

[0397] The method of embodiment U1, wherein the fluorophilic compound is dimethyl ether,
20 methyl ethyl ether, methyl n-propyl ether, methyl isopropyl ether, methyl-n-butyl ether, diethyl ether, methyl tert-butyl ether, or ethyl tert-butyl ether.

Embodiment U15

[0398] The method of embodiment U1, further comprising, prior to said contacting, freezing the natural material at a temperature from about 0 °C to about -60 °C.

25 Embodiment U16

[0399] The method of embodiment U1, wherein the mole fraction of the fluorophilic compound is at least four-fold greater than the mole fraction of the hydrofluorocarbon.

Embodiment U17

[0400] The method of embodiment U1, further comprising separating said extraction fluid from said natural material by volatilizing said extraction fluid to form a volatilized extraction fluid.

5 Embodiment U18

[0401] The method of embodiment U17, further comprising chilling and compressing the volatilized extraction fluid to form a liquid extraction fluid.

Embodiment U19

10 [0402] The method of embodiment U17, further comprising recirculating the liquid extraction fluid to the natural material.

Embodiment U20

[0403] A fluid comprising chlorodifluoromethane and dimethyl ether.

WHAT IS CLAIMED IS:

- 1 1. A method of extracting a natural organic compound from a natural
2 material, said method comprising contacting said natural material with an extraction fluid
3 thereby extracting said natural organic compound from said natural material into said extraction
4 fluid to form an extracted fluid solution, wherein said extraction fluid comprises a fluorophilic
5 compound and a hydrofluorocarbon.
- 1 2. The method of claim 1, wherein said extraction fluid is a non-ideal fluid.
- 1 3. The method of claim 1, wherein the natural material is a material derived
2 from a plant, an animal, a fungi, a bacteria or a virus.
- 1 4. The method of claim 1, wherein the natural material is a material derived
2 from a plant.
- 1 5. The method of claim 3, wherein the plant is *Piper methysticum*, *Cannabis*
2 *spp.*, *Salvia spp.*, *Banisteriopsis caapi*, *Psychotria viridis (chacrana)*, *Diplopterys cabrerana*,
3 *Peganum harmala*, *Humulus lupulus* or mixture thereof.
- 1 6. The method of claim 3, wherein the plant is Cannabis Sativa.
- 1 7. The method of one of claims 1 to 6, wherein the natural organic compound
2 is a biologically active organic compound.
- 1 8. The method of one of claims 1 to 6, wherein the natural organic compound
2 is an aromatic compound.
- 1 9. The method of one of claims 1 to 6, wherein the natural organic compound
2 forms part of an aromatic oil or essential oil.
- 1 10. The method of one of claim 1 to 5, wherein the natural organic compound
2 is caffeine.

- 1 11. The method of one of claims 1 to 6, wherein the natural organic compound
2 is a terpene, a humulone, a lupulone, a myrcene, a humulene, a caryophyllene, an alkaloid, a
3 flavonoid, a cannabinoid, menthol, capsaicin, anise or camphor.
- 1 12. The method of one of claims 1 to 4, wherein the natural organic compound
2 is xanthohumol, 8-prenylnaringenin or isoxanthohumol.
- 1 13. The method of one of claims 1 to 6, wherein the natural organic compound
2 is a prenylflavonoid.
- 1 14. The method of one of claims 1 to 5, wherein the natural organic compound
2 is a kavalactone or a salvorin.
- 1 15. The method of one of claims 1 to 6, wherein the natural organic compound
2 is a cannabinoid.
- 1 16. The method of one of claims 1 to 6, wherein the natural organic compound
2 is tetrahydrocannabinol, cannabidiol or cannabinol.
- 1 17. The method of one of claims 1 to 6, wherein the natural organic compound
2 is tetrahydrocannabinol.
- 1 18. The method of one of claims 1 to 6, wherein at least 5,000 g of said
2 natural organic compound is present in said extracted fluid solution.
- 1 19. The method of one of claim 1 to 6, wherein said extraction fluid does not
2 comprise supercritical CO₂.
- 1 20. The method of one of claims 1 to 6, wherein said extraction fluid does not
2 comprise argon.
- 1 21. The method of one of claims 1 to 6, wherein said extraction fluid does not
2 comprise xenon.

- 1 22. The method of one of claims 1 to 6, wherein said extraction fluid does not
2 comprise nitrous oxide.
- 1 23. The method of one of claims 1 to 6, wherein said extraction fluid further
2 comprises trifluorethanol or hexafluoroisopropanol.
- 1 24. The method of one of claim 1 to 6, wherein said extraction fluid is above
2 about 15°C.
- 1 25. The method of one of claims 1 to 6, wherein said extraction fluid is above
2 about 20°C.
- 1 26. The method of one of claims 1 to 6, wherein said extraction fluid is from
2 about 15°C to about 35°C.
- 1 27. The method of one of claim 1 to 6, wherein said extraction fluid is from
2 about 20°C to about 30°C.
- 1 28. The method of one of claims 1 to 6, wherein the hydrofluorocarbon is a
2 hydrofluoroether, a hydrofluoroketone, a hydrofluoroaromatic or a hydrofluoroolefin.
- 1 29. The method of one of claims 1 to 6, wherein the hydrofluorocarbon is
2 chlorodifluoromethane, methyl nonafluoroisobutyl ether, methyl nonafluorobutyl ether, ethyl
3 nonafluoroisobutyl ether, ethyl nonafluorobutyl ether, 3-ethoxy-1, 1,1,2,3,4,4,5, 5,6,6,6-
4 dodecafluoro-2-trifluoromethylhexane, trifluoromethane (HFC-23), difluoromethane (HFC-32),
5 pentafluoroethane (HFC-125), 1,1,2,2-tetrafluoroethane (HFC-134), 1,1,1,2- tetrafluoroethane
6 (HFC-134a), 1,1,1-trifluoroethane (HFC-143a), 1,1- difluoroethane (HFC-152a) or fluoroethane
7 (HFC-161).
- 1 30. The method of one of claims 1 to 6, wherein the fluorophilic compound is
2 dimethyl ether.
- 1 31. The method of one of claim 1 to 6, wherein the extraction fluid is a liquid-
2 gas mixture fluid.

1 32. The method of one of claim 1 to 6, further comprising, prior to said
2 contacting, freezing the natural material at a temperature from about 0 °C to about -60 °C.

1 33. The method of one of claims 1 to 6, wherein a mole fraction of the
2 fluorophilic compound is at least four-fold greater than a mole fraction of the hydrofluorocarbon.

1 34. The method of one of claims 1 to 6, further comprising separating said
2 extraction fluid from said natural material by volatilizing said extraction fluid to form a volatilized
3 extraction fluid.

1 35. The method of claim 34, further comprising chilling and compressing said
2 volatilized extraction fluid to form a liquid extraction fluid.

1 36. The method of claim 35, further comprising recirculating said liquid
2 extraction fluid to the natural material.

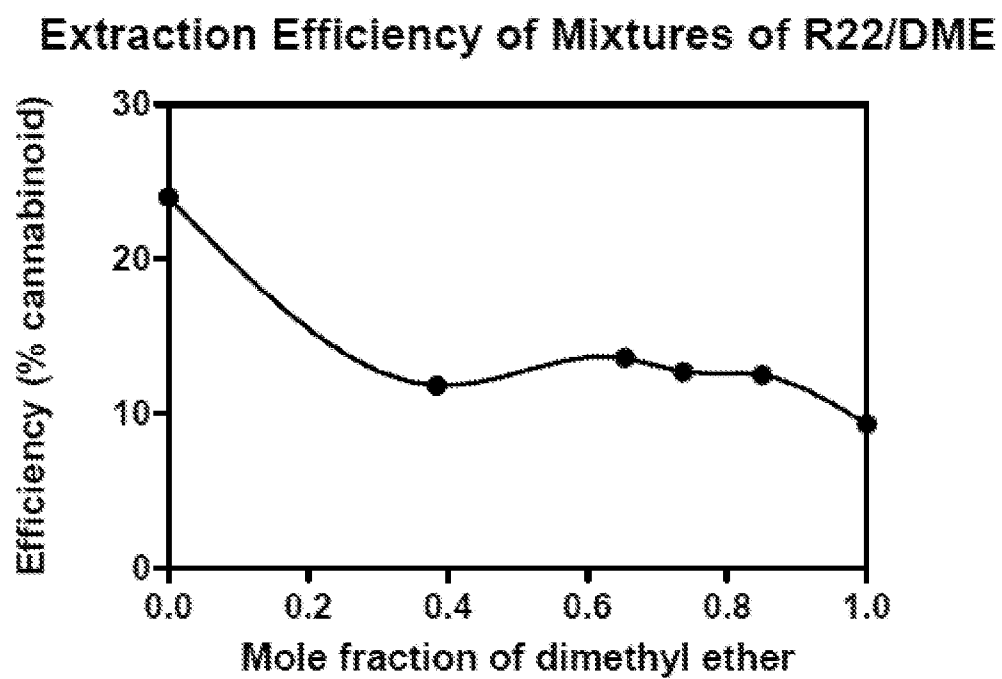
1 37. The method of claim 35, further comprising collecting separated fractions
2 of the liquid extraction fluid.

1 38. A fluid comprising chlorodifluoromethane and dimethyl ether.

1 39. The fluid of claim 38, wherein said fluid is a non-ideal fluid.

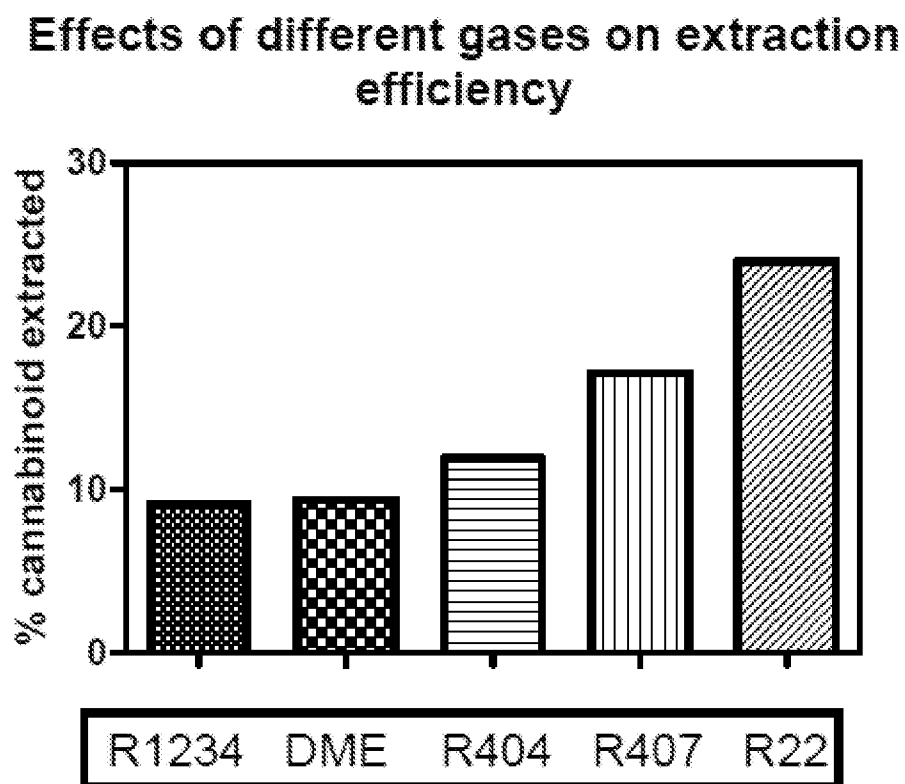
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FIG. 1



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FIG. 2



INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 17/65199

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - A61K 36/185, A61K 31/352, A61K 31/465 (2018.01)

CPC - A61K 31/352, A61K 2236/33, A61K 2236/15, A61K 36/81, A61K 36/185, A61K 31/465

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History Document

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

See Search History Document

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

See Search History Document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2001/0021367 A1 (Powell et al.) 13 September 2001 (13.09.2001) abstract, para [0007], [0012], [0024], [0026], [0030]-[0032], [0035]	1, 3-4, (7-9)/(1,3-4), 11/(1,3-4), (18-22)/(1,3-4), (29-30)/(1,3-4), (32-37)/(1,3-4) ----- 2, 5-6, (7-9)/(2,5-6), 10, 11/(2, 5-6), 12-17, (18-22)/(2,5-6), 23-28, (29-30)/(2,5-6), 31, (32-37)/(2,5-6)
X --- Y	Noles et al. Vapor-Liquid Equilibrium for Chlorodifluoromethane + Dimethyl Ether from 283 to 395 K at Pressures to 5.0 MPa. J. Chem. Eng. Data 1992, 37, 306-310; abstract;	38-39 ----- 31
Y	US2008103193 A1 (Castor et al.) 01 May 2008 (01.05.2008) abstract, para [0038], [0043]	5-6, (7-9)/(5-6), 10/5, 11/(5-6), 13/(5-6), 14/5, 15-17, (18-37)/(5-6)
Y	WO 00/64555 A2 (Imperial Chemical Industries PLC) 02 November 2000 (02.11.2000) pg8, ln9,13	2, (7-23)/2, 24-27/(1-4), (28-37)/2
Y	US 6,746,695 B1 (Martin et al.) 08 June 2004 (08.06.2004) col8,ln22; col9,ln24; col17, ln60	10, 14

☒ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:

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

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

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document member of the same patent family

Date of the actual completion of the international search

06 February 2018

Date of mailing of the international search report

06 MAR 2018

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 17/65199

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2007/0110835 A1 (Maes et al.) 17 May 2007 (17.05.2007) para [0034], [0046]	12-13
Y	US 2009/0286301 A1 (Tao et al.) 19 November 2009 (19.11.2009) abstract, para [0338]	23
Y	US 2006/0182689 A1 (Dournel et al.) 17 April 2006 (17.04.2006) para [0014]	28