

PROCESS FOR MAKING A CONJUGATED DIENE FROM AN ALLYL ALCOHOL**TECHNICAL FIELD**

The present invention relates generally to an *in-situ* method for making a conjugated diene from an allyl alcohol comprising the conversion of the allyl alcohol to an allyl carbonate, allyl ester or allyl formate followed by conversion of the allyl carbonate, allyl ester or allyl formate to the conjugated diene. The present invention further relates to the conjugated dienes obtained by and/or obtainable by said method and the uses of said conjugated dienes, particularly for the formation of fragrance ingredients.

10

BACKGROUND

Conjugated dienes frequently serve as substrates for conversion to highly functionalized products via numerous organic reactions such as Diels-Alder reactions, hydroformylation, carbonylation, and cyclopropanation.

15

For this purpose, conjugated dienes have been prepared directly from allyl alcohols by elimination under relatively harsh reaction conditions such as high temperature and basic or acidic conditions. However, these direct elimination reactions lack selectivity, especially when the number of R_1 groups of formula (I) herein that are not hydrogen is more than one, thus resulting in regioisomer mixtures of conjugated dienes, including oligomerization and cyclization by-products.

20

Transition metal catalyzed elimination of allyl carbonates, allyl esters or allyl formates to form conjugated dienes can improve yield and selectivities compared to the direct elimination of the allyl alcohols under harsh conditions (see, for example, J.-P.Barras, B.Bourdin and F.Schröder, *Chimia* 60, 574, 2006). However, it is first necessary to form the allyl carbonate, allyl ester or allyl formate, for example from an allyl alcohol, before the transition metal catalyzed elimination can take place. This is a disadvantage, particularly in an industrial environment, because additional isolation and purification steps are required before the conjugated diene is formed.

30

The examples of JP2006327960 disclose the direct elimination of 2,7-octadiene-1-ol to 1,3,7-octatriene in the presence of $Pd(OAc)_2$ and triphenylphosphine in a continuous process by feeding the allyl alcohol continuously to the catalyst and ligand with concomitant distillation of the conjugated diene at temperatures ranging from 120°C to 230°C. However, regioisomer by-products can be expected from allyl alcohols with a higher substitution pattern than 2,7-octadiene-1-ol (*i.e.* the number of R_1 groups of formula (I) herein that are not

35

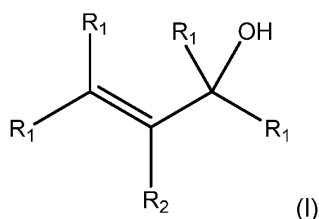
hydrogen is more than one). Further, the distillation of the conjugated diene products may be difficult due to the similarity of the allyl alcohol and conjugated diene boiling points. No intermediate compounds are formed in this reaction.

- 5 Verholt *et al.*, Cat. Sci. & Tech., 6, 1302, 2016 describes the elimination of allyl alcohols in the presence of catalytic amounts of Pd(acac)₂, xantphos and trifluoroacetic acid (TFA) in toluene at 105°C. However, relatively high catalyst loadings of 1% are used and a carbon monoxide pressure of 10 – 40 bar is necessary. The use of carbon monoxide under pressure and corrosive TFA is a disadvantage, particularly in an industrial environment, because of
10 the toxicity of the reactants and the fact that the conjugated diene products cannot be removed continuously from the reaction mixture by distillation.

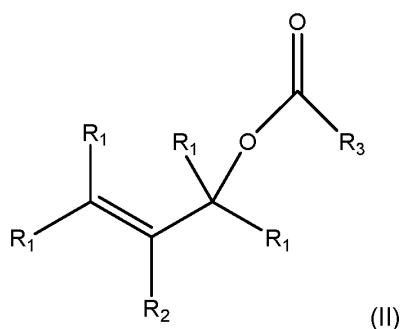
It is therefore desirable to provide new or improved methods for making conjugated dienes,
15 for example which may provide a more direct conversion of allyl alcohols to conjugated dienes.

SUMMARY

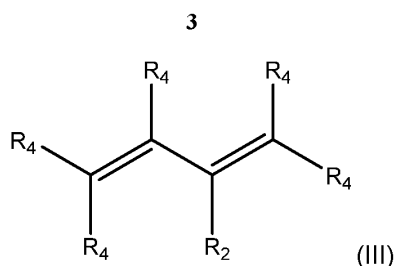
- In accordance with a first aspect of the present invention there is provided a method for the *in-situ* formation of a conjugated diene of formula (III) from an allyl alcohol of formula (I), the
20 method comprising conversion of the allyl alcohol of formula (I)



to an allyl carbonate, allyl ester or allyl formate of formula (II)



- in the presence of a base followed by conversion of the allyl carbonate, allyl ester or allyl
25 formate of formula (II) to the conjugated diene of formula (III)



using a palladium catalyst or catalyst precursor and an organic phosphorous ligand,
wherein

each R₁ is independently selected from H, alkyl, substituted alkyl, alkenyl, substituted
5 alkenyl, aromatic hydrocarbon, and substituted aromatic hydrocarbon;

R₂ is selected from H, alkyl, substituted alkyl, alkenyl, substituted alkenyl, aromatic
hydrocarbon, and substituted aromatic hydrocarbon;

R₃ is selected from H, alkyl, substituted alkyl, alkoxy, substituted alkoxy, phenyl and
substituted phenyl;

10 each R₄ is independently selected from H, alkyl, substituted alkyl, alkenyl, substituted
alkenyl, aromatic hydrocarbon, and substituted aromatic hydrocarbon;

wherein at least one R₁ bears a proton in α-position of the allylic C3 group which is
deprotonated under basic reaction conditions thus forming a diene of formula (III) via 1,2 or
1,4 elimination and the at least one R₁ is alkyl, substituted alkyl, alkenyl, substituted alkenyl,
15 aromatic hydrocarbon, or substituted aromatic hydrocarbon.

In accordance with a second aspect of the present invention there is provided a conjugated
diene of formula (III) obtained by and/or obtainable by the method of the first aspect of the
present invention.

20

In accordance with a third aspect of the present invention there is provided a use of a
conjugated diene of the second aspect of the present invention to make a fragrance
ingredient.

25 Certain embodiments of any aspect of the present invention may provide one or more of the
following advantages:

- *in-situ* method for making conjugated dienes from allyl alcohols;
- *EZ* mixtures of allyl alcohols give *E*-dienes or dienes with an enriched *EZ* proportion due
to an equilibration of the intermediate Pd-allyl complexes
- 30 • good selectivity for conjugated diene, in particular *exo*-dienes;
- good yield and purity of the desired conjugated diene;
- reduction in the number of purification and isolation steps;

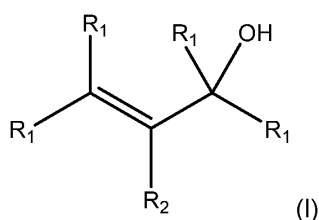
- milder reaction conditions, e.g. lower temperature, no pressure, no acid (which is detrimental to the stability of the dienes which are prone to carbocationic side reactions)
- low catalyst loadings.

5 The details, examples and preferences provided in relation to any particular one or more of the stated aspects of the present invention will be further described herein and apply equally to all aspects of the present invention. Any combination of the embodiments, examples and preferences described herein in all possible variations thereof is encompassed by the present invention unless otherwise indicated herein, or otherwise clearly contradicted by
10 context.

DETAILED DESCRIPTION

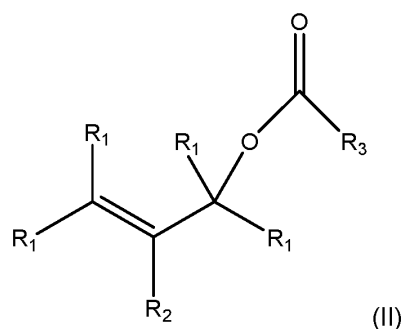
The present invention is based on the surprising finding that conjugated dienes can be formed *in-situ* from allyl carbonates or allyl esters or allyl formates prior to work-up and
15 isolation. The present invention is further based on the surprising finding that the *in-situ* reaction has high selectivity and efficiency and can be effected with similar or even lower catalyst loadings in impure reaction mixtures compared to reaction mixtures of isolated and purified allyl carbonates or allyl esters or allyl formates. It is also surprising that the palladium catalysts and their ligands used for the elimination reaction are not deactivated by impurities
20 which might be present in the mixture. There are some indications that the catalyst system is even more active in these mixtures.

There is therefore provided herein a method for the *in-situ* formation of a conjugated diene of formula (III) from an allyl alcohol of formula (I), the method comprising conversion of the allyl
25 alcohol of formula (I)

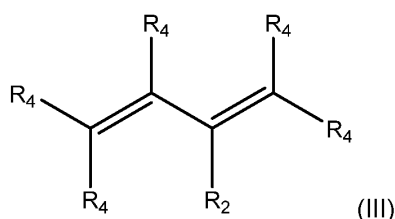


to an allyl carbonate, allyl ester or allyl formate of formula (II)

5



in the presence of a base followed by conversion of the allyl carbonate, allyl ester or allyl formate of formula (II) to the conjugated diene of formula (III)



- 5 using a palladium catalyst or catalyst precursor and an organic phosphorous ligand, wherein

each R_1 is independently selected from H, alkyl, substituted alkyl, alkenyl, substituted alkenyl, aromatic hydrocarbon, and substituted aromatic hydrocarbon;

- 10 R_2 is selected from H, alkyl, substituted alkyl, alkenyl, substituted alkenyl, aromatic hydrocarbon, and substituted aromatic hydrocarbon;

R_3 is selected from H, alkyl, substituted alkyl, alkoxy, substituted alkoxy, phenyl and substituted phenyl;

each R_4 is independently selected from H, alkyl, substituted alkyl, alkenyl, substituted alkenyl, aromatic hydrocarbon, and substituted aromatic hydrocarbon;

- 15 wherein at least one R_1 bears a proton in α -position of the allylic C3 group which is deprotonated under basic reaction conditions thus forming a diene of formula (III) via 1,2 or 1,4 elimination and the at least one R_1 is alkyl, substituted alkyl, alkenyl, substituted alkenyl, aromatic hydrocarbon, or substituted aromatic hydrocarbon.

- 20 As used herein the phrase "*in-situ* formation of a conjugated diene of formula (III) from an allyl alcohol of formula (I)" refers to a method wherein the entire reaction takes place in a single reaction mixture and any intermediate compounds that are formed (e.g. the allyl carbonate or allyl ester or allyl formate of formula (II)) are not isolated or purified before the subsequent steps are carried out to form the final product (*i.e.* the conjugated diene of formula (III)). In other words, the conversion of the allyl alcohol of formula (I) to an allyl carbonate, allyl ester or allyl formate of formula (II) in the presence of a base and the conversion of the allyl carbonate, allyl ester or allyl formate of formula (II) to the conjugated
- 25

diene of formula (III) takes place in the same reaction mixture without isolation or purification of the allyl carbonate, allyl ester or allyl formate of formula (II).

As used herein, the term "alkyl" refers to a radical derived from a saturated cyclic, linear or
5 branched hydrocarbon by removal of a hydrogen atom. For example, the alkyl may be
derived from a saturated linear or branched hydrocarbon by removal of a hydrogen atom.
Each alkyl may, for example, independently comprise from 1 to 16 carbon atoms. For
example, each alkyl may independently comprise from 1 to 12 carbon atoms or from 1 to 10
10 carbon atoms or from 1 to 8 carbon atoms or from 1 to 6 carbon atoms or from 1 to 5 carbon
atoms or from 1 to 4 carbon atoms or from 1 to 3 carbon atoms or from 1 to 2 carbon atoms.
For example, each alkyl may independently comprise from 2 to 16 carbon atoms or from 2 to
12 carbon atoms or from 2 to 10 carbon atoms or from 2 to 8 carbon atoms or from 2 to 6
carbon atoms or from 2 to 5 carbon atoms or from 2 to 4 carbon atoms or from 2 to 3 carbon
atoms. For example, each alkyl may independently comprise from 3 to 16 carbon atoms or
15 from 3 to 12 carbon atoms or from 3 to 10 carbon atoms or from 3 to 8 carbon atoms or from
3 to 6 carbon atoms or from 3 to 5 carbon atoms or from 3 to 4 carbon atoms.

As used herein, the term "substituted alkyl" refers to a radical derived from a saturated cyclic,
linear or branched hydrocarbon by removal of a hydrogen atom, wherein one or more of the
20 remaining hydrogen atoms on the saturated hydrocarbon is replaced by a functional group
(also referred to herein as a substituent). For example, the substituted alkyl may be derived
from a saturated linear or branched hydrocarbon by removal of a hydrogen atom, wherein
one or more of the remaining hydrogen atoms on the saturated hydrocarbon is replaced by a
functional group (also referred to herein as a substituent). The substituted alkyl may, for
25 example, have one, two, three, four or five functional groups. The substituted alkyl may, for
example, have one or two functional groups.

Each substituted alkyl may, for example, independently comprise from 1 to 16 carbon atoms
(not including any carbon atoms present in the functional groups). For example, each
30 substituted alkyl may independently comprise from 1 to 12 carbon atoms or from 1 to 10
carbon atoms or from 1 to 8 carbon atoms or from 1 to 6 carbon atoms or from 1 to 5 carbon
atoms or from 1 to 4 carbon atoms or from 1 to 3 carbon atoms or from 1 to 2 carbon atoms
(not including any carbon atoms present in the functional groups). For example, each
substituted alkyl may independently comprise from 2 to 16 carbon atoms or from 2 to 12
35 carbon atoms or from 2 to 10 carbon atoms or from 2 to 8 carbon atoms or from 2 to 6
carbon atoms or from 2 to 5 carbon atoms or from 2 to 4 carbon atoms or from 2 to 3 carbon
atoms (not including any carbon atoms present in the functional groups). For example, each

substituted alkyl may independently comprise from 3 to 16 carbon atoms or from 3 to 12 carbon atoms or from 3 to 10 carbon atoms or from 3 to 8 carbon atoms or from 3 to 6 carbon atoms or from 3 to 5 carbon atoms or from 3 to 4 carbon atoms (not including any carbon atoms present in the functional groups).

5

As used herein, the term "alkenyl" refers to a radical derived from an unsaturated cyclic, linear or branched hydrocarbon by removal of a hydrogen atom. For example, the alkenyl may be derived from an unsaturated linear or branched hydrocarbon by removal of a hydrogen atom. "Alkenyl" does not encompass aromatic hydrocarbons described below. The

10 alkenyl may, for example, have one, two, or three carbon-carbon double bonds. For example, the alkenyl may have one carbon-carbon double bond. Each alkenyl may, for example, independently comprise from 2 to 12 carbon atoms. For example, each alkenyl may independently comprise from 2 to 10 carbon atoms or from 2 to 8 carbon atoms or from 2 to 6 carbon atoms or from 2 to 5 carbon atoms or from 2 to 4 carbon atoms or from 2 to 3
15 carbon atoms. For example, each alkenyl may independently comprise from 3 to 12 carbon atoms or from 3 to 10 carbon atoms or from 3 to 8 carbon atoms or from 3 to 6 carbon atoms or from 3 to 5 carbon atoms or from 3 to 4 carbon atoms (not including any carbon atoms present in the functional groups).

20 As used herein, the term "substituted alkenyl" refers to a radical derived from an unsaturated cyclic, linear or branched hydrocarbon by removal of a hydrogen atom, wherein one or more of the remaining hydrogen atoms on the unsaturated hydrocarbon is replaced by a functional group (also referred to herein as a substituent). For example, the substituted alkenyl may be derived from an unsaturated linear or branched hydrocarbon by removal of a hydrogen atom,
25 wherein one or more of the remaining hydrogen atoms on the unsaturated hydrocarbon is replaced by a functional group (also referred to herein as a substituent). "Substituted alkenyl" does not encompass aromatic hydrocarbons described below. The substituted alkenyl may, for example, have one, two, or three carbon-carbon double bonds. For example, the substituted alkenyl may have one carbon-carbon double bond. The substituted alkenyl may,
30 for example, have one, two, three, four or five functional groups. The substituted alkenyl may, for example, have one or two functional groups.

Each substituted alkenyl may, for example, independently comprise from 2 to 12 carbon atoms (not including any carbon atoms present in the functional groups). For example, each
35 substituted alkenyl may independently comprise from 2 to 10 carbon atoms or from 2 to 8 carbon atoms or from 2 to 6 carbon atoms or from 2 to 5 carbon atoms or from 2 to 4 carbon atoms or from 2 to 3 carbon atoms (not including any carbon atoms present in the functional

groups). For example, each substituted alkenyl may independently comprise from 3 to 12 carbon atoms or from 3 to 10 carbon atoms or from 3 to 8 carbon atoms or from 3 to 6 carbon atoms or from 3 to 5 carbon atoms or from 3 to 4 carbon atoms (not including any carbon atoms present in the functional groups).

5

As used herein, the term "aromatic hydrocarbon" refers to a radical derived from a hydrocarbon group comprising an unsaturated ring of resonance bonds by removal of a hydrogen atom. The aromatic hydrocarbon may, for example, comprise one or more heteroatoms (e.g. one or more of oxygen, nitrogen or sulfur). Alternatively, the aromatic hydrocarbon may not comprise any heteroatoms (*i.e.* comprises only carbon and hydrogen atoms). The aromatic hydrocarbon radical may, for example, be derived from benzene (C_6H_6), toluene ($C_6H_5CH_3$), ethylbenzene ($C_6H_5CH_2CH_3$), xylene ($C_6H_4(CH_3)_2$), mesitylene ($(C_6H_3(CH_3)_3)$), durene ($C_6H_2(CH_3)_4$), biphenyl ($C_6H_5-C_6H_5$), naphthalene ($C_{10}H_8$), furane, thiofurane, pyrazole, imidazole, isoxazole, oxazole, isothiazole or thiazole. For example, the aromatic hydrocarbon may be derived from benzene or toluene or naphthalene. The aromatic hydrocarbon may, for example, comprise from 3 to 12 carbon atoms or from 3 to 10 carbon atoms or from 3 to 8 carbon atoms or from 3 to 6 carbon atoms. For example, the aromatic hydrocarbon may comprise from 4 to 12 carbon atoms or from 4 to 10 carbon atoms or from 4 to 8 carbon atoms or from 4 to 6 carbon atoms. For example, the aromatic hydrocarbon may comprise from 6 to 12 carbon atoms or from 6 to 10 carbon atoms or from 6 to 8 carbon atoms.

As used herein, the term "substituted aromatic hydrocarbon" refers to a radical derived from a hydrocarbon group comprising an unsaturated ring of resonance bonds by removal of a hydrogen atom, wherein one or more of the remaining hydrogen atoms on the unsaturated hydrocarbon is replaced by a functional group (also referred to herein as a substituent). The substituted aromatic hydrocarbon may, for example, comprise one or more heteroatoms in the ring of resonance bonds (e.g. one or more of oxygen, nitrogen or sulfur). Alternatively, the substituted aromatic hydrocarbon may not comprise any heteroatoms in the ring of resonance bonds (*i.e.* comprises only carbon and hydrogen atoms). The substituted aromatic hydrocarbon radical may, for example, be derived from substituted benzene (C_6H_6), substituted toluene ($C_6H_5CH_3$), substituted ethylbenzene ($C_6H_5CH_2CH_3$), substituted xylene ($C_6H_4(CH_3)_2$), substituted mesitylene ($(C_6H_3(CH_3)_3)$), substituted durene ($C_6H_2(CH_3)_4$), substituted biphenyl ($C_6H_5-C_6H_5$), substituted naphthalene ($C_{10}H_8$), substituted furane, substituted thiofurane, substituted pyrazole, substituted imidazole, substituted isoxazole, substituted oxazole, substituted isothiazole or substituted thiazole. For example, the substituted aromatic hydrocarbon may be derived from substituted benzene or substituted

toluene or substituted naphthalene. The substituted aromatic hydrocarbon may, for example, have one, two, three, four or five functional groups. The substituted aromatic hydrocarbon may, for example, have one or two functional groups.

- 5 The substituted aromatic hydrocarbon may, for example, comprise from 3 to 12 carbon atoms or from 3 to 10 carbon atoms or from 3 to 8 carbon atoms or from 3 to 6 carbon atoms (not including any carbon atoms present in the functional groups). For example, the substituted aromatic hydrocarbon may comprise from 4 to 12 carbon atoms or from 4 to 10 carbon atoms or from 4 to 8 carbon atoms or from 4 to 6 carbon atoms (not including any
- 10 carbon atoms present in the functional groups). For example, the substituted aromatic hydrocarbon may comprise from 6 to 12 carbon atoms or from 6 to 10 carbon atoms or from 6 to 8 carbon atoms (not including any carbon atoms present in the functional groups).

- As used herein, the term "alkoxy" refers to a group having the formula "-OR", wherein R is an
- 15 alkyl group. The alkyl in the alkoxy group may be as described herein. The alkyl in the alkoxy group may, for example, be a saturated linear or branched chain hydrocarbon. The alkyl in the alkoxy group may, for example, comprise from 1 to 8 carbon atoms or from 1 to 6 carbon atoms or from 1 to 4 carbon atoms or from 1 to 3 carbon atoms or from 1 to 2 carbon atoms.

- 20 As used herein, the term "substituted alkoxy" refers to a group having the formula "-OR", wherein R is a substituted alkyl group. The substituted alkyl in the alkoxy group may be as described herein. The substituted alkyl in the alkoxy group may, for example, be a saturated linear or branched chain hydrocarbon wherein one or more of the hydrogen atoms of the hydrocarbon is replaced by a functional group (also referred to herein as a substituent). The
- 25 substituted alkyl in the substituted alkoxy group may, for example, comprise from 1 to 8 carbon atoms or from 1 to 6 carbon atoms or from 1 to 4 carbon atoms or from 1 to 3 carbon atoms or from 1 to 2 carbon atoms. The substituted alkoxy may, for example, have one, two, three, four or five functional groups. The substituted alkoxy may, for example, have one or two functional groups.

- 30 Each functional group (substituent) on the substituted alkyl or substituted alkenyl or substituted aromatic hydrocarbon or substituted alkoxy or substituted phenyl may, for example, independently be selected from a hydroxyl group (-OH), an alkoxy group (-OR wherein R is alkyl including cyclic ethers such as epoxides, oxetanes, tetrahydrofuranes, tetrahydropyranes and oxepanes, all optionally substituted), an amino group (-NR, wherein
- 35 each R is independently hydrogen or alkyl), a nitro group (-NO₂), an acyl group (-CO-R, wherein R is hydrogen or alkyl), an ester group (-O-CO-R, wherein R is alkyl), an

alkoxycarbonyl group (-CO-O-R, wherein R is alkyl), an aryloxy group (-O-R, wherein R is an aromatic hydrocarbon), a halogen (e.g. F, Cl, Br or I), and an aromatic hydrocarbon group. In certain embodiments, each functional group on the substituted alkyl or substituted alkenyl or substituted aromatic hydrocarbon or substituted alkoxy may be hydroxyl (-OH).

5

Where relevant, each functional group may, for example, independently comprise from 1 to 12 carbon atoms. For example, each functional group may independently comprise from 1 to 10 carbon atoms or from 1 to 8 carbon atoms or from 1 to 6 carbon atoms or from 1 to 5 carbon atoms or from 1 to 4 carbon atoms or from 1 to 3 carbon atoms or from 1 to 2 carbon

10

atoms. The compound of formula (I) is an allyl alcohol. The term "allyl alcohol" as used herein refers to a compound of formula (I) which comprises at least one double bond and at least one alcohol (-OH) group in the α -position of the double bond.

15

Each R_1 is independently selected from hydrogen (H), alkyl, substituted alkyl, alkenyl, substituted alkenyl, aromatic hydrocarbon, and substituted aromatic hydrocarbon, wherein at least one R_1 is alkyl, substituted alkyl, alkenyl, substituted alkenyl, aromatic hydrocarbon, or substituted aromatic hydrocarbon (i.e. the at least one R_1 is not hydrogen), capable of being deprotonated in the α -position of the allylic C3 group thus forming a conjugated double bond (compound of formula (III)).

20

For example, each R_1 may independently be selected from hydrogen, alkyl, substituted alkyl, alkenyl and substituted alkenyl, wherein at least one R_1 is capable of being deprotonated in the α -position of the allylic C3 group thus forming a conjugated double bond (compound of formula (III)), and the at least one R_1 is alkyl, substituted alkyl, alkenyl, or substituted alkenyl.

25

For example, each R_1 may independently be selected from hydrogen, alkyl, and alkenyl, wherein at least one R_1 is capable of being deprotonated in the α -position of the allylic C3 group thus forming a conjugated double bond (compound of formula (III)), and the at least one R_1 is alkyl, or alkenyl.

30

The R_1 groups are not all hydrogen. For example, at least one R_1 is alkyl, substituted alkyl, alkenyl, substituted alkenyl, aromatic hydrocarbon or substituted aromatic hydrocarbon, capable of being deprotonated in the α -position of the allylic C3 group thus forming a conjugated double bond (compound of formula (III)). For example, at least one R_1 is alkyl,

35

substituted alkyl, alkenyl or substituted alkenyl capable of being deprotonated in the α -position of the allylic C3 group thus forming a conjugated double bond (compound of formula (III)). For example, at least one R_1 is alkyl or alkenyl, capable of being deprotonated in the α -position of the allylic C3 group thus forming a conjugated double bond (compound of formula (III)).

For example, at least one R_1 may be hydrogen. For example, from one to three R_1 groups may be hydrogen. For example, one or two R_1 groups may be hydrogen.

For example, at least one R_1 may be alkyl or substituted alkyl. For example, from one to three R_1 groups may be alkyl or substituted alkyl. For example, one or two R_1 groups may be alkyl or substituted alkyl. For example, at least one R_1 may be alkyl. For example, from one to three R_1 groups may be alkyl. For example, one or two R_1 groups may be alkyl.

For example, at least one R_1 may be alkenyl or substituted alkenyl. For example, from one to three R_1 groups may be alkenyl or substituted alkenyl. For example, one or two R_1 groups may be alkenyl or substituted alkenyl. For example, at least one R_1 may be alkenyl. For example, from one to three R_1 groups may be alkenyl. For example, one or two R_1 groups may be alkenyl.

For example, at least one R_1 may be hydrogen and at least one R_1 may be alkyl or substituted alkyl. For example, at least one R_1 may be hydrogen and at least one R_1 may be alkyl.

For example, at least one R_1 may be hydrogen and at least one R_1 may be alkenyl or substituted alkenyl. For example, at least one R_1 may be hydrogen and at least one R_1 may be alkenyl.

For example, at least one R_1 may be hydrogen, at least one R_1 may be alkyl or substituted alkyl, and at least one R_1 may be alkenyl or substituted alkenyl. For example, at least one R_1 may be hydrogen, at least one R_1 may be alkyl, and at least one R_1 may be alkenyl.

R_2 is selected from hydrogen, alkyl, substituted alkyl, alkenyl, substituted alkenyl, aromatic hydrocarbon, and substituted aromatic hydrocarbon. R_2 may, for example, be selected from hydrogen, alkyl, substituted alkyl, alkenyl, and substituted alkenyl. R_2 may, for example, be selected from hydrogen, alkyl, and alkenyl. R_2 may, for example, be hydrogen or alkyl. R_2 may, for example, be hydrogen.

- The total number of carbon atoms in the allyl alcohol of formula (I) may, for example, be from 4 to 40 (including any carbon atoms present in any functional groups of a substituted alkyl, substituted alkenyl or substituted aromatic hydrocarbon). For example, the total number of carbon atoms in the allyl alcohol of formula (I) may be from 4 to 35 or from 4 to 30 or from 4 to 25 or from 4 to 20 or from 4 to 18 or from 4 to 16 or from 4 to 15 (including any carbon atoms present in any functional groups of a substituted alkyl, substituted alkenyl or substituted aromatic hydrocarbon). For example, the total number of carbon atoms in the allyl alcohol of formula (I) may be from 6 to 40 or from 6 to 35 or from 6 to 30 or from 6 to 25 or from 6 to 20 or from 6 to 18 or from 6 to 16 or from 6 to 15 (including any carbon atoms present in any functional groups of a substituted alkyl, substituted alkenyl or substituted aromatic hydrocarbon). For example, the total number of carbon atoms in the allyl alcohol of formula (I) may be from 8 to 40 or from 8 to 35 or from 8 to 30 or from 8 to 25 or from 8 to 20 or from 8 to 18 or from 8 to 16 or from 8 to 15. For example, the total number of carbon atoms in the allyl alcohol of formula (I) may be from 10 to 40 or from 10 to 35 or from 10 to 30 or from 10 to 25 or from 10 to 20 or from 10 to 18 or from 10 to 16 or from 10 to 15 (including any carbon atoms present in any functional groups of a substituted alkyl, substituted alkenyl or substituted aromatic hydrocarbon).
- The compound of formula (I) may, for example, be selected from 2,7-octadiene-1-ol, 3,7,11-trimethyldodeca-1,6,10-trien-3-ol (nerolidol), 4,8-dimethylnona-2,7-dien-4-ol (homolinalool), 3,7-dimethylnona-1,6-dien-3-ol (ethyl linalool), 2,6-dimethyloct-2-ene-1,8-diol, 3,7-dimethyloct-5-ene-1,7-diol, 3,7-dimethyloct-7-ene-1,6-diol, 2,4,8-trimethylnona-2,7-dien-4-ol, 4,8-dimethylnona-3,7-dien-2-ol (methylgeraniol), 3,5-dimethylhex-2-en-1-ol, 6,10-dimethylundeca-1,5,9-trien-4-ol, 6,10-dimethylundeca-5,9-dien-1-yn-4-ol and 1-(3-hydroxy-3-methylpent-4-en-1-yl)-2,5,5,8a-tetramethyl-decahydronaphthalen-2-ol (Sclareol).

- The compound of formula (II) is an allyl carbonate, allyl ester or allyl formate. Where R_3 is hydrogen, the compound of formula (II) is an allyl formate. Where R_3 is alkyl, substituted alkyl, phenyl or substituted phenyl the compound of formula (II) is an allyl ester. Where R_3 is alkoxy or substituted alkoxy, the compound of formula (II) is an allyl carbonate.

- Each R_1 group in the compound of formula (II) is the same as the corresponding R_1 group in the compound of formula (I).

- The R_2 group in the compound of formula (II) is the same as the R_2 group in the compound of formula (I).

R₃ is selected from hydrogen, alkyl, substituted alkyl, alkoxy, substituted alkoxy, phenyl and substituted phenyl. R₃ may, for example, be selected from alkyl, substituted alkyl, alkoxy, substituted alkoxy, and phenyl. R₃ may, for example, be selected from alkyl, alkoxy, and phenyl.

Where R₃ may be alkyl, the alkyl may, for example, be selected from methyl, ethyl, propyl, isopropyl, n-butyl, and isobutyl.

Where R₃ may be alkoxy, the alkoxy may, for example, be selected from methoxy, ethoxy, propoxy, isopropoxy, n-butoxy, and isobutoxy.

The total number of carbon atoms in R₃ (including any carbon atoms present in any functional groups of a substituted alkoxy) may, for example, be from 1 to 8. For example, the total number of carbon atoms in R₃ (including any carbon atoms present in any functional groups of a substituted alkoxy) may, for example, be from 1 to 6 or from 1 to 4 or from 1 to 3 or from 1 to 2.

The compound of formula (III) is a conjugated diene formed by elimination of the -O-C(O)-R₃ group of the compound of formula (II). Therefore, at least two of the R₄ groups may be the same as the corresponding R₁ groups of the compound of formula (I) and (II). For example, three of the R₄ groups may be the same as the corresponding R₁ groups of the compound of formula (I) and (II).

The R₂ group in the compound of formula (III) is the same as the R₂ group in the compound of formula (I).

Each R₄ is independently selected from hydrogen (H), alkyl, substituted alkyl, alkenyl, substituted alkenyl, aromatic hydrocarbon, and substituted aromatic hydrocarbon.

For example, each R₄ may independently be selected from hydrogen, alkyl, substituted alkyl, alkenyl and substituted alkenyl.

For example, each R₄ may independently be selected from hydrogen, alkyl, and alkenyl.

For example, at least one R₄ may be hydrogen. For example, from one to three R₄ groups may be hydrogen. For example, one or two R₄ groups may be hydrogen.

For example, at least one R₄ may be alkyl or substituted alkyl. For example, from one to three R₄ groups may be alkyl or substituted alkyl. For example, one or two R₄ groups may be alkyl or substituted alkyl. For example, at least one R₄ may be alkyl. For example, from one to three R₄ groups may be alkyl. For example, one or two R₄ groups may be alkyl.

For example, at least one R₄ may be alkenyl or substituted alkenyl. For example, from one to three R₄ groups may be alkenyl or substituted alkenyl. For example, one or two R₄ groups may be alkenyl or substituted alkenyl. For example, at least one R₄ may be alkenyl. For example, from one to three R₄ groups may be alkenyl. For example, one or two R₄ groups may be alkenyl.

For example, at least one R₄ may be hydrogen and at least one R₄ may be alkyl or substituted alkyl. For example, at least one R₄ may be hydrogen and at least one R₄ may be alkyl.

For example, at least one R₄ may be hydrogen and at least one R₄ may be alkenyl or substituted alkenyl. For example, at least one R₄ may be hydrogen and at least one R₄ may be alkenyl.

For example, at least one R₄ may be hydrogen, at least one R₄ may be alkyl or substituted alkyl, and at least one R₄ may be alkenyl or substituted alkenyl. For example, at least one R₄ may be hydrogen, at least one R₄ may be alkyl, and at least one R₄ may be alkenyl.

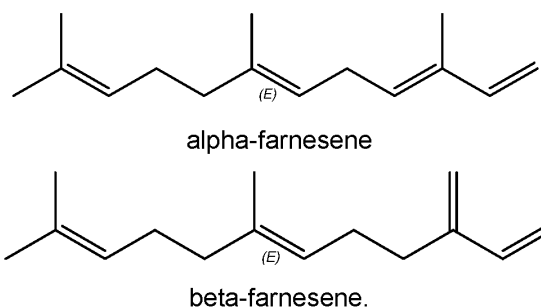
In one specific embodiment the substitution pattern of the compounds of formula (III) is such that the compound of formula (III) represents a diene comprising an exo-methylene group. By the term "exo-methylene group" is meant a non-terminal CH₂ entity attached by a double bond to a carbon chain or ring. As specific examples one may cite homomyrcene (e.g. *E*-Homomyrcene), ethyl myrcene, 5-methyl-3-methylenhex-1-ene, farnesene (e.g. 6-*E*-farnesene), 2,8-dimethyl-4-methylenonona-2,7-diene, 10-methyl-6-methyleneundeca-1,4,9-triene (e.g. *E*-10-methyl-6-methyleneundeca-1,4,9-triene) and 10-methyl-6-methyleneundeca-4,9-dien-1-yne (e.g. *E*-10-methyl-6-methyleneundeca-4,9-dien-1-yne). In particular this class of dienes can undergo optional subsequent Diels-Alder or 1,4-hydrogenations reactions with good selectivity, resulting in precursors useful in the fragrance industry.

With other words, to provide dienes with an exo-methylene group at least one R_1 in formula (I) must be a methyl group, which is selectively deprotonated.

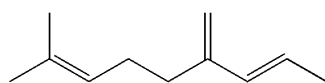
R_2 is selected from hydrogen, alkyl, substituted alkyl, alkenyl, substituted alkenyl, aromatic hydrocarbon, and substituted aromatic hydrocarbon. R_2 may, for example, be selected from hydrogen, alkyl, substituted alkyl, alkenyl, and substituted alkenyl. R_2 may, for example, be selected from hydrogen, alkyl, and alkenyl. R_2 may, for example, be hydrogen or alkyl. R_2 may, for example, be hydrogen.

- 10 The total number of carbon atoms in the conjugated diene of formula (III) may, for example, be from 6 to 40 (including any carbon atoms present in any functional groups of a substituted alkyl, substituted alkenyl or substituted aromatic hydrocarbon). For example, the total number of carbon atoms in the conjugated diene of formula (III) may be from 6 to 35 or from 6 to 30 or from 6 to 25 or from 6 to 20 or from 6 to 18 or from 6 to 16 or from 6 to 15
- 15 (including any carbon atoms present in any functional groups of a substituted alkyl, substituted alkenyl or substituted aromatic hydrocarbon). For example, the total number of carbon atoms in the conjugated diene of formula (III) may be from 7 to 40 or from 7 to 35 or from 7 to 30 or from 7 to 25 or from 7 to 20 or from 7 to 18 or from 7 to 16 or from 7 to 15 (including any carbon atoms present in any functional groups of a substituted alkyl,
- 20 substituted alkenyl or substituted aromatic hydrocarbon). For example, the total number of carbon atoms in the conjugated diene of formula (III) may be from 8 to 40 or from 8 to 35 or from 8 to 30 or from 8 to 25 or from 8 to 20 or from 8 to 18 or from 8 to 16 or from 8 to 15. For example, the total number of carbon atoms in the conjugated diene of formula (III) may be from 10 to 40 or from 10 to 35 or from 10 to 30 or from 10 to 25 or from 10 to 20 or from
- 25 10 to 18 or from 10 to 16 or from 10 to 15 (including any carbon atoms present in any functional groups of a substituted alkyl, substituted alkenyl or substituted aromatic hydrocarbon).

- 30 The compound of formula (III) may, for example, be 6-*E*-farnesene, which may, for example, be a α/β -mixture of 6-*E*-farnesene,



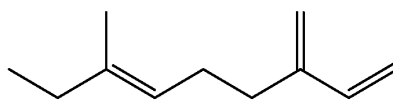
The compound of formula (III) may, for example, be homomyrcene,



homomyrcene.

5

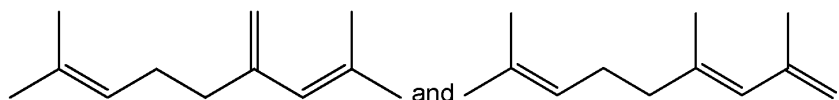
The compound of formula (III) may, for example, be ethyl myrcene,



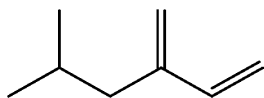
ethyl myrcene.

10

The compound of formula (III) may, for example, be a mixture (e.g. a 1:1 mixture) of

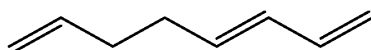


The compound of formula (III) may, for example, be 5-methyl-3-methylenehex-1-ene,



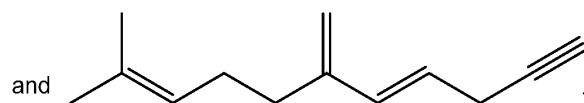
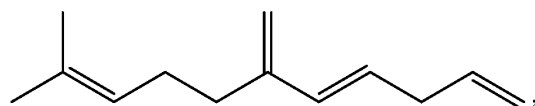
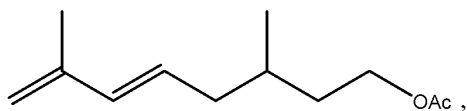
15

The compound of formula (III) may, for example, be octa-1,3,7-triene



20

In a further embodiment the compound of formula (III) may, for example, be a compound selected from



The conversion of the allyl carbonate or allyl ester or allyl formate of formula (II) to the conjugated diene of formula (III) may be concomitant with or subsequent to the conversion of the allyl alcohol of formula (I) to the allyl carbonate, allyl ester or allyl formate of formula (II).

5

By "concomitant with" it is meant that the reagents for the conversion of the allyl carbonate or allyl ester or allyl formate of formula (II) to the conjugated diene of formula (III) are added to the reaction mixture at the same time as the reagents for the conversion of the allyl alcohol of formula (I) to the allyl carbonate, allyl ester or allyl formate of formula (II) such that both

10 conversion reactions take place in the reaction mixture at the same time. The intermediate allyl carbonate or allyl ester or allyl formate of formula (II) is therefore withdrawn from the equilibrium with the allyl alcohol of formula (I) by elimination and production of the conjugated diene of formula (III).

15 By "subsequent to" it is meant that at least some of the reagents (e.g. the palladium catalyst or catalyst precursor and/or the organic phosphorous ligand) for the conversion of the allyl carbonate or allyl ester or allyl formate of formula (II) to the conjugated diene of formula (III) are added to the reaction mixture after complete or incomplete conversion of the allyl alcohol of formula (I) to the allyl carbonate, allyl ester or allyl formate of formula (II). Where the

20 conversion of the allyl alcohol of formula (I) to the allyl carbonate, allyl ester or allyl formate of formula (II) was incomplete, addition of the reagents for the conversion of the allyl carbonate, allyl ester or allyl formate of formula (II) to the conjugated diene of formula (III) may result in a period in which both conversion reactions take place in the reaction mixture at the same time. However, there is first a period in which only the conversion of the allyl

25 alcohol of formula (I) to the allyl carbonate, allyl ester or allyl formate of formula (II) is taking place. The subsequent conversion takes place in the same reaction mixture and no isolation or purification of the compound of formula (II) takes place, therefore the subsequent conversion is an *in-situ* reaction in accordance with the present disclosure.

30 The conversion of the allyl alcohol of formula (I) to the allyl carbonate, allyl ester or allyl formate of formula (II) and/or the conversion of the allyl carbonate, allyl ester or allyl formate of formula (II) to the conjugated diene of formula (III) may, for example, take place in an inert atmosphere. By "inert atmosphere" it is meant an atmosphere that does not undergo any chemical reactions in the conditions used for the conversion of the allyl alcohol of formula (I)

35 to the allyl carbonate, allyl ester or allyl formate of formula (II) and/or the conversion of the allyl carbonate, allyl ester or allyl formate of formula (II) to the conjugated diene of formula (III).

- The conversion of the allyl alcohol of formula (I) to the allyl carbonate, allyl ester or allyl formate of formula (II) and/or the conversion of the allyl carbonate, allyl ester or allyl formate of formula (II) to the conjugated diene of formula (III) may, for example, take place in a noble gas (e.g. argon) or nitrogen atmosphere. The conversion of the allyl alcohol of formula (I) to the allyl carbonate, allyl ester or allyl formate of formula (II) and/or the conversion of the allyl carbonate, allyl ester or allyl formate of formula (II) to the conjugated diene of formula (III) may, for example, take place in a nitrogen atmosphere.
- 10 The conversion of the allyl alcohol of formula (I) to the allyl carbonate, allyl ester or allyl formate of formula (II) and/or the conversion of the allyl carbonate, allyl ester or allyl formate of formula (II) to the conjugated diene of formula (III) may, for example, take place under atmospheric pressure (around 101 kPa).
- 15 The conversion of the allyl alcohol of formula (I) to the allyl carbonate, allyl ester or allyl formate of formula (II) and/or the conversion of the allyl carbonate, allyl ester or allyl formate of formula (II) to the conjugated diene of formula (III) may, for example, take place at a temperature less than about 120°C. For example, the conversion of the allyl alcohol of formula (I) to the allyl carbonate, allyl ester or allyl formate of formula (II) and/or the conversion of the allyl carbonate, allyl ester or allyl formate of formula (II) to the conjugated diene of formula (III) may, for example, take place at a temperature equal to or less than about 119°C or equal to or less than about 118°C or equal to or less than about 117°C or equal to or less than about 116°C or equal to or less than about 115°C. The conversion of the allyl alcohol of formula (I) to the allyl carbonate, allyl ester or allyl formate of formula (II) and/or the conversion of the allyl carbonate, allyl ester or allyl formate of formula (II) to the conjugated diene of formula (III) may, for example, take place at a temperature equal to or greater than about 80°C or equal to or greater than about 90°C or equal to or greater than about 100°C or equal to or greater than about 105°C or equal to or greater than about 110°C. For example, the conversion of the allyl alcohol of formula (I) to the allyl carbonate, allyl ester or allyl formate of formula (II) and/or the conversion of the allyl carbonate, allyl ester or allyl formate of formula (II) to the conjugated diene of formula (III) may, for example, take place at a temperature ranging from about 80°C to less than about 120°C or from about 90°C to less than about 120°C or from about 100°C to less than about 120°C or from about 105°C to less than about 120°C.
- 35 The conversion of the allyl alcohol of formula (I) to the allyl carbonate or allyl ester or allyl formate of formula (II) takes place in the presence of a base.

The base may, for example, be one or more amine(s) or one or more alkoxide(s) or a combination thereof. The amine base may, for example, be a primary, secondary or tertiary amine base. For example, the amine base may be a tertiary amine base. The alkoxide may, for example, be an alkoxide salt.

Bases such as metal hydrides, e.g. LiH, NaH or KH might also be used. However they are less preferred.

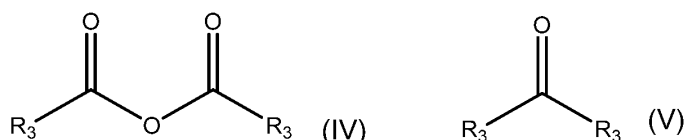
Examples of amine bases include, for example, mono-, di-, or tri-alkylamines (e.g. methylamine, ethylamine, butylamine, dimethylamine, diethylamine, dibutylamine, trimethylamine, tributylamine, substituted and unsubstituted aniline (e.g. *N,N*-dimethylaniline), and substituted and unsubstituted heterocyclic amines (e.g. pyridine, dimethylaminopyridine, pyrrolidine, pyrrole, purines, imidazole).

Examples of alkoxide bases include, for example, methoxide salts (e.g. sodium methoxide), ethoxide salts, isopropoxide salts, and butoxide salts.

The base may, for example, be selected from triethylamine, tributylamine, dimethylaminopyridine, sodium methoxide, and combinations thereof.

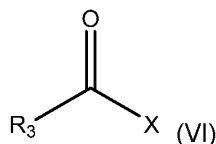
For example, the total amount of base used in the method may range from about 0.1 – 10 mol%, preferentially 0.3 – 3% mol% in case of the alkoxides and from about 1 – 5 mol eq, preferentially 2 - 3 mol eq in case of the tertiary amines. In case of the alkoxides too low quantities of base may react with traces of water thus inhibiting their reactivities, too large quantities can cause stirring problems. In case of the amines at least 1 mol eq is preferably used to quench the acid, e.g. HOAc, generated after elimination reaction of the allylic acetates (II), too large quantities are economically detrimental because these amines must be usually recycled.

The conversion of the allyl alcohol of formula (I) to the allyl carbonate, allyl ester or allyl formate of formula (II) may take place by reacting the allyl alcohol of the formula (I) with a compound of formula (IV) or a compound of formula (V) in the presence of a base,



wherein R_3 is as described herein in relation to the compound of formula (II).

Alternatively the conversion of allyl alcohol of formula (I) to the allyl carbonate, allyl ester or allyl formate of formula (II) may take place by reacting the allyl alcohol of the formula (I) with a compound of formula (VI) in the presence of a base



wherein X is Cl, or Br.

The compound of formula (IV) may, for example, be acetic anhydride, or dimethyl carbonate.

- For example, the compound of formula (IV) may, for example, be used in the method in an amount ranging from about 1 – 10 mol eq, e.g. acetic anhydride, for example in a range from about 2.5 – 7.5 mol eq, or in a range from about 4.5 – 5.5 eq. At least about one mol eq anhydride (IV) should be used to convert the allylic alcohol fully to the acetate (II). However, higher amounts might be preferred because the anhydride (IV) could also act like a solvent, allows stirring and accelerates the reaction. However, more than about 10 mol eq of the anhydride (IV) might be uneconomical because the anhydride must be recycled.

For example, the carbonates of formula (V) may, for example, be used in an amount ranging from about 2 to 10 mol eq, for example, about 3 to 5 mol eq.

The conversion of the allyl carbonate, allyl ester or allyl formate of formula (II) to the conjugated diene of formula (III) uses a palladium catalyst or catalyst precursor and an organic phosphorous ligand.

- The organic phosphorous ligand assists in providing and maintaining the catalytic activity of the palladium catalyst or catalyst precursor.

The palladium catalyst may, for example, be palladium on carbon (Pd/C) wherein the palladium metal is supported on activated carbon.

- The palladium catalyst precursor may, for example be selected from palladium acetate ($\text{Pd}(\text{OAc})_2$), palladium bisacetylacetonate ($\text{Pd}(\text{acac})_2$), allylpalladium chloride dimer ($[(\text{C}_3\text{H}_5)\text{PdCl}]_2$), bis(acetonitrile)dichloropalladium ($\text{Pd}(\text{MeCN})_2\text{Cl}_2$), palladium bis(dibenzylideneacetone) ($\text{Pd}(\text{dba})_2$), palladium trifluoroacetate ($\text{Pd}(\text{TFA})_2$), tris(dibenzylideneacetone) dipalladium ($\text{Pd}_2(\text{dba})_3$), tetrakis(triphenylphosphine) palladium

(Pd(PPh₃)₄), dichlorobis(tricyclohexylphosphine)palladium (PdCl₂[P(cy)₃]₂), dichlorobis(triphenylphosphine) palladium (Pd(PPh₃)₂Cl₂), dichlorobis(tri-*o*-tolylphosphine) palladium (Pd[P(*o*-tol)₃]₂Cl₂), bis(di-*tert*-butyl(4-dimethylaminophenyl)phosphine) (Pd(amphos)Cl₂), [bis(diphenylphosphino)ferrocene]dichloro palladium (Pd(dppf)Cl₂), [bis(di-*tert*-butylphenylphosphino)ferrocene]dichloro palladium (Pd(dtbpf)Cl₂), tetrakis(acetonitrile) palladium tetrafluoroborate (Pd(MeCN)₄(BF₄)₂), palladium bromide (PdBr₂), palladium chloride (PdCl₂), bis(1,5-cyclooctadiene) palladium (Pd(C₈H₁₂)₂), bis(triphenylphosphine) (maleic anhydride) palladium, tri(di-benzylideneacetone) dipalladium, (1,5-cyclooctadiene) (maleic anhydride) palladium, palladium propionate (Pd(C₂H₅CO₂)₂), palladium carbonate (Pd(CO₃)), palladium benzoate (Pd(CO₂-C₆H₅)₂), palladium sulfate (Pd(SO₄)), palladium nitrate (Pd(NO₃)₂), lithium palladium chloride (Cl₂LiPd), bisbenzonitrile palladium chloride (PdCl₂(NCC₆H₅)₂), bistriphenylphosphine palladium chloride (PdCl₂(PPh₃)₂), and bistriphenylphosphine palladium acetate ([(C₆H₅)₃P]₂Pd(CH₃COO)₂).

15 The palladium catalyst precursor may, for example, be a catalyst selected from palladium acetate (Pd(OAc)₂), palladium bis(dibenzylideneacetone) (Pd(dba)₂), and tetrakis(triphenylphosphine) palladium (Pd(PPh₃)₄).

20 The organic phosphorous ligand may, for example, be an organic phosphite ligand, an organic phosphine ligand, an organic phosphonium ligand, an organic phosphin oxide, an organic bisphosphine or a combination thereof.

25 The organic phosphorous ligand may, for example, be a bidentate organic phosphorous ligand. The bidentate organic phosphorous ligand may be partially oxidized thus containing one phosphine and one phosphin oxide group.

For example, the organic phosphorous ligand may be an organic phosphine ligand. The organic phosphine compound may, for example, be an organic bisphosphine ligand.

30 Examples of organic phosphite ligands include triethyl phosphite, triisopropyl phosphite, tridecyl phosphite, tridodecyl phosphite, triphenyl phosphite, tris (*pt*-butylphenyl) phosphite, tris(nonylphenyl) phosphite, trioctyl phosphite, diphenyl monodecyl phosphite, and combinations thereof.

35 Examples of organic phosphine ligands include xantphos, trimethylphosphine, triethylphosphine, triisopropylphosphine, tri-*n*-butylphosphine, tri-*t*-butylphosphine, tri-*n*-hexylphosphine, tri-*n*-octylphosphine, tricyclohexylphosphine, triphenylphosphine (TPP) or

PPh₃), dimethylphenylphosphine, methyldiphenylphosphine, ethyldiphenylphosphine, cyclohexyldiphenylphosphine, tri-p-tolylphosphine, tri-o-tolylphosphine, tris(p-chlorophenyl) phosphine, tri(1-naphthyl) phosphine, tris (4-carboxyphenyl) phosphine, tris (4-dimethylaminophenyl) phosphine, lithium diphenylphosphinobenzene-m-sulfonate, tris (o-methoxyphenyl) phosphine, tris (p-methoxyphenyl) phosphine, 1,2-bis (diphenylphosphino) ethane, 1,3-bis (diphenylphosphino) propane, 1,3-bis(di(o-methoxyphenyl) phosphino) propane, 1,4-bis (diphenylphosphino) butane, 1,2-bis(diphenylphosphino) benzene, bis(diphenylphosphino) methane (dppm), bid(diphenylphosphino)hexane (dpph), (oxydi-2,1-phenylene)bis(diphenylphosphine) (DPEphos), 1,5-pentanediybis[diphenylphosphine] (dpppe), 1,1'-Bis(diphenylphosphino)ferrocene (dppf), 2,2'-bis(diphenylphosphino)-1,1'-binaphthyl (BINAP), 1,2-Bis(diphenylphosphino)ethane (dppe), and combinations thereof.

The palladium catalyst or catalyst precursor may, for example, be used in an amount equal to or less than about 0.5 mol%. For example, the palladium catalyst or catalyst precursor may be used in an amount equal to or less than about 0.4 mol% or equal to or less than about 0.3 mol% or equal to or less than about 0.2 mol% or equal to or less than about 0.1 mol% or equal to or less than about 0.05 mol%.

The palladium catalyst or catalyst precursor may, for example, be used in an amount equal to or greater than about 0.001 mol%. For example, the palladium catalyst or catalyst precursor may be used in an amount equal to or greater than about 0.003 mol% or equal to or greater than about 0.005 mol% or equal to or greater than about 0.01 mol% or equal to or greater than about 0.02 mol% or equal to or greater than about 0.03 mol% or equal to or greater than about 0.04 mol%.

For example, the palladium catalyst or catalyst precursor may be used in an amount ranging from about 0.001 mol% to about 0.5 mol% or from about 0.01 mol% to about 0.2 mol% or from about 0.02 mol% to about 0.1 mol%.

The organic phosphorous ligand may, for example, be used in an amount equal to or less than about 0.25 mol%. For example, the organic phosphorous ligand may be used in an amount equal to or less than about 0.20 mol% or equal to or less than about 0.15 or equal to or less than about 0.10 mol% or equal to or less than about 0.05 mol% or equal to or less than about 0.025 mol%.

The organic phosphorous ligand may, for example, be used in an amount equal to or greater than about 0.002 mol%. For example, the organic phosphorous ligand may be used in an amount equal to or greater than about 0.002 mol% or equal to or greater than about 0.0025

mol% or equal to or greater than about 0.005 mol% or equal to or greater than about 0.01 mol% or equal to or greater than about 0.015 or equal to or greater than about 0.02 mol%.

In one particular embodiment the organic phosphorous ligand may be used with at least 2
5 mol eq monophosphine and at least 1 mol eq bisphosphine ligand / Pd-catalyst.

The yield of the conjugated diene of formula (III) may, for example, be equal to or greater than about 45 %. For example, the yield of the conjugated diene of formula (III) may be equal to or greater than about 50 % or equal to or greater than about 55 % or equal to or greater
10 than about 60 % or equal to or greater than about 65 % or equal to or greater than about 70 % or equal to or greater than about 75 % or equal to or greater than about 80 % or equal to or greater than about 85 % or equal to or greater than about 90 %.

The yield of the conjugated diene of formula (III) may, for example, be equal to or less than about 100 %. For example, the yield of the conjugated diene of formula (III) may be equal to
15 or less than about 99 % or equal to or less than about 98 % or equal to or less than about 97 % or equal to or less than about 96 % or equal to or less than about 95 %.

For example, the yield of the conjugated diene of formula (III) may range from about 45 % to about 100 % or from about 60 % to about 100 % or from about 80 % to about 100 % or from
20 about 90 % to about 98 %.

The purity of the conjugated diene of formula (III) may, for example be equal to or greater than about 75 %. For example, the purity of the conjugated diene of formula (III) may be
25 equal to or greater than about 80 % or equal to or greater than about 85 % or equal to or greater than about 90 %.

The purity of the conjugated diene of formula (III) may, for example, be equal to or less than about 100 %. For example, the purity of the conjugated diene of formula (III) may be equal to
30 or less than about 99 % or equal to or less than about 98 % or equal to or less than about 97 % or equal to or less than about 96 % or equal to or less than about 95 %.

For example, the purity of the conjugated diene of formula (III) may range from about 75 % to about 100 % or from about 80 % to about 100 % or from about 85 % to about 99 % or from
35 about 90 % to about 98 %.

Yield and purity may be measured by gas chromatography, NMR-calibration and HPLC might be other analytical methods.

The method may, for example, be a continuous process wherein the reagents are continually
5 fed to the reaction mixture as the final product (composition comprising the conjugated diene of formula (III) is removed). Alternatively, the method may, for example, be a batch process wherein a specified amount of reagents are fed into the reaction mixture before the reaction is stopped and the final product recovered.

10 As a specific example one may mention the method using a compound of formula (V) wherein R_3 is alkoxy (i.e. a carbonate), the method may be a continuous process wherein the carbonate and / or the base is continuously fed to the reaction mixture whereas the thus formed alcohol or a mixture of this alcohol and carbonate is continuously removed by distillation.

15 The method may, for example, further comprise isolating and/or purifying the conjugated diene of formula (III) from the reaction mixture. The isolating and/or purifying may involve methods known to persons skilled in the art, for example, distillation or column chromatography. Alternatively, the crude diene (III) formed may be subjected as crude or in
20 the work-up solvent to the subsequent reaction.

Work-up solvents are usually inexpensive nonpolar and aprotic solvents, such as hexane, cyclohexane, heptane, tert-butyl methyl ether, toluene or xylene, to dissolve the non-polar
25 products and allow good phase separation. Solvents which form azeotropes with water would be preferred because drying can be performed azeotropically before distillation of diene (III).

Excess reactants (e.g. base and/or compound of formula (IV) or (V)) may, for example, be removed and/or recycled, for example by distillation.

30 The basic product mixture may, for example, be cooled (e.g. to a temperature ranging from about 5°C to about 25 °C) and neutralized, for example using a hydrochloric acid solution. Excess acid and too low pH's should be avoided because the dienes (III) formed are usually instable under too acidic conditions. Distillation could therefore be carried out after (careful)
35 neutralization and/or even under slightly basic conditions.

Solvent extraction may be used to separate the conjugated diene of formula (III), for example, using an organic solvent such as tertiary-butyl methyl ether or hexane. The organic layers may then be washed, for example with water, brine and sodium bicarbonate, and optionally dried, for example with magnesium sulphate.

5

The organic solvent may then be removed and the conjugated diene of formula (III) used as crude or further purified by distillation including wipe-film distillation

There is further provided herein the conjugated dienes obtained by and/or obtainable by the methods described herein. The conjugated dienes may, for example, have a yield and/or purity as described herein.

The conjugated dienes prepared according to the present procedure as described hereinabove may, for example, be used as starting materials for the formation of various fragrance ingredients, including Ambrofix™, and Georgywood™.

15

EXAMPLES

General:

20

GCMS: 50 °C / 2 min, 20 °C / min 240 °C, 35 °C / min 270 °C. Agilent 5975C MSD with HP 7890A Series GC system. Non-polar column: BPX5 from SGE, 5% phenyl 95% dimethylpolysiloxan 0.2 mm x 0.25 µm x 12 m. Carrier gas: helium. Injector temperature: 230 °C. Split 1:50. Flow: 1.0 ml/min. Transfer line: 250 °C. MS-quadrupol: 160 °C. MS-source: 230 °C. Injection vol. 1 µl. Ionization mode Electron Impact (EI) at 70 eV. GC percentage = rpa (relative peak area).

25

¹H- and ¹³C-NMR: Bruker-DPX-400 MHz spectrometer; spectra were recorded at 400 MHz (¹H) and 100 MHz (¹³C) respectively in CDCl₃; δ in ppm rel. to SiMe₄; coupling constants *J* in Hz.

30

Starting materials are either commercially available or are prepared easily in 1-2 steps by the chemist skilled in the art from commercial compounds as described in the literature.

35 Abbreviations:

DPEphos = oxydi-2,1-phenylene)bis(diphenylphosphine)

DMAP = N,N-Dimethylpyridin-4-amine

Xanthphos = 4,5-Bis(diphenylphosphino)-9,9-dimethylxanthene

Example 1: 6-*E*-Farnesene from *E*-Nerolidol

General conditions of the Pd-catalyzed elimination via in-situ acetates

- 5 Acetic anhydride (2.6 kg, 25.3 mol) is mixed with *E*-Nerolidol (1.1 kg, 5 mol) under nitrogen and stirring, followed by tributylamine (1.9 kg, 10.1 mol), DMAP (32 g), DPEphos (1.55 g, 2.9 mmol) and Pd(OAc)₂ (0.3 g, 1.25 mmol, 0.025 mol%). The mixture is heated to 115 °C, stirred at this temperature for 4 h, then cooled to 70 °C. Vacuum (25 – 55 mbar) is applied and excess acetic anhydride distilled at 66 °C head temperature giving 1.9 kg of an acetic
- 10 anhydride / tributylamine mixture (ratio 83:17). The distillation residue is cooled to 15 °C and a mixture of 32% HCl (1.43 kg) and H₂O (1 kg) is added at 15 – 20 °C under stirring. The 2-phase mixture is heated to 40 °C and extracted with *tert*-butyl methyl ether (2 x 2 l). The combined organic layers are washed with 2 kg of water, 0.5 kg brine and saturated NaHCO₃ (2.5 l). After partial evaporation of *tert*-butyl methyl ether, toluene (1 l) is added. Evaporation
- 15 under reduced pressure gives 999 g of crude Farnesene which is wipe-film-distilled at 105 °C / 0.3 mbar giving 945 g of 6-*E*-Farnesene (93% yield) as a 1:2 mixture of α - and β -isomers (purity 90%). The analytical data are identical to the ones described for 6-*E*-Farnesene, e.g. by E.J.Corey et al. *J. Am. Chem. Soc.* 140, 16909 – 16913 (2018).

20 Example 2:

Under the general conditions of example 1 the influence of the catalyst / ligand loading on yield and purity of the elimination product 6-*E*-Farnesene was explored. As shown in table 1 lower catalyst / ligand loadings than 0.02 mol% Pd(OAc)₂ and 0.05% DPEphos are possible giving similar and only slightly lower yields and purities.

25

Table 1: Influence of catalyst / ligand loadings on yield and purity of 6-*E*-Farnesene.

run	scale Nerolidol	Pd(OAc) ₂ / DPEphos ^a	time	Farnesyl acetate ^b	ratio α / β Farnesene ^b	Farnesene purity ^{b,d}	yield istd ^c
1	111 g	200 / 500	5 h	2%	32:66	98%	83%
2	25 g	200 / 500	5 h	6%	29:66	94%	85%
3	2.5 g	100 / 250	1 h	10%	25:64	89%	80%
4	2.5 g	50 / 125	3 h	13%	24:63	87%	79%

- General conditions as in example 1 but lower *E*-Nerolidol scale. All runs at 115 °C and with 97 – 100 % conversion of Nerolidol, except run 4 (97%). a) mol ppm. b) GC rpa. c) internal
- 30 standard tridecane added to crude product. d) 6-*E*-Farnesene α + β .

Example 3:

Under the general conditions of example 1 the influence of the bisphosphine ligand on yield and purity of the elimination product 6-*E*-Farnesene was explored. As shown in tables 2 and 3 other bisphosphine ligands such as dpppe and dppf give similar and only slightly lower yields and purities. Bisphosphine ligands BINAP, dppb and dppe and monodentate ligand triphenylphosphine (TPP) give lower yields and purities.

Table 2: Influence of ligand at 0.02 mol% Pd(OAc)₂ and 0.05% bisphosphine loading.

run	ligand ^a	time	Allofarnesene ^{b,d}	Farnesyl acetate ^b	ratio α / β - Farnesene ^b	Farnesene purity ^{b,e}	yield istd ^c
1	DPEphos	5 h		6%	29:66	94%	85%
2	dpppe	7 h	2%	9%	26:61	87%	80%
3	dppf	6 h	3%	6%	30:61	91%	82%

- 10 General conditions as in example 1 but 25 g scale of *E*-Nerolidol. Quantitative conversions. All runs at 115 °C. a) 0.02 mol% Pd(OAc)₂ and 0.055 mol% ligand. b) GC rpa. c) internal standard tridecane added to crude product. d) Allofarnesene = 3,7,11-trimethyldodeca-2,4,6,10-tetraene. e) 6-*E*-Farnesene α + β .

- 15 Table 3: Influence of ligand at 0.5 mol% Pd(OAc)₂ and 1.2% ligand loading.

run	ligand ^a	time	Allofarnesene ^{b,d}	acetates ^{b,e}	ratio α / β - Farnesene ^b	Farnesene purity ^{b,h}	yield istd ^c
1	DPEphos	1.5 h	4%		26 : 70	96%	81%
2	dpppe	2 h			46 : 51	97%	76%
3	dppf	1 h	2%		38 : 56	94%	75%
4	dppb	2 h	4%		45 : 51	96%	68%
5	BINAP	2.5 h			42 : 54	96%	74%
6	dppe	6 h	3%	17% ^e	29 : 47	76%	69%
7	TPP ^g	3 h	7%	12% ^f	41 : 41	82%	45%

- General conditions as in example 1 but 2.5 g scale of *E*-Nerolidol. All runs at 115 °C. Quantitative conversions of *E*-Nerolidol, except in run 3 (97%). a) 0.02 mol% Pd(OAc)₂ and 0.055 mol% ligand. b) GC rpa. c) internal standard tridecane added to crude product. d) Allofarnesene = 3,7,11-trimethyldodeca-2,4,6,10-tetraene. e) *E*-Nerolidol acetate. f) Farnesyl acetate. g) 2.5 mol% PPh₃ ligand. h) 6-*E*-Farnesene α + β .

Example 4:

Under the general conditions of example 1 the influence of the Palladium catalyst precursor was examined. As shown in table 4 combinations of Pd(0) and Pd(II) precursors with ligand DPEphos catalyzed the elimination of *E*-Nerolidol to 6-*E*-Farnesene with similar and with slightly lower yields and purities at lower catalyst loadings (Table 5).

Table 4: Influence of the Pd-catalyst precursor at 0.5 mol% Palladium catalyst and 1.25% DPEphos loading.

run	Pd-precursor ^a	Allofarnesene ^d	ratio α/β -Farnesene ^b	Farnesene ^{b,d} purity ^{b,e}	yield istd ^c
1	Pd(OAc) ₂	4%	26 : 70	96%	81%
2	Pd ₂ (dba) ₃	3%	33 : 57	90%	78%
3	Pd/C		43 : 57	99%	82%

General conditions as in example 1 but 2.5 g scale of *E*-Nerolidol. All runs 1.5 h at 115 °C and with quantitative conversion of *E*-Nerolidol except run 2 (97%). a) 0.5 mol% Pd(OAc)₂ and 1.25 mol% DPEphos. b) GC rpa. c) internal standard tridecane added to the crude elimination product. d) Allofarnesene = 3,7,11-trimethyldodeca-2,4,6,10-tetraene. e) 6-*E*-Farnesene $\alpha + \beta$.

Table 5: Influence of the Pd-catalyst precursor at 0.1 mol% Palladium catalyst and 0.25% DPEphos loading.

run	Pd precursor ^a	Allofarnesene ^d	Farnesyl acetate ^b	ratio α / β Farnesene ^b	Farnesene purity ^{b,e}	yield istd ^c
1	Pd(OAc) ₂	4%		40:57	97%	81%
2	Pd/C		7%	27:59	86%	78%

General conditions as in example 1 but 2.5 g scale of *E*-Nerolidol. All runs 2 h at 115 °C with 98 – 100 % conversion of Nerolidol. a) 0.1 mol% Pd(OAc)₂ or Pd/C and 0.25 mol% DPEphos. b) GC rpa. c) Internal standard tridecane added to the crude elimination product. d) Allofarnesene = 3,7,11-trimethyldodeca-2,4,6,10-tetraene. e) 6-*E*-Farnesene $\alpha + \beta$.

Example 5: *E*-Homomyrcene from Homolinalool

Under the general conditions of example 1 acetic anhydride (44.6 g, 437 mmol) and 4,8-dimethylnona-2,7-dien-4-ol (Homolinalool, 15.1 g, 87 mmol) are mixed under nitrogen and stirring, followed by tributylamine (32.4 g, 175 mmol), DMAP (0.53 g, 4.4 mmol), DPEphos (59 mg, 0.11 mmol) and Pd(OAc)₂ (9.8 g, 0.045 mmol, 0.05 mol%). After heating to 115 °C, stirring at this temperature for 3 h and cooling to r.t. the biphasic reaction mixture is poured

upon 2 M HCl and extracted with *tert*-butyl methyl ether. The combined organic layers are washed with water and conc. NaHCO₃ and are dried over MgSO₄, filtered and evaporated under reduced pressure. The clear brown residue (16 g) is distilled at 50 – 100 °C / 43 mbar giving 12.3 g of a fraction containing 69% *E*-Homomyrcene and 25% 2-*E*-Methylocimene (4-
5 *EZ* ratio 1 : 1). For analytical data of *E*-Homomyrcene see for example B.Hauer et al. *Nat. Chem. Biol.* 13, 275-281 (2017). Analytical data of (2*E*)-4,8-dimethylnona-2,4,7-triene (2-*E*-Methylocimene):

¹H-NMR (400 MHz, CDCl₃) of the 2*E*,4*E*-isomer: δ (ppm) = 6.06 (m, 1H), 5.57 (dq, J=15.8, 6.6
10 Hz, 1H), 5.31 (t, J=7.4 Hz, 1H), 5.11 (m, 1H), 2.79 (t, J=7.2 Hz, 2H), 1.75 (m, 3H), 1.74 (m, 3H), 1.69 (m, 3H), 1.63 (m, 3H). ¹H-NMR (400 MHz, CDCl₃) of the 2*E*,4*Z*-isomer: 6.47 (m, 1H), 5.69 (dq, J=15.4, 6.8 Hz, 1H), 5.19 (t, J=7.5 Hz, 1H), 5.11 (m, 1H), 2.83 (t, J=7.1 Hz, 2H), 1.81 (dd, J=6.6, 1.2 Hz, 3H), 1.79 (m, 3H), 1.69 (m, 3H), 1.64 (m, 3H).

¹³C-NMR (100 MHz, CDCl₃) of the 2*E*,4*E*-isomer: δ (ppm) = 136.0 (d), 133.3, 131.7, 128.6
15 (d), 122.6 (d), 122.0 (d), 27.2 (t), 25.6, 18.1 (q), 17.7, 12.3 (q) ppm. ¹³C-NMR (100 MHz, CDCl₃) of the 2*E*,4*Z*-isomer: δ (ppm) = 131.7, 131.6, 128.4 (d), 126.8 (d), 125.2 (d), 122.9 (d), 26.4 (t), 25.6, 20.5 (q), 18.6 (q), 17.7 ppm.

GCMS: Homomyrcene: 69 % (rpa), t_R: 4.61 min (EI⁺-MS): m/z = 150 [M]⁺ (3 %), 135 [M⁺-CH₃] (5 %), 121 (2 %), 108 (9 %), 107 (100 %), 93 (8 %), 91 (12 %), 79 (27 %), 69 (42 %), 67 (11
20 %), 53 (11 %), 41 (58 %), 39 (21 %). (2*E*,4*Z*)-Methylocimene: 12 % (rpa), t_R: 5.0 min, (EI⁺-MS): m/z = 150 [M]⁺ (7 %), 135 [M⁺-CH₃] (22 %), 121 (11 %), 119 (8 %), 108 (9 %), 107 (100 %), 106 (23 %), 105 (22 %), 94 (12 %), 93 (28 %), 91 (43 %), 79 (28 %), 77 (20 %), 67 (13 %), 55 (12 %), 53 (11 %), 43 (13 %), 41 (34 %), 39 (26 %). (2*E*,4*E*)-Methylocimene: 13 % (rpa), t_R: 5.2 min, (EI⁺-MS): m/z = 150 [M]⁺ (12 %), 135 [M⁺-CH₃] (30 %), 121 (12 %), 119 (10
25 %), 108 (9 %), 107 (100 %), 106 (12 %), 105 (25 %), 94 (29 %), 93 (32 %), 91 (48 %), 79 (30 %), 77 (22 %), 67 (14 %), 55 (15 %), 53 (14 %), 43 (14 %), 41 (41 %), 39 (32 %).

IR (film/ATR) of an isolated 2-*E*-Methylocimene sample with 4*EZ* 2:1: 3028 (w), 2968 (m),
2914 (m), 2882 (w), 2857 (w), 1445 (m), 1376 (m), 1111 (w), 1100 (w), 960 (s), 859 (w), 831
30 (w), 780 (w), 755 (w).

Example 6: Ethyl myrcene from Ethyl linalool

Under the general conditions of example 1 acetic anhydride (303 g, 3 mol) and Ethyl linalool (100 g, 0.6 mol) are mixed under nitrogen and stirring, followed by triethylamine (120 g, 1.2
35 mol), DMAP (3.6 g, 30 mmol), DPEphos (160 mg, 0.3 mmol) and Pd(OAc)₂ (27 mg, 0.12 mmol, 0.02 mol%). After heating to 115 °C, stirring at this temperature for 1.5 h and cooling to r.t. the reaction mixture is poured upon 2 M HCl and extracted with *tert*-butyl methyl ether.

The combined organic layers are washed with water and sat. NaHCO₃, water and brine. After drying over MgSO₄, filtration and evaporation under reduced pressure the clear brown residue (88 g) is distilled at 30 °C / 0.04 mbar giving 60 g (67%) of ethyl myrcene with a purity of 77% (*EZ* ratio 53:24) plus three 3,7-dimethylnona-1,3,6-triene regioisomers (ethyl ocimene with rpa 12:6:4). Analytical data:

¹H-NMR (400 MHz, CDCl₃) of the main-isomer: δ (ppm) = 6.4 (m, 1 H), 5.25 (m, 1 H), 5.0 – 5.2 (4 H), 2.0 (4 H), 2.0 (2 H), 2.65 (s, 3 H), 1.0 (t, 3 H).

¹³C{¹H}-NMR (100 MHz, CDCl₃) of the main isomer: δ (ppm) = 146.2 (s), 139.0 (d), 137.3 (s), 122.5 (d), 115.7 (t), 113.0 (t), 32.3 (t), 31.5 (t), 26.4 (t), 16.0 (q), 12.8 (q).

GCMS (EI⁺-MS): t_R: 4.5 min (24%, *Z*-isomer), 4.6 min (53%, *E*-isomer): m/z = 150 [M]⁺ (3 %), 135 (1 %), 121 (6 %), 94 (12 %), 93 (100 %), 92 (11 %), 91 (21 %), 79 (20 %), 67 (12 %), 55 (78 %), 53 (12 %), 41 (42 %), 39 (21 %).

15 Example 7: *E*-3,7-dimethylocta-5,7-dien-1-yl acetate from *E*-2,6-dimethyloct-2-ene-1,8-diol

Under the general conditions of example 1, acetic anhydride (49 g, 0.475 mol) and *E*-2,6-dimethyloct-2-ene-1,8-diol (16.4 g, 95 mmol) are mixed under nitrogen and stirring, followed by tributylamine (35.8 g, 0.19 mol), DMAP (0.6 g, 4.7 mmol), DPEphos (0.65 g, 1.2 mmol) and Pd(OAc)₂ (0.11, 0.48 mmol, 0.1 mol%). After heating to 115 °C, stirring at this temperature for 7 h and cooling to r.t. the reaction mixture is poured upon 2 M HCl and extracted with tert-butyl methyl ether. The combined organic layers are washed with 2 M HCl, water, brine and sat. NaHCO₃. After drying over MgSO₄, filtration and evaporation under reduced pressure the orange residue (21 g) is distilled at 70 °C / 0.02 mbar giving 14 g (69%) of *E*-3,7-dimethylocta-5,7-dien-1-yl acetate with a purity of 90%. Analytical data:

¹H-NMR (400 MHz, CDCl₃): δ (ppm) = 6.15 (m, 1 H), 6.6 – 6.7 (m, 1 H), 4.9 (2 H), 4.1 – 4.2 (2 H), 2.1 (s, 3 H), 2 – 2.2 (m, 1 H), 1.8 (s, 3 H), 1.7 (2 H), 1.5 (2 H), 0.95 (d, 3 H).

¹³C{¹H}-NMR (100 MHz, CDCl₃): δ (ppm) = 171.2 (s), 142.0 (s), 134.5 (d), 128.5 (d), 114.5 (t), 62.9 (t), 48.6 (t), 35.0 (t), 30.3 (d), 20.3 (q), 19.4 (q), 18.7 (q).

GCMS (EI⁺-MS): m/z = 196 [M]⁺ (0.2 %), 181 (0.2%), 163 (0.2%), 153 (1 %), 136 (21%), 121 (92 %), 109 (8%), 108 (17%), 107 (23%), 94 (22%), 93 (65 %), 81 (27 %), 79 (35 %), 68 (11%), 67 (13 %), 55 (41%), 49 (16 %), 43 (100 %), 41 (23 %).

35 Example 8: Elimination of a mixture of 3,7-dimethyloct-5-ene-1,7-diol and 3,7-dimethyloct-7-ene-1,6-diol

Under the general conditions of example 1, acetic anhydride (59.9 g, 0.58 mol) and an equimolar mixture of 3,7-dimethyloct-5-ene-1,7-diol and 3,7-dimethyloct-7-ene-1,6-diol (20 g,

116 mmol) are mixed under nitrogen and stirring, followed by tributylamine (43.7 g, 0.232 mol), DMAP (0.72 g, 5.81 mmol), DPEphos (0.8 g, 1.45 mmol) and Pd(OAc)₂ (0.13 g, 0.58 mmol, 0.5 mol%). After heating to 115 °C, stirring at this temperature for 5 h and cooling to r.t. the reaction mixture is poured upon 2 M HCl and extracted with tert-butyl methyl ether.

5 The combined organic layers are washed with 2 M HCl, water, brine and sat. NaHCO₃. After drying over MgSO₄, filtration and evaporation under reduced pressure the clear brown residue (26.5 g) is distilled at 70 °C / 0.02 mbar giving 19 g (96%) of *E*-3,7-dimethylocta-5,7-dien-1-yl acetate with a purity of 95%. The analytical data are identical with the ones obtained for this compound in example 7.

10 Example 9: Elimination of 2,4,8-trimethylnona-2,7-dien-4-ol

Under the general conditions of example 1, acetic anhydride (67 g, 0.65 mol) and 2,4,8-trimethylnona-2,7-dien-4-ol (23.8 g, 131 mmol) are mixed under nitrogen and stirring, followed by triethylamine (26.4 g, 0.26 mol), DMAP (0.8 g, 6.5 mmol), DPEphos (35 mg, 0.065 mmol) and Pd(OAc)₂ (5.9 mg, 0.026 mmol, 0.02 mol%). After heating to 115 °C, stirring at this temperature for 3.5 h and cooling to r.t. the reaction mixture is poured upon 2 M HCl and extracted with *tert*-butyl methyl ether. The combined organic layers are washed with 2 M HCl, water, brine and sat. NaHCO₃. After drying over MgSO₄, filtration and evaporation under reduced pressure the clear brown residue (21.5 g) is distilled at 70 °C / 0.02 mbar giving 17.8 g (83%) of a mixture of 2,8-dimethyl-4-methylenenona-2,7-diene (*exo*-isomer) and *E*-2,4,8-trimethylnona-1,3,7-triene (*endo*-isomer) (ratio 44:46 rpa, combined purity 90 % according to GCMS).

The analytical data of the *exo* isomer are identical with the ones described for this compound by C.Mazet et al. ACS Catal. 8, 1392 (2018). Analytical data of the *endo*-isomer 2,4,8-trimethylnona-1,3,7-triene:

¹³C{¹H}-NMR (100 MHz, CDCl₃): δ (ppm) = 142.3 (s), 134.8 (s), 131.6 (s), (d), 126.8 (d), 124.1 (d), 113.7 (t), 40.9 (t), 26.7 (t), 26.6 (q), 23.8 (q), 17.9 (q), 17.7 (q).

GCMS (EI⁺-MS) t_R: 5.16 min (44%, *exo*-isomer), 5.26 min (46%, *endo*-isomer). m/z of the *exo*-isomer = 164 [M]⁺ (2 %), 149 (8 %), 122 (10 %), 121 (100 %), 107 (10 %), 93 (27 %), 91 (9 %), 79 (18 %), 77 (9 %), 69 (48 %), 67 (12 %), 55 (10 %), 53 (14 %), 41 (60 %), 39 (19%). m/z of the *endo*-isomer = 164 [M]⁺ (2 %), 149 (25 %), 136 (9 %), 121 (32 %), 107 (10 %), 96 (11 %), 95 (31 %), 93 (12 %), 91 (8 %), 79 (13 %), 77 (11 %), 69 (100 %), 67 (32 %), 55 (21 %), 53 (18 %), 41 (77 %), 39 (23%).

Example 10: Elimination of Methylgeraniol

General conditions of the Pd-catalyzed elimination via in-situ carbonates.

Sodium methoxide (4.8 g, 9 mmol) is added to water-free Methylgeraniol (505 g, 3 mol) in
5 water-free dimethyl carbonate (811 g, 9 mol) under stirring and nitrogen in a distillation flask
equipped with a Vigreux column and a Liebig condenser. The cloudy solution is heated to
110 °C and a methanol / dimethyl carbonate mixture (454 g) is distilled at 40 – 75 °C head
temperature until a final temperature of 100 °C is reached in the distillation flask and nearly
quantitative conversion (98%) of methylgeraniol to its carbonate is detected by GC. The
10 mixture is cooled to 60 °C and DPEphos (280 mg, 0.5 mmol) is added. After 10 min stirring
Pd(OAc)₂ (34 mg, 0.15 mmol, 50 ppm) is added at 60 °C. Under strong stirring the cloudy
solution is heated to 110 °C and methanol (177 g) is distilled meanwhile the flask
temperature raises to 100 °C. PEG 400 (86 g) is added and the distillation continued under
reduced pressure (20 mbar) giving 410 g (98%) of a homomyrcene / methylocimene /
15 methylgeraniol mixture (GC ratio 69 : 20 : 9) at 67 °C / 20 mbar. Corrected yield of
Homomyrcene based on purity: 78%. For analytical data of Homomyrcene see for example
B.Hauer et al. *Nat. Chem. Biol.* 13, 275-281 (2017), for the analytical data of the 4EZ-
isomers of 2-E-Methylocimene see example 5.

Example 11: 5-methyl-3-methylenehex-1-ene

Sodium methoxide (0.3 g, 5.6 mmol) is added to water-free 3,5-dimethylhex-2-en-1-ol (24 g,
187 mmol) in water-free dimethyl carbonate (50.7 g, 562 mmol) under stirring and nitrogen in
a distillation flask equipped with a Vigreux column and a condenser. The solution is heated to
80 °C and a methanol / dimethyl carbonate mixture (40 ml) is distilled at 35 – 45 °C head
25 temperature and a 85% conversion of 3,5-dimethylhex-2-en-1-ol to its carbonate is detected
by GC. The mixture is cooled to 60 °C, and DPEphos (0.53 g, 1 mmol) is added. After 10 min
stirring Pd(OAc)₂ (0.1 g, 0.44 mmol, 0.23 mol%) is added at 60 °C. Under stirring the solution
is heated to 80 °C and methanol (7 ml) is distilled at 30 – 35 °C head temperature followed
by 7.2 g (37%) of 5-methyl-3-methylenehex-1-ene (*exo/endo* 89:11).

30 ¹H-NMR (400 MHz, CDCl₃): δ (ppm) = 6.35 (m, 1 H), 5.2 (d, 1 H), 5.07 (2 H), 4.92 (1 H), 2.1
(d, 2 H), 1.8 (m, 1 H), 0.9 (d, 6 H).

¹³C-NMR (100 MHz, CDCl₃): δ (ppm) = 145.5 (s), 139.1 (d), 116.7 (t), 113.2 (t), 41.5 (t), 26.8
(d), 22.8 (2 q).

35 GCMS (EI+-MS): m/z = 110 [M]⁺ (14 %), 95 (72 %), 81 (30 %), 68 (100 %), 67 (87 %), 55
(14 %), 53 (28 %), 43 (54 %), 41 (52 %), 39 (32 %), 27 (18 %).

IR (film/ATR): 2956 (s), 1752 (m), 1594 (w), 1465 (m), 1384 (w), 1267 (s), 991 (m), 894 (s).

Example 12: Elimination of 6,10-dimethylundeca-1,5,9-trien-4-ol

Sodium methoxide (26 mg, 0.46 mmol) is added to water-free 6,10-dimethylundeca-1,5,9-trien-4-ol (30 g, 154 mmol) in water-free dimethyl carbonate (40 ml, 0.5 mol) under stirring and nitrogen in a distillation flask equipped with a condenser. The solution is heated to 97 °C (internal temperature) and a methanol / dimethyl carbonate mixture (22 g) is distilled at 82 °C head temperature. After 3 h another portion of NaOMe is added (26 mg, 0.46 mmol), after 20 h another portion (26 mg, 0.46 mmol), followed by the addition of another portion of dimethyl carbonate (20 ml, 230 mmol) and NaOMe (26 mg, 0.46 mmol). After distillation of more methanol / dimethyl carbonate (7.8 g) at 81 °C head temperature a 98% conversion of 6,10-dimethylundeca-1,5,9-trien-4-ol to its carbonate is detected by GC. DPEphos (0.145 g, 262 mmol) is added and, after 10 min stirring Pd(OAc)₂ (20 mg, 0.08 mmol, 0.05 mol%). At 110 °C (102 °C internal temperature) methanol (16.8 g) is distilled at 73 °C head temperature. After 1 h *tert*-butyl methyl ether and water are added at room temperature, and after phase separation the water phase is extracted with *tert*-butyl methyl ether. The organic layers are combined, dried over MgSO₄, filtered and evaporated giving 27.3 g of crude product (67%, GC rpa) which is purified chromatographically through 100 g SiO₂ using *tert*-butyl methyl ether / heptane 0 – 40% as eluent and giving after evaporation 22.7 g of *E*-10-methyl-6-methyleneundeca-1,4,9-triene (*exo*) as colorless liquid and with a purity of 73% according to GCMS accompanied by the *endo*-isomers (4*E*,6*E*)-6,10-dimethylundeca-1,4,6,9-tetraene and (4*E*,6*Z*)-6,10-dimethylundeca-1,4,6,9-tetraene (both 22%) which were separated by preparative GC. GCMS-data:

GCMS (EI⁺-MS) of the *exo*-isomer (*t*_R 6.1 min, 73 %): *m/z* = 161 ([*M* - 15]⁺, 1 %), 133 (71 %), 105 (28 %), 93 (17 %), 91 (55 %), 79 (28 %), 77 (18 %), 69 (72 %), 67 (35 %), 55 (11 %), 53 (19 %), 41 (100 %), 39 (30 %). (4*E*,6*Z*)-6,10-dimethylundeca-1,4,6,9-tetraene (*t*_R 6.4 min, 9 %): *m/z* = 176 (*M*, 1 %), 161 ([*M* - 15]⁺, 2 %), 135 (35 %), 133 (10 %), 120 (13 %), 119 (20 %), 107 (42 %), 105 (53 %), 94 (16 %), 93 (100 %), 92 (27 %), 91 (70 %), 79 (37 %), 77 (33 %), 69 (10 %), 67 (27 %), 65 (13 %), 55 (20 %), 53 (18 %), 43 (38 %), 41 (52 %), 39 (29 %). (4*E*,6*E*)-6,10-dimethylundeca-1,4,6,9-tetraene (*t*_R 6.7 min, 13 %): *m/z* = 176 (*M*, 5 %), 136 (10 %), 135 (88 %), 133 (10 %), 120 (10 %), 119 (24 %), 117 (10 %), 107 (52 %), 105 (56 %), 94 (11 %), 93 (100 %), 92 (13 %), 91 (80 %), 79 (47 %), 77 (37 %), 69 (10 %), 67 (21 %), 65 (13 %), 55 (24 %), 53 (20 %), 43 (42 %), 41 (59 %), 39 (32 %).

NMR-data of the *exo*-isomer:

¹H-NMR (400 MHz, CDCl₃): δ (ppm) = 1.6 (s, 3 H), 1.7 (s, 3 H), 2.1 – 2.25 (2 CH₂, 4 H), 2.85 (CH₂, 2 H), 4.9 (d, 1 H), 5.0 (d, 1 H), 5.1 – 5.2 (3 H), 5.7 – 5.8 (m, 1 H), 5.8 – 5.9 (m, 1 H), 6.1 (d, 1 H).

$^{13}\text{C}\{^1\text{H}\}$ -NMR (100 MHz, CDCl_3): δ (ppm) = 145.9 (s), 136.7 (d), 133.1 (d), 131.7 (s), 127.2 (d), 124.2 (d), 115.3 (t), 113.8 (t), 36.9 (t), 32.3 (t), 26.9 (t), 25.7 (q), 17.7 (q).

NMR- data of the *endo*-isomers:

5 ^1H -NMR (400 MHz, C_6D_6) of (4*E*,6*E*)-6,10-dimethylundeca-1,4,6,9-tetraene: δ (ppm) = 1.55 (s, 3 H), 1.65 (s, 3 H), 1.7 (s, 3 H), 2.75 (dd, 2 H), 2.8 (dd, 2 H), 4.95 – 5.1 (2 H), 5.2 (m, 1 H), 5.45 (m, 1 H), 5.55 (m, 1 H), 5.85 (m, 1 H), 6.15 (d, 1 H). (4*E*,6*Z*)-6,10-dimethylundeca-1,4,6,9-tetraene: δ (ppm) = 1.6 (s, 3 H), 1.65 (s, 3 H), 1.8 (s, 3 H), 2.75 (dd, 2 H), 2.9 (dd, 2 H), 4.95 – 5.05 (2 H), 5.2 (m, 1 H), 5.35 (m, 1 H), 5.65 (m, 1 H), 5.8 (m, 1 H), 6.65 (d, 1 H).

10

$^{13}\text{C}\{^1\text{H}\}$ -NMR (100 MHz, C_6D_6) of (4*E*,6*E*)-6,10-dimethylundeca-1,4,6,9-tetraene: δ (ppm) = 137.2 (d), 136.3 (d), 133.4 (s), 131.5 (s), 129.8 (d), 124.7 (d), 122.9 (d), 115.1 (t), 37.1 (t), 27.4 (t), 26.7 (q), 17.5 (q), 12.4 (q). (4*E*,6*Z*)-6,10-dimethylundeca-1,4,6,9-tetraene: δ (ppm) = 136.9 (d), 131.7 (s), 131.4 (s), 128.5 (d), 128.2 (d), 128.0 (d), 123.3 (d), 115.3 (t), 37.6 (t),
15 26.8 (t), 25.7 (q), 20.8 (q), 17.6 (q).

Example 13: Elimination of 6,10-dimethylundeca-5,9-dien-1-yn-4-ol

Sodium methoxide (4.4 mg, 0.08 mmol) is added to water-free 6,10-dimethylundeca-5,9-dien-1-yn-4-ol (5 g, 26 mmol) in water-free dimethyl carbonate (7 g, 78 mmol) under stirring
20 and nitrogen in a distillation flask equipped with a condenser. The solution is heated to 110 °C and a methanol / dimethyl carbonate mixture (4 ml) is distilled at 76 °C head temperature. After stirring for 23 h a 91% conversion of 6,10-dimethylundeca-5,9-dien-1-yn-4-ol to its carbonate is detected by GC and another portion of sodium methoxide (4.4 mg, 0.08 mmol) and dimethyl carbonate (1.1 ml, 13 mmol) is added. After another 3 h and a 96% conversion
25 DPEphos (24 mg, 0.044 mmol) is added. After 10 min stirring $\text{Pd}(\text{OAc})_2$ (3 mg, 0.013 mmol, 0.05 mol%) is added at 100 °C. After 4 h stirring at this temperature, water (30 ml) and *tert*-butyl methyl ether (30 ml) are added at room temperature. Phase separation, extraction with another portion *tert*-butyl methyl ether (30 ml), washing of the combined organic phases with saturated NaHCO_3 (30 ml), drying over MgSO_4 , filtration and evaporation under reduced
30 pressure gives 4.4 g of crude product containing 45% containing of (*E*)-10-methyl-6-methyleneundeca-4,9-dien-1-yne and two main impurities (2 x 9%) of the same molecular weight (M 174). Flash chromatography through SiO_2 using a heptane / *tert*-butyl methyl ether gradient gives (*E*)-10-methyl-6-methyleneundeca-4,9-dien-1-yne with a purity of 83%.

35 ^1H -NMR (400 MHz, CDCl_3): δ (ppm) = 1.6 (s, 3 H), 1.7 (s, 3 H), 1.9 – 2.2 (2 CH_2 , 4 H), 3.05 (1 H), 5.0 (2 H), 5.1 – 5.2 (1 H), 5.7 (1 H), 6.35 (1 H).

$^{13}\text{C}\{^1\text{H}\}$ -NMR (100 MHz, CDCl_3): δ (ppm) = 145.3 (s), 133.8 (d), 131.8 (s), 124.1 (d), 122.6 (d), 114.8 (t), 81.4 (s), 70.3 (d), 32.1 (t), 26.7 (t), 25.7 (q), 21.8 (t), 17.7 (q).

GCMS (EI^+ -MS): m/z = 159 [$\text{M} - 15$] $^+$ (3 %), 135 (11 %), 132 (10 %), 131 (100 %), 129 (10%), 116 (15 %), 91 (40 %), 77 (12 %), 69 (61 %), 41 (72 %), 39 (25 %).

5

Example 14: 1,3,7-Octatriene from *E*-octa-2,7-dien-1-ol

Sodium methoxide (6.8 mg, 0.12 mmol) is added to water-free *E*-octa-2,7-dien-1-ol (5 g, 40 mmol) in water-free dimethyl carbonate (10.8 g, 119 mmol) under stirring and nitrogen in a distillation flask equipped with a condenser. The solution is heated to 100 °C and a methanol / dimethyl carbonate mixture (2.5 ml) is distilled at 63 °C head temperature until a 98% conversion of *E*-octa-2,7-dien-1-ol to its carbonate is detected by GC. The mixture is cooled to 60 °C and DPEphos (10.9 g, 0.02 mmol) is added. After 10 min stirring $\text{Pd}(\text{OAc})_2$ (15 mg, 0.07 mmol, 0.2 mol%) is added at 60 °C. Under stirring the solution is heated to 110 °C for 1 h. At r.t. *tert*-butyl methyl ether and water are added, and after phase separation the water phase is extracted with *tert*-butyl methyl ether. The organic layers are combined, dried over MgSO_4 , filtered and evaporated at 70 °C / 45 mbar giving 3.3 g (78%) of crude Octa-1,3,7-triene with 79% purity and an *EZ* reatio of 1:1. The analytical data are consistent with the ones in the literature, see for example E.J.Smutny *J. Am. Chem. Soc.* 89, 6793 (1967) and references therein.

20

^1H -NMR (400 MHz, CDCl_3) of the *EZ* mixture: δ (ppm) = 2.0 - 2.35 (2 x 4 H, CH_2), 4.9 – 5.2 (2 x 4 H, $=\text{CH}_2$), 5.45 (m, 1 H), 5.7 (m, 1 H), 5.8 (m, 2 H), 6.05 (m, 2 H), 6.35 (m, 1 H), 6.65.

^{13}C -NMR (100 MHz, CDCl_3) of the 3*Z*-isomer: δ (ppm) = 138.1 (d), 137.2 (d), 134.4 (d), 131.3 (d), 115.0 (t), 114.9 (t), 33.3 (t), 31.9 (t). ^{13}C -NMR (100 MHz, CDCl_3) of the 3*E*- isomer: δ (ppm) = 138.0 (d), 132.2 (d), 131.8 (d), 129.6 (d), 117.1 (t), 114.8 (t), 33.7 (t), 27.1 (t).

25

GCMS (EI^+ -MS): t_R : 2.82 min (39%, *Z*-isomer), 2.85 min (41%, *E*-isomer): m/z of the *Z*-isomer = 108 [M] $^+$ (12 %), 93 (25 %), 79 (8 %), 77 (5 %), 67 (100 %), 65 (20 %), 54 (9 %), 41 (48 %), 39 (41 %). m/z of the *E*-isomer = 108 [M] $^+$ (12 %), 93 (30 %), 80 (8 %), 79 (19 %), 77 (8 %), 67 (100 %), 65 (22 %), 54 (13 %), 41 (49 %), 39 (38 %), 27 (14 %).

30

(Comparative) Example 15: 1,3,7-Octatriene from *E*-octa-2,7-dien-1-ol

This example is based on Example 5 - Table 1 of JP 2006327960 (Kuraray).

$\text{Pd}(\text{OAc})_2$ (45 mg, 0.2 mmol, 0.25 mol%) and PPh_3 (0.5 g, 2 mmol) are added to *E*-octa-2,7-dien-1-ol (10 g, 79 mmol) in xylene (10 ml) under nitrogen and stirring. The yellow reaction mixture is heated to 150 °C (internal temperature 130 °C decreases over time to 110 °C). GC-analysis (rpa, corrected by xylene) after 4 h shows *E*-octa-2,7-dien-1-ol (36 %) and

35

1,3,7-Octatriene (29 %) and after 23 h *E*-octa-2,7-dien-1-ol (8 %) and 1,3,7-Octatriene (55 %). At r.t. *tert*-butyl methyl ether (20 ml) and water (20 ml) are added. After phase separation the aqueous phase is extracted with *tert*-butyl methyl ether (20 ml). The combined organic layers are dried over MgSO₄, filtered and evaporated at 45 °C / 70 mbar. The residue (15.8 g), analyzed by GCMS (rpa, corrected by xylene, 44%), shows Octa-1,3,7-triene (27%, E/Z 1:2) and *E*-octa-2,7-dien-1-ol (9%) and unidentified byproducts (54%) at higher retention times. These results are in agreement with example 5 and table 1 in JP 2006327960 (Kuraray): Octa-1,3,7-triene (34%) and *E*-octa-2,7-dien-1-ol (39%). For analytical data see example 14.

(Comparative) Example 16: Farnesene from E-Nerolidol

This example is based on the conditions of example 11 and JP 2006327960 (Kuraray).

Pd(OAc)₂ (26 mg, 0.11 mmol, 0.25 mol%) and PPh₃ (0.3 g, 1.1 mmol) are added to *E*-Nerolidol (10 g, 45 mmol) in xylene (10 ml) under nitrogen and stirring. The yellow reaction mixture is heated to 150 °C (internal temperature 130 °C decreases slightly over time). GC-analysis (rpa, corrected by xylene) after 3 h shows a 10% conversion and after 21 h a 55% conversion of *E*-Nerolidol. At r.t. *tert*-butyl methyl ether (20 ml) and water (20 ml) are added. After phase separation the aqueous phase is extracted with *tert*-butyl methyl ether (20 ml). The combined organic layers are dried over MgSO₄, filtered and evaporated. The residue (16.5 g), analyzed by GCMS (rpa, corrected by xylene, 42%), shows 6-*E*-Farnesene (20%, β : α Z: α E = 6:3:11), *E*-Nerolidol (58%), Allofarnesene (19%) and Farnesol (3%). These results show that selectivity and overall efficiency of the method revealed in JP 2006327960 (Kuraray) is much lower than the one described in example 1.

(Comparative) Example 17: Elimination of E-Nerolidol according to Vorholt

This example is based on the elimination conditions described by Vorholt et al. (*Cat. Sci. & Tech.* 6, 1302, 2016).

Pd(acac)₂ (6.2 mg, 0.02 mmol, xanthphos (13 mg, 0.022 mmol) and *E*-Nerolidol (0.45 g, 2 mmol) are dissolved in a stainless steel autoclave in toluene (2.5 ml). After addition of trifluoroacetic acid (23 mg, 0.2 mmol) the autoclave is pressurized with 40 bar carbon monoxide and the mixture is stirred at 105 °C for 17 h. After cooling to room temperature the autoclave is vented and flushed with argon. GCMS analysis (rpa) shows complete conversion to 6-*E*- β -Farnesene (24%), 6*E*-3*Z*-Farnesene (28%), 6*E*-3*E*-Farnesene (43%), three allofarnesene isomers (5%) and Bisabolene (1%). The yield of 6-*E*-Farnesene was determined to 71% as analyzed with standard dodecane.

These results show that under acidic conditions a lower yield of 6-*E*-Farnesene is obtained, compared to the one obtained by Pd-catalyzed elimination under basic conditions as described in example 1.