CLAIMS

[Claim 1]

A method for producing a halogenated butene compound represented by formula (2A):

$CX^1X^2X^3CX^4=CHCX^5X^6X^7$ (2A)

wherein X^1, X^2, X^3, X^4, X^5, X^6, and X^7 are the same or different and each is a halogen atom,

the method comprising subjecting a halogenated butane compound represented by formula (1A):

$CX^1X^2X^3CHX^4CFHCX^5X^6X^7$ (1A)

wherein X^1, X^2, X^3, X^4, X^5, X^6, and X^7 are as defined above, to a dehydrofluorination reaction in a gas phase or a liquid phase,

wherein the dehydrofluorination reaction is performed in the presence of at least one catalyst selected from the group consisting of an activated carbon catalyst, a chromium oxide catalyst, and a silica alumina catalyst, when the dehydrofluorination reaction is performed in a gas phase.

[Claim 2]

A method for producing a halogenated butyne compound represented by formula (3A):

$CX^1X^2X^3C\equiv CCX^5X^6X^7$ (3A)

wherein X^1, X^2, X^3, X^5, X^6, and X^7 are the same or different and each is a halogen atom,

the method comprising subjecting a halogenated butene compound represented by formula (2A):

$CX^1X^2X^3CX^4=CHCX^5X^6X^7$ (2A)

wherein X^1, X^2, X^3, X^5, X^6, and X^7 are as defined above, and X^4 is a halogen atom, to a dehydrohalogenation reaction in a gas phase,

wherein the dehydrohalogenation reaction is performed in the presence of at least one catalyst selected from the group consisting of an activated carbon catalyst, a chromium oxide catalyst, and a silica alumina catalyst.

[Claim 3]

A method for producing a halogenated butyne compound represented by formula (3A):

$CX^1X^2X^3C{\equiv}CCX^5X^6X^7$ (3A)

wherein X^1, X^2, X^3, X^5, X^6, and X^7 are the same or different and each is a halogen atom,

the method comprising:

(IA) subjecting a halogenated butane compound represented by formula (1A):

$CX^1X^2X^3CHX^4CFHCX^5X^6X^7$ (1A)

wherein X^1, X^2, X^3, X^5, X^6, and X^7 are as defined above, and X^4 is a halogen atom, to a dehydrofluorination reaction in a gas phase or a liquid phase to produce a halogenated butene compound represented by formula (2A):

$CX^1X^2X^3CX^4{=}CHCX^5X^6X^7$ (2A)

wherein X^1, X^2, X^3, X^4, X^5, X^6, and X^7 are as defined above,

wherein the dehydrohalogenation reaction is performed in the presence of at least one catalyst selected from the group consisting of an activated carbon catalyst, a chromium oxide catalyst, and a silica alumina catalyst, when the dehydrofluorination reaction is performed in a gas phase;

(IIA) after step (IA), removing hydrogen fluoride; and

(IIIA) after step (IIA), subjecting the obtained halogenated butene compound represented by formula (2A):

$CX^1X^2X^3CX^4{=}CHCX^5X^6X^7$ (2A)

wherein X^1, X^2, X^3, X^4, X^5, X^6, and X^7 are as defined above, to a dehydrohalogenation reaction in a gas phase to produce the halogenated butyne compound represented by formula (3A):

$CX^1X^2X^3C{\equiv}CCX^5X^6X^7$ (3A)

wherein X^1, X^2, X^3, X^5, X^6, and X^7 are as defined above,

wherein the dehydrohalogenation reaction is performed in the presence of at least one catalyst selected from the group consisting of an activated carbon catalyst, a chromium oxide catalyst, and a silica alumina catalyst.

[Claim 4]

A method for producing a halogenated butene compound represented by formula (2A):

$CX^1X^2X^3CX^4=CHCX^5X^6X^7$ (2A)

wherein X^1, X^2, X^3, X^4, X^5, X^6, and X^7 are the same or different and each is a halogen atom,

the method comprising subjecting a halogenated butane compound represented by formula (1A):

$CX^1X^2X^3CHX^4CFHCX^5X^6X^7$ (1A)

wherein X^1, X^2, X^3, X^4, X^5, X^6, and X^7 are as defined above, to a dehydrofluorination reaction in the presence of a cyclic halogen carbide compound in which all hydrogen atoms bonded to carbon atoms in a hydrocarbon compound are replaced by halogen atoms.

[Claim 5]

A method for producing a halogenated butyne compound represented by formula (3A):

$CX^1X^2X^3C\equiv CCX^5X^6X^7$ (3A)

wherein X^1, X^2, X^3, X^5, X^6, and X^7 are the same or different and each is a halogen atom,

the method comprising subjecting a halogenated butene compound represented by formula (2A):

$CX^1X^2X^3CX^4=CHCX^5X^6X^7$ (2A)

wherein X^1, X^2, X^3, X^5, X^6, and X^7 are as defined above, and X^4 is a halogen atom, to a dehydrohalogenation reaction in the presence of a cyclic halogen carbide compound in which all hydrogen atoms bonded to carbon atoms in a hydrocarbon compound are replaced by halogen atoms.

[Claim 6]

A method for producing a halogenated butyne compound represented by formula (3A):

$CX^1X^2X^3C\equiv CCX^5X^6X^7$ (3A)

wherein X^1, X^2, X^3, X^5, X^6, and X^7 are the same or different and each is a halogen atom,

the method comprising:

(IA) subjecting a halogenated butane compound represented by formula (1A):

$CX^1X^2X^3CHX^4CFHCX^5X^6X^7$ (1A)

wherein X^1, X^2, X^3, X^5, X^6, and X^7 are as defined above, and X^4 is a halogen atom, to a dehydrofluorination reaction to produce a halogenated butene compound represented by formula (2A):

$CX^1X^2X^3CX^4=CHCX^5X^6X^7$ (2A)

wherein X^1, X^2, X^3, X^4, X^5, X^6, and X^7 are as defined above,

wherein the dehydrohalogenation reaction is performed in the presence of a cyclic halogen carbide compound in which all hydrogen atoms bonded to carbon atoms in a hydrocarbon compound are replaced by halogen atoms;

(IIA) after step (IA), removing hydrogen fluoride; and

(IIIA) after step (IIA), subjecting the obtained halogenated butene compound represented by formula (2A):

$CX^1X^2X^3CX^4=CHCX^5X^6X^7$ (2A)

wherein X^1, X^2, X^3, X^4, X^5, X^6, and X^7 are as defined above, to a dehydrohalogenation reaction to produce the halogenated butyne compound represented by formula (3A):

$CX^1X^2X^3C\equiv CCX^5X^6X^7$ (3A)

wherein X^1, X^2, X^3, X^5, X^6, and X^7 are as defined above,

wherein the dehydrohalogenation reaction is performed in the presence of a cyclic halogen carbide compound in which all hydrogen atoms bonded to carbon atoms in a hydrocarbon compound are replaced by halogen atoms.

[Claim 7]

The production method according to any one of claims 1 and 3 to 6, wherein the step of the dehydrofluorination reaction and/or the dehydrohalogenation reaction is performed in a liquid phase.

[Claim 8]

The production method according to claim 7, wherein the

step of the dehydrofluorination reaction and/or the dehydrohalogenation reaction is performed in the presence of a base.

[Claim 9]

The production method according to claim 7 or 8, wherein the step of the dehydrofluorination reaction and/or the dehydrohalogenation reaction is performed in the presence of a base and a catalyst.

[Claim 10]

The production method according to any one of claims 7 to 9, wherein the step of the dehydrofluorination reaction and/or the dehydrohalogenation reaction is performed in a closed reaction process.

[Claim 11]

The production method according to any one of claims 1 and 3 to 6, wherein the step of the dehydrofluorination reaction and/or the dehydrohalogenation reaction is performed in a gas phase.

[Claim 12]

The production method according to any one of claims 4 to 11, wherein the step of the dehydrofluorination reaction and/or the dehydrohalogenation reaction is performed in the presence of at least one catalyst selected from the group consisting of an activated carbon catalyst, a chromium oxide catalyst, a zeolite catalyst, and a silica alumina catalyst.

[Claim 13]

A method for producing a halogenated alkene compound represented by formula (2B):

$CX^8A^1=CHA^2$ (2B)

wherein A^1 and A^2 are the same or different and each is a fluorine

atom or a perfluoroalkyl group, and X^8 is a halogen atom,

the method comprising subjecting a halogenated alkane compound represented by formula (1B):

$CHX^8A^1CHX^9A^2$ (1B)

wherein A^1 and A^2 are as defined above, and X^8 and X^9 are the same or different and each is a halogen atom, to a dehydrohalogenation reaction in the presence of a catalyst in a gas phase,

wherein the catalyst is at least one member selected from the group consisting of activated carbon, chromium oxide, fluorinated chromium oxide, aluminum oxide, fluorinated aluminum oxide, iron oxide, fluorinated iron oxide, nickel oxide, fluorinated nickel oxide, magnesium oxide, and fluorinated magnesium oxide.

[Claim 14]

A method for producing a fluorinated alkyne compound represented by formula (3B):

$CA^1{\equiv}CA^2$ (3B)

wherein A^1 and A^2 are the same or different and each is a fluorine atom or a perfluoroalkyl group,

the method comprising subjecting a halogenated alkene compound represented by formula (2B):

$CX^8A^1{=}CHA^2$ (2B)

wherein A^1 and A^2 are as defined above, and X^8 is a halogen atom, to a dehydrohalogenation reaction in the presence of a catalyst in a gas phase,

wherein the catalyst is at least one member selected from the group consisting of activated carbon, chromium oxide, fluorinated chromium oxide, aluminum oxide, fluorinated aluminum oxide, iron oxide, fluorinated iron oxide, nickel oxide, fluorinated nickel oxide, magnesium oxide, and fluorinated magnesium oxide.

[Claim 15]

A method for producing a halogenated alkene compound

represented by formula (2B):

$CX^8A^1=CHA^2$ (2B)

wherein A^1 and A^2 are the same or different and each is a fluorine atom or a perfluoroalkyl group, and X^8 is a halogen atom,

the method comprising subjecting a halogenated alkane compound represented by formula (1B):

$CHX^8A^1CHX^9A^2$ (1B)

wherein A^1 and A^2 are as defined above, and X^8 and X^9 are the same or different and each is a halogen atom, to a dehydrohalogenation reaction in the presence of the catalyst and a cyclic halogen carbide compound in which all hydrogen atoms bonded to carbon atoms in a hydrocarbon compound are replaced by halogen atoms in a gas phase.

[Claim 16]

A method for producing a fluorinated alkyne compound represented by formula (3B):

$CA^1\equiv CA^2$ (3B)

wherein A^1 and A^2 are the same or different and each is a fluorine atom or a perfluoroalkyl group,

the method comprising subjecting a halogenated alkene compound represented by formula (2B):

$CX^8A^1=CHA^2$ (2B)

wherein A^1 and A^2 are as defined above, and X^8 is a halogen atom, to a dehydrohalogenation reaction in the presence of a catalyst and a cyclic halogen carbide compound in which all hydrogen atoms bonded to carbon atoms in a hydrocarbon compound are replaced by halogen atoms.

[Claim 17]

The production method according to claim 16, wherein the step of the dehydrohalogenation reaction is performed in a gas phase.

[Claim 18]

A method for producing a fluorinated alkyne compound represented by formula (3B):

$CA^1{\equiv}CA^2$ (3B)

wherein A^1 and A^2 are the same or different and each is a fluorine atom or a perfluoroalkyl group,

the method comprising:

(IB) subjecting a halogenated alkane compound represented by formula (1B):

$CHX^8A^1CHX^9A^2$ (1B)

wherein A^1 and A^2 are as defined above, and X^8 and X^9 are the same or different and each is a halogen atom, to a dehydrohalogenation reaction in the presence of a catalyst in a gas phase to produce a halogenated alkene compound represented by formula (2B):

$CX^8A^1{=}CHA^2$ (2B)

wherein A^1, A^2, and X^8 are as defined above,

wherein the catalyst is at least one member selected from the group consisting of activated carbon, chromium oxide, fluorinated chromium oxide, aluminum oxide, fluorinated aluminum oxide, iron oxide, fluorinated iron oxide, nickel oxide, fluorinated nickel oxide, magnesium oxide, and fluorinated magnesium oxide;

(IIB) after step (IB), removing hydrogen halide; and

(IIIB) after step (IIB), subjecting the obtained halogenated alkene compound represented by formula (2B):

$CX^8A^1{=}CHA^2$ (2B)

wherein A^1, A^2, and X^8 are as defined above, to a dehydrohalogenation reaction in the presence of a catalyst in a gas phase to produce the fluorinated alkyne compound represented by formula (3B):

$CA^1{\equiv}CA^2$ (3B)

wherein A^1 and A^2 are as defined above,

wherein the catalyst is at least one member selected from the group consisting of activated carbon, chromium oxide, fluorinated chromium oxide, aluminum oxide, fluorinated aluminum

oxide, iron oxide, fluorinated iron oxide, nickel oxide, fluorinated nickel oxide, magnesium oxide, and fluorinated magnesium oxide.

[Claim 19]

A method for producing a fluorinated alkyne compound represented by formula (3B):

$CA^1{\equiv}CA^2$ (3B)

wherein A^1 and A^2 are the same or different and each is a fluorine atom or a perfluoroalkyl group,

the method comprising:

(IB) subjecting a halogenated alkane compound represented by formula (1B):

$CHX^8A^1CHX^9A^2$ (1B)

wherein A^1 and A^2 are as defined above, and X^8 and X^9 are the same or different and each is a halogen atom, to a dehydrohalogenation reaction in the presence of a catalyst and a cyclic halogen carbide compound in which all hydrogen atoms bonded to carbon atoms in a hydrocarbon compound are replaced by halogen atoms in a gas phase to produce a halogenated alkene compound represented by formula (2B):

$CX^8A^1{=}CHA^2$ (2B)

wherein A^1, A^2, and X^8 are as defined above;

(IIB) after step (IB), removing hydrogen halide; and

(IIIB) after step (IIB), subjecting the obtained halogenated alkene compound represented by formula (2B):

$CX^8A^1{=}CHA^2$ (2B)

wherein A^1, A^2, and X^8 are as defined above, to a dehydrohalogenation reaction in the presence of a catalyst and a cyclic halogen carbide compound in which all hydrogen atoms bonded to carbon atoms in a hydrocarbon compound are replaced by halogen atoms in a gas phase to produce the fluorinated alkyne compound represented by formula (3B):

$CA^1{\equiv}CA^2$ (3B)

wherein A^1 and A^2 are as defined above.

[Claim 20]

The production method according to any one of claims 1 to 3 and 8 to 19, wherein the step of the dehydrofluorination reaction and/or the dehydrohalogenation reaction is performed by a gas-phase continuous flow process.

[Claim 21]

The production method according to any one of claims 1 to 3 and 7 to 20, wherein the step of the dehydrofluorination reaction and/or the dehydrohalogenation reaction is performed in the presence of a cyclic halogen carbide compound in which all hydrogen atoms bonded to carbon atoms in a hydrocarbon compound are replaced by halogen atoms.

[Claim 22]

A composition comprising a halogenated butene compound represented by formula (1A):

$CX^1X^2X^3CX^4=CHCX^5X^6X^7$ (1A)

wherein X^1, X^2, X^3, X^4, X^5, X^6, and X^7 are the same or different and each is a halogen atom,

the halogenated butene compound represented by formula (1A) being contained in an amount of 80.00 to 99.99 mol% based on the total amount of the composition, which is taken as 100 mol%.

[Claim 23]

The composition according to claim 22, comprising, as the halogenated butene compound represented by formula (1A), an (E)-halogenated butene compound in an amount of 85.00 to 99.98 mol% based on the total amount of the composition, which is taken as 100 mol%.

[Claim 24]

A composition comprising:

a halogenated alkene compound represented by formula (2B):

$CX^8A^1=CHA^2$ (2B)

wherein A^1 and A^2 are the same or different and each is a fluorine atom or a perfluoroalkyl group, and X^8 is a halogen atom; and

at least one hydrofluorocarbon (HFC) compound selected from the group consisting of hexafluorobutene, hexafluorobutane, and octafluorobutane,

wherein the halogenated alkene compound represented by formula (2B) is contained in an amount of 80 mol% or more, and the hydrofluorocarbon (HFC) compound is contained in an amount of 20 mol% or less, based on the total amount of the composition, which is taken as 100 mol%.

[Claim 25]

A composition comprising:

a fluorinated alkyne compound represented by formula (3B):

$CA^1\equiv CA^2$ (3B)

wherein A^1 and A^2 are the same or different and each is a fluorine atom or a perfluoroalkyl group; and

at least one hydrofluorocarbon (HFC) compound selected from the group consisting of trifluoromethane, difluoromethane, tetrafluoromethane, and monofluoromethane,

wherein the fluorinated alkyne compound represented by formula (3B) is contained in an amount of 80 mol% or more, and the hydrofluorocarbon (HFC) compound is contained in an amount of 20 mol% or less, based on the total amount of the composition, which is taken as 100 mol%.

[Claim 26]

A composition comprising:

a halogenated butyne compound represented by formula (3A):

$CX^1X^2X^3C\equiv CCX^5X^6X^7$ (3A)

wherein X^1, X^2, X^3, X^5, X^6, and X^7 are the same or different and each is a halogen atom; and

at least one hydrofluorocarbon (HFC) compound selected from the group consisting of trifluoromethane, difluoromethane, tetrafluoromethane, and monofluoromethane,

wherein the halogenated butyne compound represented by formula (3A) is contained in an amount of 80 mol% or more, and the hydrofluorocarbon (HFC) compound is contained in an amount of 20 mol% or less, based on the total amount of the composition, which is taken as 100 mol%.

[Claim 27]

The composition according to any one of claims 22 to 26, which is used as a cleaning gas, an etching gas, a refrigerant, a heat transfer medium, or a building block for organic synthesis.