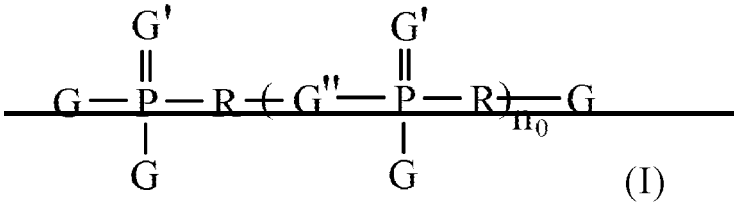
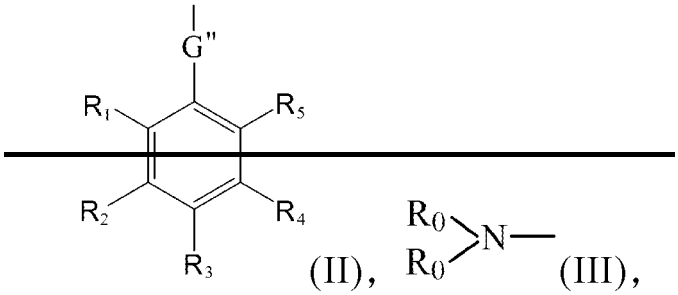
Claims

1. An organophosphorus compound, which has a structure as represented by the general formula (I):



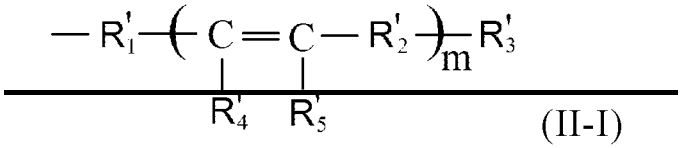
(I)

In the general formula (I), groups G are, identical to or different from each other, each independently selected from H, C_1-C_{30} linear or branched alkyl, C_1-C_{30} linear or branched alkoxyl, C_6-C_{20} aryl, C_1-C_{20} linear or branched alkyl C_6-C_{20} aryl, a group represented by the formula (II) and a group represented by the formula (III) (preferably each independently selected from H, C_1-C_{10} linear or branched alkyl, C_1-C_{10} linear or branched alkoxyl, C_6-C_{10} aryl, C_1-C_{14} alkyl phenyl, a group represented by the formula (II) and a group represented by the formula (III)), wherein at least one G is a group represented by the formula (II);



(II), (III),

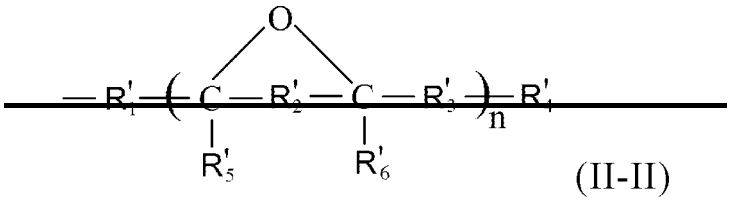
In the general formula (II), groups R_1, R_2, R_3, R_4 and R_5 are, identical to or different from each other, each independently selected from H, C_1-C_{20} linear or branched alkyl, C_1-C_{20} linear or branched alkoxyl, a group represented by the formula (II-I), a group represented by the formula (II-II) and a group represented by the formula (II-III), at least one group of groups R_1, R_2, R_3, R_4 and R_5 is selected from a group represented by the formula (II-I), a group represented by the formula (II-II) and a group represented by the formula (II-III);



(II-I)

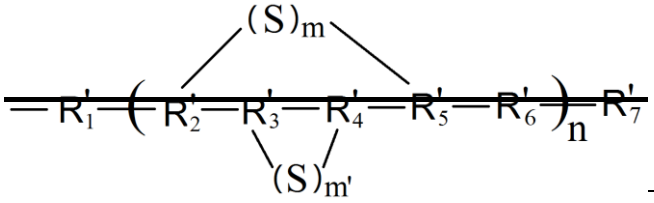
In the general formula (II-I), group R_1' is selected from single bond and C_1-C_{20} linear or branched alkylene (preferably selected from single bond and C_1-C_4 linear or branched

alkylene); groups R_2' in m repeating units are, identical to or different from each other, each independently selected from single bond and C_1-C_{20} linear or branched alkylene (preferably each independently selected from single bond and C_1-C_4 linear or branched alkylene); group R_3' is selected from hydrogen and C_1-C_{20} linear or branched alkyl (preferably selected from hydrogen and C_1-C_4 linear or branched alkyl); groups R_4' in m repeating units are, identical to or different from each other, each independently selected from hydrogen and C_1-C_{20} linear or branched alkyl (preferably each independently selected from hydrogen and C_1-C_4 linear or branched alkyl); groups R_5' in m repeating units are, identical to or different from each other, each independently selected from hydrogen and C_1-C_{20} linear or branched alkyl (preferably each independently selected from hydrogen and C_1-C_4 linear or branched alkyl); m is an integral number (preferably an integral number of 0-10, more preferably a positive integral number of 1-3);



(II-II)

In the general formula (II-II), group R_1' is selected from single bond and C_1-C_{20} linear or branched alkylene (preferably selected from single bond and C_1-C_4 linear or branched alkylene); groups R_2' in n repeating units are, identical to or different from each other, each independently selected from single bond and C_1-C_{20} linear or branched alkylene (preferably each independently selected from single bond and C_1-C_4 linear or branched alkylene); groups R_3' in n repeating units are, identical to or different from each other, each independently selected from single bond and C_1-C_{20} linear or branched alkylene (preferably each independently selected from single bond and C_1-C_4 linear or branched alkylene); group R_4' is selected from hydrogen and C_1-C_{20} linear or branched alkyl (preferably selected from hydrogen and C_1-C_4 linear or branched alkyl); groups R_5' in n repeating units are, identical to or different from each other, each independently selected from hydrogen and C_1-C_{20} linear or branched alkyl (preferably each independently selected from hydrogen and C_1-C_4 linear or branched alkyl); groups R_6' in n repeating units are, identical to or different from each other, each independently selected from hydrogen and C_1-C_{20} linear or branched alkyl (preferably each independently selected from hydrogen and C_1-C_4 linear or branched alkyl); n is a positive integral number (preferably a positive integral number of 1-10, more preferably a positive integral number of 1-3);



(II-III)

In the general formula (II-III), group R_1' is selected from single bond and C_1-C_{20} linear or branched alkylene (preferably selected from single bond and C_1-C_4 linear or branched alkylene); groups R_2' in n repeating units are, identical to or different from each other, each independently 2 valent, 3 valent or 4 valent C_1-C_{20} linear or branched alkyl (preferably each independently 2 valent, 3 valent or 4 valent C_1-C_4 linear or branched alkyl); groups R_3' in n repeating units are, identical to or different from each other, each independently selected from single bond and 2 valent or 3 valent C_1-C_{20} linear or branched alkyl (preferably each independently selected from single bond and 2 valent or 3 valent C_1-C_4 linear or branched alkyl); groups R_4' in n repeating units are, identical to or different from each other, each independently selected from single bond and 2 valent or 3 valent C_1-C_{20} linear or branched alkyl (preferably each independently selected from single bond and 2 valent or 3 valent C_1-C_4 linear or branched alkyl); groups R_5' in n repeating units are, identical to or different from each other, each independently 2 valent, 3 valent or 4 valent C_1-C_{20} linear or branched alkyl (preferably each independently 2 valent, 3 valent or 4 valent C_1-C_4 linear or branched alkyl); groups R_6' in n repeating units are, identical to or different from each other, each independently selected from single bond and C_1-C_{20} linear or branched alkylene (preferably each independently selected from single bond and C_1-C_4 linear or branched alkylene); group R_7' is selected from hydrogen and C_1-C_{20} linear or branched alkyl (preferably selected from hydrogen and C_1-C_4 linear or branched alkyl); n is an integral number of 1-10 (preferably an integral number of 1-3); the numbers m in n repeating units are, identical to or different from each other, each independently selected from an integral number of 0-10 (preferably an integral number of 0-5); the numbers m' in n repeating units are, identical to or different from each other, each independently selected from an integral number of 0-10 (preferably an integral number of 0-5); in each repeating unit of the formula (II-III), when m is greater than 0, the linking group formed by m sulfur atoms is bonded to groups R_2' and R_5'; when m' is greater than 0, the linking group formed by m' sulfur atoms is bonded to groups R_3' and R_4'; in each repeating unit of the formula (II-III), when group R_3' is a single bond, the end of the linking group formed by m' sulfur atoms, that is connected to group R_3', is bonded to group R_2', when group R_4' is a single bond, the end of the linking group formed by m' sulfur atoms, that is connected to group R_4', is bonded to group R_5';

In the general formula (III), groups R_0 are each independently selected from H, C_6-C_{20} aryl, C_1-C_{20} linear or branched alkyl C_6-C_{20} aryl and C_1-C_{30} linear or branched alkyl (preferably each independently selected from phenyl, C_1-C_{14} alkyl phenyl and C_1-C_{20} linear or branched alkyl);

Groups G' present in the general formula (I) are, identical to or different from each other, each independently selected from O, S and NR_0' or the absence (the absence of group G' means that P is a tervalent P atom), wherein R_0' is selected from H, C_6-C_{20} aryl, C_1-C_{20} linear or branched alkyl C_6-C_{20} aryl and C_1-C_{30} linear or branched alkyl (preferably selected from phenyl, C_1-C_{14} alkyl phenyl and C_1-C_{20} linear or branched alkyl);

Groups G" present in the general formula (I) and the general formula (II) are, identical to or different from each other, each independently selected from single bond, O, S and NR_0', wherein R_0' is selected from H, C_6-C_{20} aryl, C_1-C_{20} linear or branched alkyl C_6-C_{20} aryl and C_1-C_{30} linear or branched alkyl (preferably selected from phenyl, C_1-C_{14} alkyl phenyl and C_1-C_{20} linear or branched alkyl);

In the general formula (I), groups R are independently selected from single bond, C_1-C_{20} linear or branched alkylene and C_6-C_{20} arylene (preferably selected from single bond, C_1-C_{10} linear or branched alkylene, C_6-C_{10} arylene);

n_0 in the general formula (I) is an integral number of 0-10, preferably an integral number of 0-5, more preferably 0, 1, 2, 3 or 4.

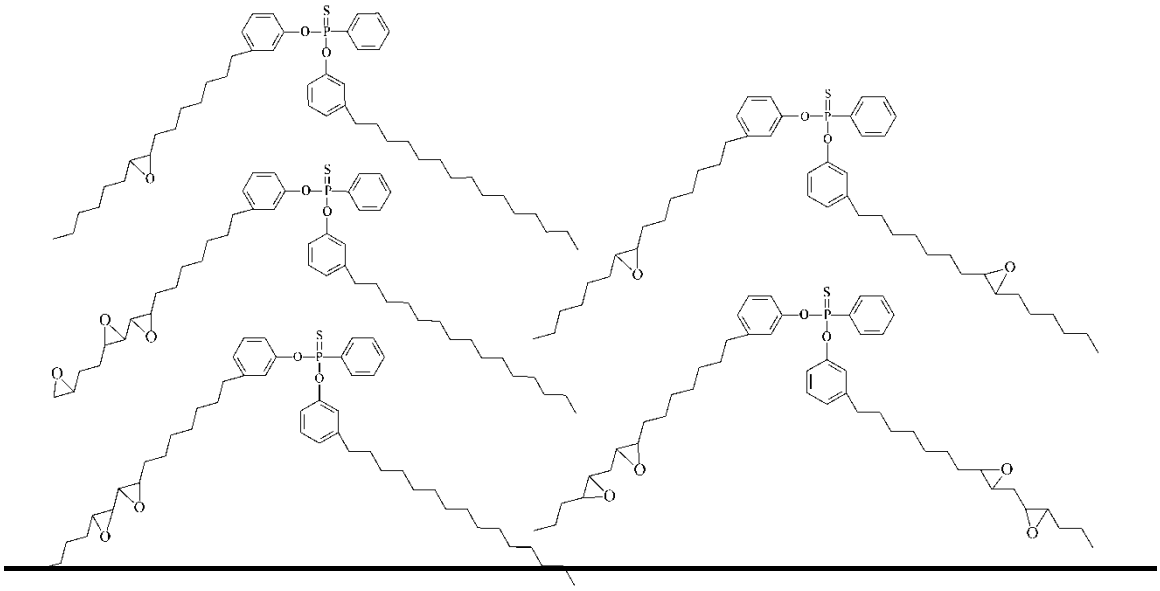
2. The organophosphorus compound according to claim 1, which is characterized in that in the general formula (II), groups R_1, R_3 and R_5 are each independently selected from H and C_1-C_4 linear or branched alkyl; preferably, in the general formula (II), groups R_1, R_3 and R_5 are each independently selected from H, methyl, ethyl, propyl, isopropyl, n-butyl, isobutyl and tert-butyl.

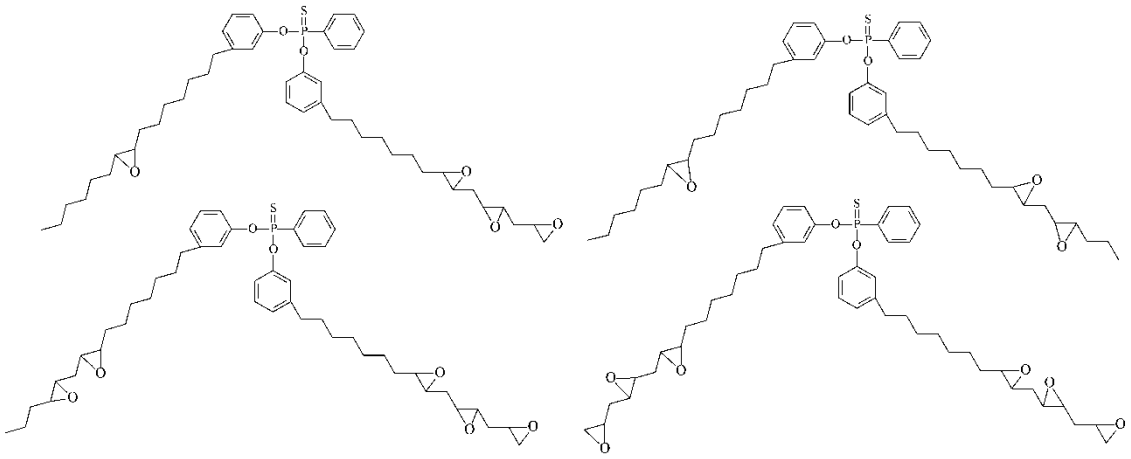
3._ The organophosphorus compound according to claim 1 or 2, which is characterized in that in the general formula (II), groups R_2 and R_4 are each independently selected from H, C_1-C_{20} linear or branched alkyl, a group represented by the formula (II-I), a group represented by the formula (II-II) and a group represented by the formula (II-III), wherein at least one group is selected from a group represented by the formula (II-I), a group represented by the formula (II-II) and a group represented by the formula (II-III); preferably, one group is a group represented by the formula (II-I), a group represented by the formula (II-II) or a group represented by the formula (II-III), the other one is H.

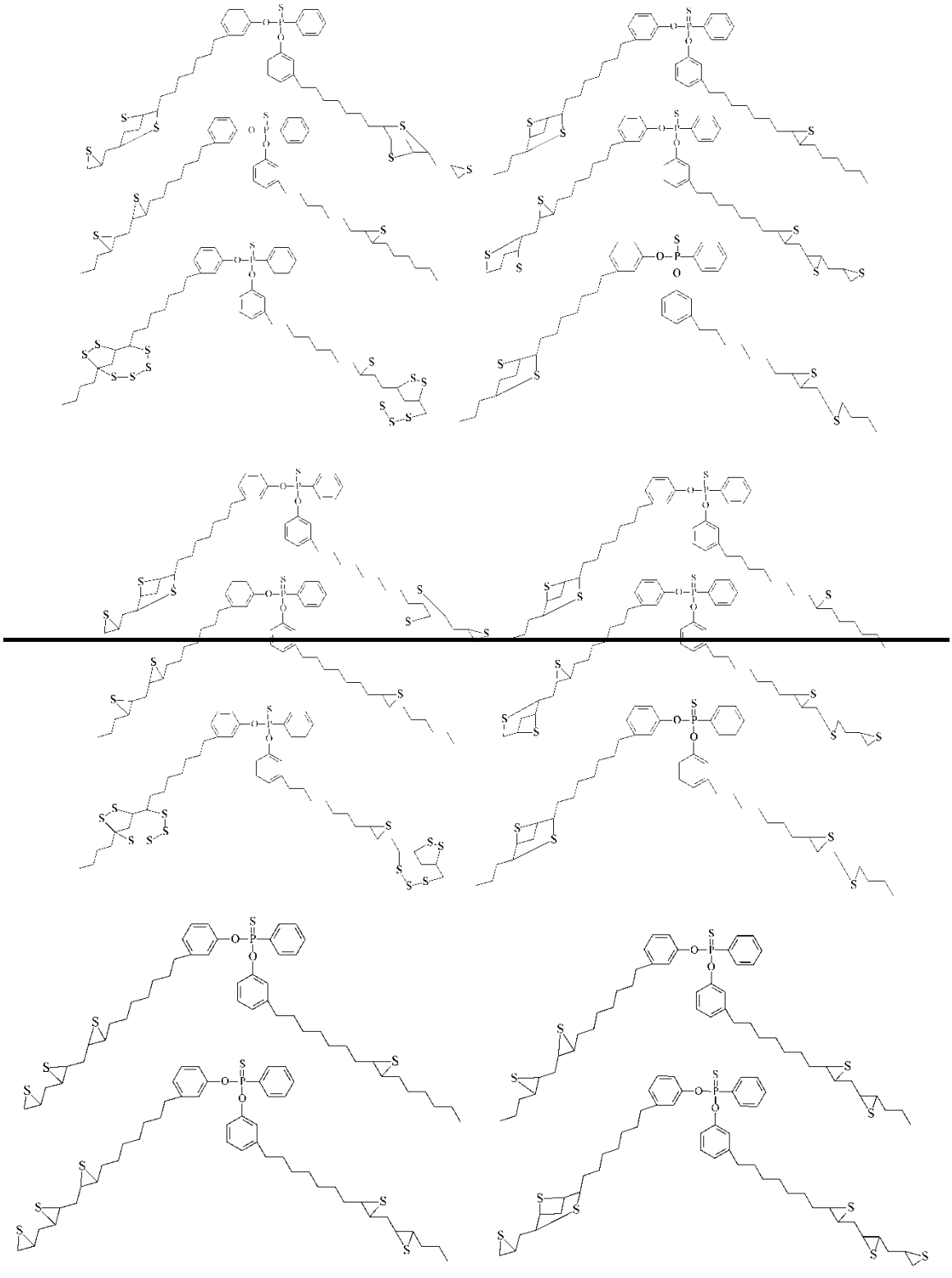
4. The organophosphorus compound according to any of claims 1-3, which is characterized in that the total carbon number of the group represented by the formula (II-I) is 2-30 (preferably

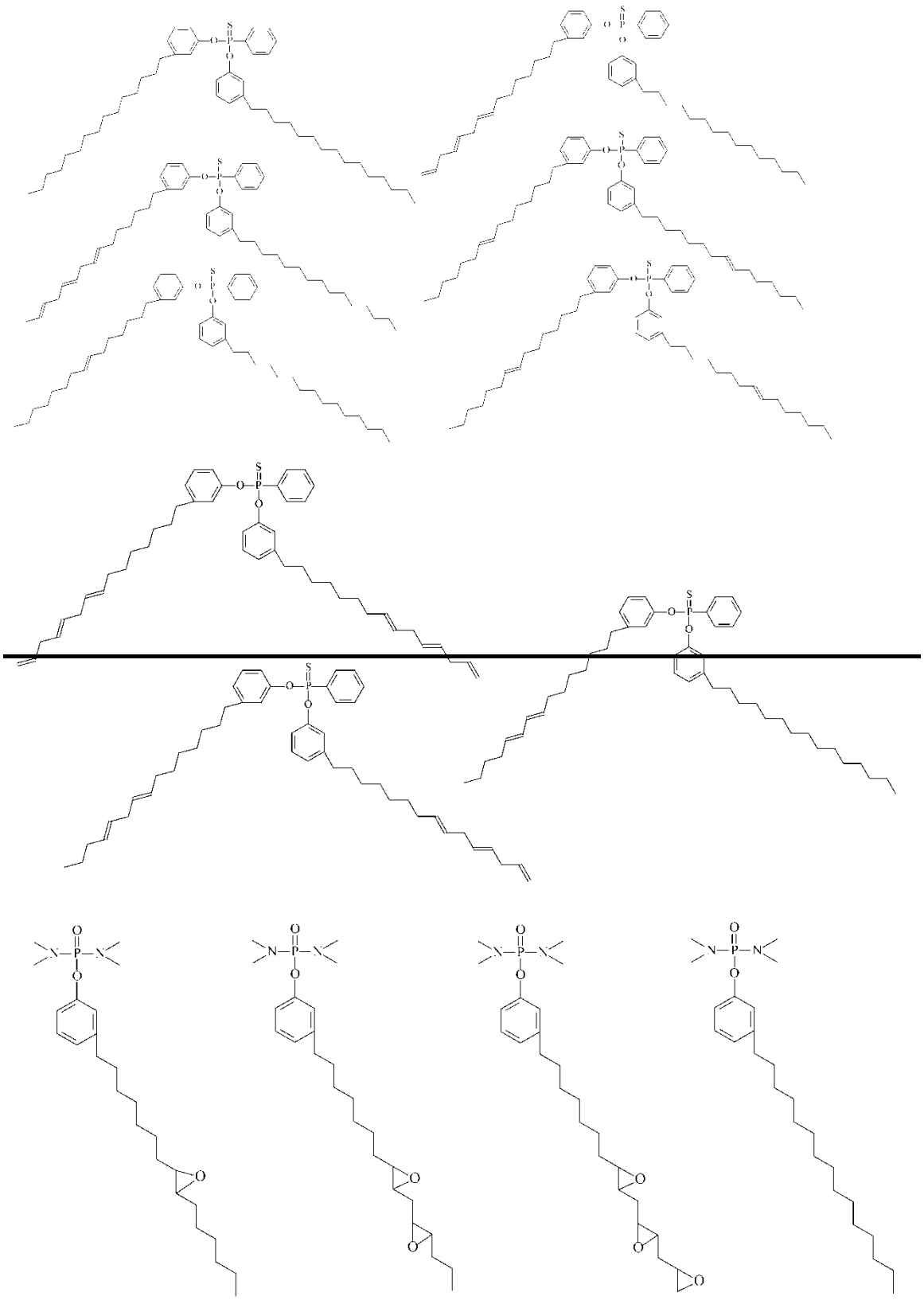
~~6-20, more preferably 10-18); the total carbon number of the group represented by the formula (II-II) is 2-30 (preferably 6-20, more preferably 10-18); the total carbon number of the group represented by the formula (II-III) is 2-30 (preferably 6-20, more preferably 10-18).~~

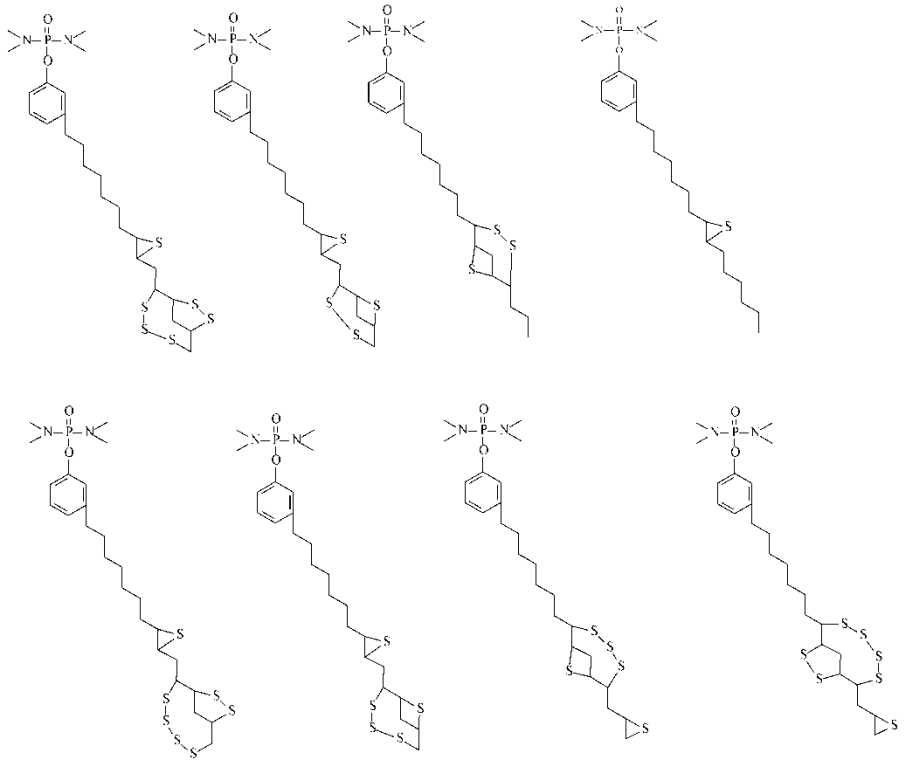
~~5. The organophosphorus compound according to any of claims 1-4, which is characterized in that the organophosphorus compound is selected from the following specific compounds or a mixture thereof in any proportion:~~

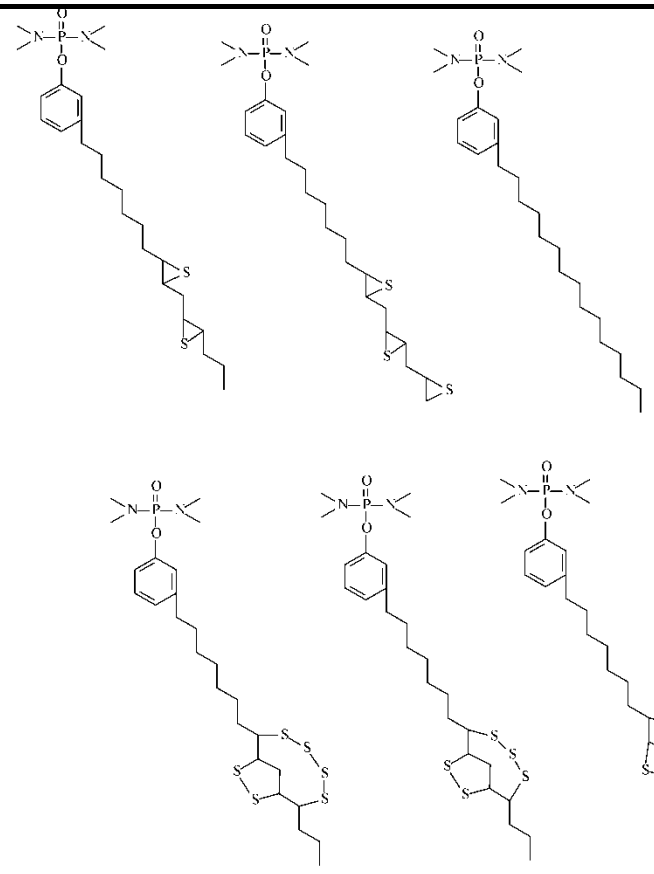


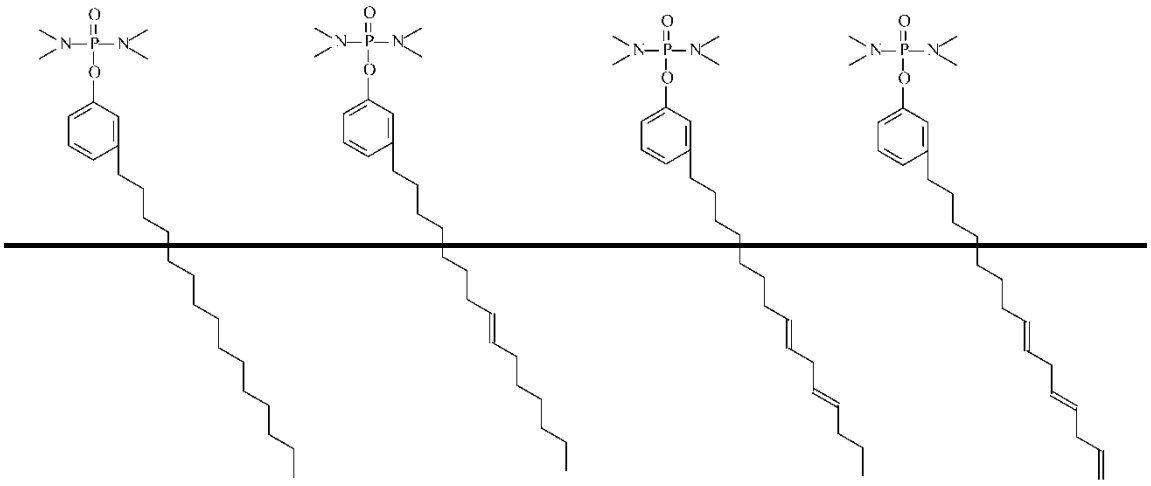












~~6~~1. A process for preparing an organophosphorus compound, which comprises the following steps:

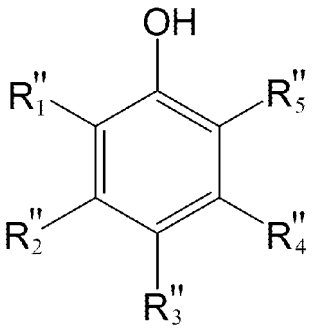
Step A of subjecting a phenol compound represented by the general formula (X) to an epoxidation reaction or a sulfurization reaction or an optional hydrogenation reaction; and step B of reacting the product obtained in step A with a phosphorous compound represented by the general formula (X');

wherein either step A of subjecting the phenol compound represented by the general formula (X) to an epoxidation reaction or a sulfurization reaction or an optional hydrogenation reaction is first performed, and step B of reacting the product of step A with the phosphorous compound represented by the general formula (X') is then performed; or step B of reacting the phenol compound represented by the general formula (X) with the phosphorous compound represented by the general formula (X') is first performed, and step A of subjecting the product of step B to an epoxidation reaction or a sulfurization reaction or an optional hydrogenation reaction is then performed,

wherein the epoxidation reaction is to react a phenol compound represented by the general formula (X) or a product obtained from step B of reacting a phenol compound represented by the general formula (X) with a phosphorous compound represented by the general formula (X') with an epoxidizing agent, preferably, the epoxidizing agent is a peroxide, more preferably the epoxidizing agent is selected from one or more of hydrogen peroxide, peroxyformic acid, peroxyacetic acid, peroxysulfonic acid, m-chloro peroxybenzoic acid, tert-butyl hydroperoxide, tert-butyl peroxyacetate, methyl ethyl ketone peroxide, dibenzoyl peroxide and cyclohexanone peroxide, and

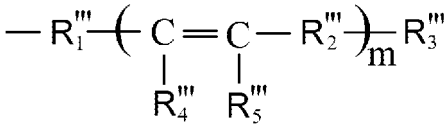
wherein the sulfurization reaction comprises a step of reacting a phenol compound represented

by the general formula (X) or a product obtained from step B of reacting a phenol compound represented by the general formula (X) with a phosphorous compound represented by the general formula (X') with a sulfurizing agent, preferably, the sulfurizing agent is an inorganic sulfurizing agent and/or an organic sulfurizing agent, more preferably the inorganic sulfurizing agent is selected from one or more of sulfur, Na_2S, K_2S, ZnS, H_2S and SCl; the organic sulfurizing agent can be selected from one or more of di-tert-butyl sulfide (DBPS), dimethyl disulfide (DMDS), dimethyl sulfide (DMS), ethyl mercaptan (EM), n-butyl mercaptan (NBM) and tert-nonyl polysulfide (TNPS),



(X)

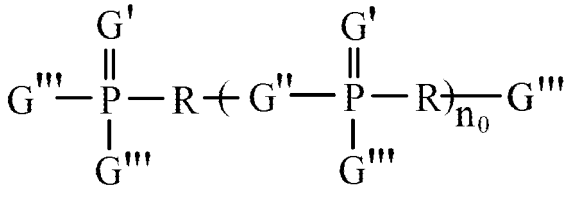
In the general formula (X), groups R_1", R_2", R_3", R_4" and R_5" are, identical to or different from each other, each independently selected from H, C_1-C_{20} linear or branched alkyl, C_1-C_{20} linear or branched alkoxyl and a group represented by the general formula (Y), wherein at least one group is a group represented by the general formula (Y);



(Y)

Wherein group R_1"' is selected from single bond and C_1-C_{20} linear or branched alkylene (preferably selected from single bond and C_1-C_4 linear or branched alkylene); groups R_2"' in m repeating units are, identical to or different from each other, each independently selected from single bond and C_1-C_{20} linear or branched alkylene (preferably each independently selected from single bond and C_1-C_4 linear or branched alkylene); group R_3"' is selected from hydrogen and C_1-C_{20} linear or branched alkyl (preferably selected from hydrogen and C_1-C_4 linear or branched alkyl); groups R_4"' in m repeating units are, identical to or different from each other, each independently selected from hydrogen and C_1-C_{20} linear or branched alkyl (preferably each independently selected from hydrogen and C_1-C_4 linear or branched alkyl); groups R_5"' in

m repeating units are, identical to or different from each other, each independently selected from hydrogen and C_1-C_{20} linear or branched alkyl (preferably each independently selected from hydrogen and C_1-C_4 linear or branched alkyl); m is a positive integral number (preferably a positive integral number of 1-10, more preferably a positive integral number of 1-3);



(X')

Groups G' present in the general formula (X') are, identical to or different from each other, each independently selected from O, S and NR_0' or absence (the absence of group G' means that P is a tervalent P atom), wherein R_0' is selected from H, C_6-C_{20} aryl, C_1-C_{20} linear or branched alkyl C_6-C_{20} aryl and C_1-C_{30} linear or branched alkyl (preferably selected from phenyl, C_1-C_{14} alkyl phenyl and C_1-C_{20} linear or branched alkyl);

Groups G" present in the general formula (X') are, identical to or different from each other, each independently selected from single bond, O, S and NR_0', wherein R_0' is selected from H, C_6-C_{20} aryl, C_1-C_{20} linear or branched alkyl C_6-C_{20} aryl and C_1-C_{30} linear or branched alkyl (preferably selected from phenyl, C_1-C_{14} alkyl phenyl and C_1-C_{20} linear or branched alkyl);

Groups R in the general formula (X') are independently selected from single bond, C_1-C_{20} linear or branched alkylene and C_6-C_{20} arylene (preferably selected from single bond, C_1-C_{10} linear or branched alkylene, C_6-C_{10} arylene);

Groups G'" present in the general formula (X') are, identical to or different from each other, each independently selected from A,-$N(R_0')_2$ and R_Z; wherein group R_Z is each independently selected from H, C_1-C_{30} linear or branched alkyl, C_1-C_{30} linear or branched alkoxyl, C_6-C_{20} aryl, C_1-C_{20} linear or branched alkyl C_6-C_{20} aryl (preferably each independently selected from H, C_1-C_{10} linear or branched alkyl, C_1-C_{10} linear or branched alkoxyl, C_6-C_{10} aryl, C_1-C_{14} alkyl phenyl), groups R_0' are each independently selected from H, C_6-C_{20} aryl, C_1-C_{20} linear or branched alkyl C_6-C_{20} aryl and C_1-C_{30} linear or branched alkyl (preferably each independently selected from phenyl, C_1-C_{14} alkyl phenyl and C_1-C_{20} linear or branched alkyl), wherein groups A are each independently selected from F, Cl, Br, I and OH (preferably each independently selected from Cl and Br), wherein at least one group G'" is A;

In the general formula (X'), n_0 is an integral number of 0-10, preferably an integral number of 0-5, more preferably 0, 1, 2, 3 or 4.

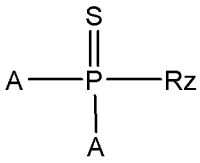
~~7~~2. The preparation process according to claim ~~6~~1, which is characterized in that in the general formula (X), groups R_1", R_3" and R_5" are, identical to or different from each other, each independently selected from hydrogen and C_1-C_4 linear or branched alkyl; preferably, groups R_1", R_3" and R_5" are, identical to or different from each other, each independently selected from H, methyl, ethyl, propyl, isopropyl, n-butyl, isobutyl and tert-butyl.

~~8~~3. The preparation process according to claim ~~6~~ 1 or ~~7~~2, which is characterized in that in the general formula (X), groups R_2" and R_4" are, identical to or different from each other, each independently selected from hydrogen, C_1-C_{20} linear or branched alkyl and a group represented by the general formula (Y), wherein at least one group is a group represented by the general formula (Y); preferably, one group of groups R_2" and R_4" is selected from a group represented by the general formula (Y), the other group is selected from hydrogen.

~~9~~4. The preparation process according to any one of claims ~~6~~1-~~8~~3, which is characterized in that the phosphorous compound represented by the general formula (X') is selected from a thiophosphorylating agent and/or a phosphorus-nitridizing agent.

~~10~~5. The preparation process according to claim ~~9~~4, which is characterized in that

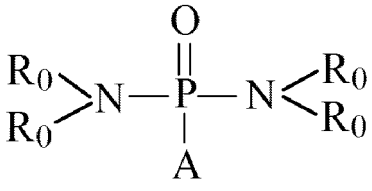
The thiophosphorylating agent has a structure as represented by the formula (Z):



(Z)

Wherein R_Z is selected from H, C_1-C_{30} linear or branched alkyl, C_1-C_{30} linear or branched alkoxyl, C_6-C_{20} aryl, C_1-C_{20} linear or branched alkyl C_6-C_{20} aryl (preferably each independently selected from H, C_1-C_{10} linear or branched alkyl, C_1-C_{10} linear or branched alkoxyl, C_6-C_{10} aryl, C_1-C_{14} alkyl phenyl); groups A are each independently selected from F, Cl, Br, I and OH (preferably each independently selected from Cl and Br);

The phosphorus-nitridizing agent has a structure as represented by the formula (Z'):



(Z')

Wherein groups R_0 are each independently selected from H, C_6-C_{20} aryl, C_1-C_{20} linear or branched alkyl C_6-C_{20} aryl and C_1-C_{30} linear or branched alkyl (preferably each independently

selected from phenyl, C_1-C_{14} alkyl phenyl and C_1-C_{20} linear or branched alkyl); group A is each independently selected from F, Cl, Br, I, H and OH (preferably each independently selected from Cl and Br).

~~11~~6. The preparation process according to claim ~~9~~ 4 or ~~10~~5, which is characterized in that the thiophosphorylating agent is selected from one or more of thiophosphoryl chloride, thiophosphonic dichloride, C_1-C_{30} linear or branched alkyl thiophosphonic dichloride, C_1-C_{20} linear or branched alkyl phenyl thiophosphonic dichloride and phenyl thiophosphonic dichloride (preferably phenyl thiophosphonic dichloride); the phosphorus-nitridizing agent is selected from one or more of amino phosphoryl chloride, C_1-C_{10} alkylaminophosphoryl chloride, C_1-C_{20} linear or branched alkyl phenylamino phosphoryl chloride and phenylamino phosphoryl chloride, preferably C_1-C_{10} alkylaminophosphoryl chloride.

~~12. The preparation process according to any of claims 6-11, which is characterized in that either step A of subjecting the phenol compound represented by the general formula (X) to an epoxidation reaction or a sulfurization reaction or an optional hydrogenation reaction is first performed, and step B of reacting the product of step A with the phosphorous compound represented by the general formula (X') is then performed; or step B of reacting the phenol compound represented by the general formula (X) with the phosphorous compound represented by the general formula (X') is first performed, and step A of subjecting the product of step B to an epoxidation reaction or a sulfurization reaction or an optional hydrogenation reaction is then performed.~~

~~13. The preparation process according to any of claims 6-12, which is characterized in that the epoxidation reaction is to react a phenol compound represented by the general formula (X) or a product obtained from step B of reacting a phenol compound represented by the general formula (X) with a phosphorous compound represented by the general formula (X') with an epoxidizing agent, preferably, the epoxidizing agent is a peroxide, more preferably the epoxidizing agent is selected from one or more of hydrogen peroxide, peroxyformic acid, peroxyacetic acid, peroxysulfonic acid, m-chloro peroxybenzoic acid, tert-butyl hydroperoxide, tert-butyl peroxyacetate, methyl ethyl ketone peroxide, dibenzoyl peroxide and cyclohexanone peroxide.~~

~~14~~7. The preparation process according to any one of claims ~~6~~1-~~13~~6, which is characterized in that the molar ratio of the phenol compound represented by the general formula (X) to the epoxidizing agent is 1:1-10 (preferably 1:2-5); the epoxidation reaction temperature is 0°C-100°C (preferably 10°C-80°C).

~~15~~8. The preparation process according to any one of claims ~~6~~1-~~14~~7, which is characterized in

that a catalyst is added to the epoxidation reaction, preferably, the catalyst is selected from inorganic acids, more preferably one or more of sulfuric acid, hydrochloric acid, phosphoric acid, nitric acid, a heteropoly acid and a solid acid.

~~16. The preparation process according to any of claims 6-12, which is characterized in that the sulfurization reaction comprises a step of reacting a phenol compound represented by the general formula (X) or a product obtained from step B of reacting a phenol compound represented by the general formula (X) with a phosphorous compound represented by the general formula (X') with a sulfurizing agent, preferably, the sulfurizing agent is an inorganic sulfurizing agent and/or an organic sulfurizing agent, more preferably the inorganic sulfurizing agent is selected from one or more of sulfur, Na_2S, K_2S, ZnS, H_2S and SCl; the organic sulfurizing agent can be selected from one or more of di-tert-butyl sulfide (DBPS), dimethyl disulfide (DMDS), dimethyl sulfide (DMS), ethyl mercaptan (EM), n-butyl mercaptan (NBM) and tert-nonyl polysulfide (TNPS).~~

~~17~~9. The preparation process according to any one of claims ~~6~~1~~-12 6~~and ~~16~~, which is characterized in that in the sulfurization reaction, the molar ratio of the phenol compound represented by the general formula (X) or the product of step B to the sulfurizing agent is 1:1-6 (preferably 1:2-4); the sulfurization reaction temperature is 100°C-240°C (preferably 140°C-190°C).

~~18~~10. The preparation process according to any one of claims ~~6~~1~~-12 6~~ and ~~16-17~~9, which is characterized in that a catalyst is added to the sulfurization reaction, preferably, the catalyst is selected from C_1-C_6 organic amine and an inorganic base, more preferably the catalyst is selected from one or more of methylamine, dimethylamine, ethylamine, diethylamine, propylamine, dipropyl amine, tripropyl amine, butyl amine, amylamine, hexylamine, ammonia water, sodium hydroxide, potassium hydroxide, zinc hydroxide, sodium oxide, potassium oxide, zinc oxide, sodium carbonate, potassium carbonate and zinc carbonate.

~~19~~11. The preparation process according to any one of claims ~~6~~1~~-12~~6, which is characterized in that the conditions of the optional hydrogenation reaction comprise: hydrogen pressure: 1.0-6.0 MPa (preferably 3.0-4.0 MPa), temperature: 60°C-260°C (preferably 180°C-220°C), time: 0.5-10 h (preferably 3-5 h).

~~20~~12. The preparation process according to any one of claims ~~6~~1~~-12 6~~ and ~~19~~11, which is characterized in that a hydrogenation catalyst is added during the hydrogenation reaction.

~~21~~13. The preparation process according to any one of claims ~~6~~1~~-20~~12, which is characterized in that the conditions for reacting the phenol compound represented by the general formula (X) or the product of step A obtained from subjecting the phenol compound represented by the

general formula (X) to the epoxidation reaction or the sulfurization reaction or the optional hydrogenation reaction with the phosphorous compound represented by the general formula (X') comprise: the molar ratio of the phosphorous compound represented by the general formula (X') to the phenol compound represented by the general formula (X) or the product of step A is 1:1-10 (preferably 1:1-5); the reaction temperature is 50°C-150°C (preferably 60°C-100°C).

~~22~~14. The preparation process according to claim ~~21~~13, which is characterized in that the catalyst is added in the reaction of the phenol compound represented by the general formula (X) or the product of step A with the phosphorous compound represented by the general formula (X'), preferably, the catalyst is C_1-C_{10} organic amine and an inorganic ammonium, more preferably selected from one or more of methylamine, dimethylamine, trimethylamine, ethylamine, diethylamine, triethylamine, propylamine, dipropylamine, tripropylamine, butylamine, dibutylamine and ammonia.

~~23~~15. The preparation process according to any one of claims ~~9~~4-~~22~~14, which is characterized in that either step A of subjecting the phenol compound represented by the general formula (X) to an epoxidation reaction or a sulfurization reaction or an optional hydrogenation reaction is first performed, and step B of subjecting the product of step A and a thiophosphorylating agent and/or a phosphorus-nitridizing agent to the thiophosphorylation reaction and/or the phosphorus-nitridation reaction is then performed, or step B of subjecting the phenol compound represented by the general formula (X) and a thiophosphorylating agent and/or a phosphorus-nitridizing agent to the thiophosphorylation reaction and/or the phosphorus-nitridation reaction is first performed, step A of subjecting the product of step B to an epoxidation reaction or a sulfurization reaction or an optional hydrogenation reaction is then performed.

~~24~~16. The preparation process according to claim ~~23~~15, which is characterized in that the conditions for reacting the phenol compound represented by the general formula (X) or the product of step A obtained from subjecting the phenol compound represented by the general formula (X) to the epoxidation reaction or the sulfurization reaction or the optional hydrogenation reaction with the thiophosphorylating agent comprise: the molar ratio of the thiophosphorylating agent to the phenol compound represented by the general formula (X) is 1:1-10 (preferably 1:1-5); the reaction temperature is 50°C-150°C (preferably 60°C-100°C).

~~25~~17. The preparation process according to claim ~~24~~16, which is characterized in that the catalyst is added in the thiophosphorylation reaction, preferably, the catalyst is selected from

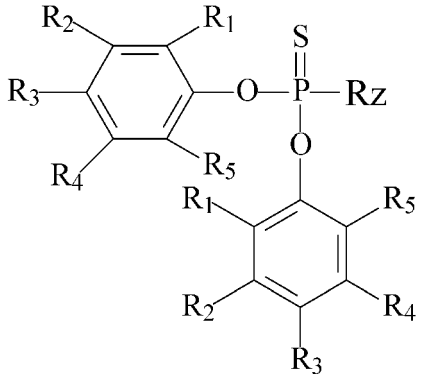
C_1-C_{10} organic amine and an inorganic ammonium, more preferably, the catalyst is selected from one or more of methylamine, dimethylamine, trimethylamine, ethylamine, diethylamine, triethylamine, propylamine, dipropylamine, tripropylamine, butylamine, dibutylamine and ammonia.

~~26~~18. The preparation process according to claim ~~23~~15, which is characterized in that the conditions for reacting the phenol compound represented by the general formula (X) or the product of step A obtained from subjecting the phenol compound represented by the general formula (X) to the epoxidation reaction or the sulfurization reaction or the optional hydrogenation reaction with the phosphorus-nitridizing agent comprise: the molar ratio of the phosphorus-nitridizing agent to the phenol compound represented by the general formula (X) or a sulfurization reaction product thereof is 1:1-10 (preferably 1:1-3); the reaction temperature is 50°C-150°C (preferably 60°C-100°C).

~~27~~19. The preparation process according to claim ~~26~~18, which is characterized in that a catalyst is added in the phosphorus-nitridation reaction, preferably, the catalyst is selected from C_1-C_{10} organic amine and an inorganic ammonium, more preferably, the catalyst is selected from one or more of methylamine, dimethylamine, trimethylamine, ethylamine, diethylamine, triethylamine, propylamine, dipropylamine, tripropylamine, butylamine, dibutylamine and ammonia.

~~28~~20. The preparation process according to any one of claims ~~6~~1-~~27~~19, which is characterized in that the phenol compound represented by the general formula (X) is derived from natural plant cashew.

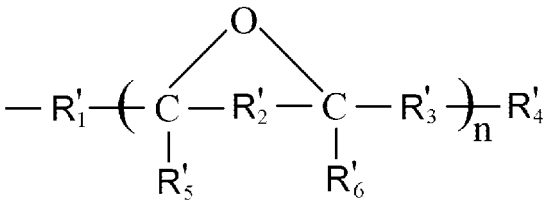
~~29~~21. ~~The~~ An organophosphorus compound ~~according to claim 1~~, which has a structure as represented by the general formula (I-1):



(I-1)

In the general formula (I-1), group R_Z is selected from H, C_1-C_{30} linear or branched alkyl, C_1-

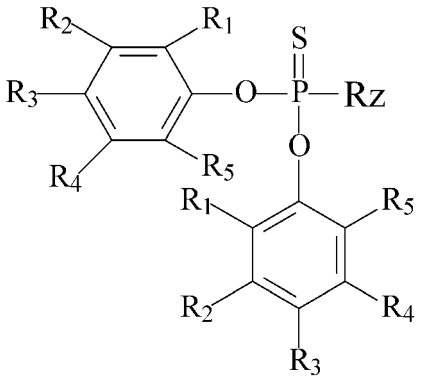
C_{30} linear or branched alkoxyl, C_6-C_{20} aryl, C_1-C_{20} linear or branched alkyl C_6-C_{20} aryl (preferably each independently selected from H, C_1-C_{10} linear or branched alkyl, C_1-C_{10} linear or branched alkoxyl, C_6-C_{10} aryl, C_1-C_{14} alkyl phenyl); groups R_1, R_2, R_3, R_4 and R_5 are, identical to or different from each other, each independently selected from H, C_1-C_{20} linear or branched alkyl, C_1-C_{20} linear or branched alkoxyl and a group represented by the formula (II-II), at least one group of groups R_1, R_2, R_3, R_4 and R_5 is a group represented by the formula (II-II);



(II-II)

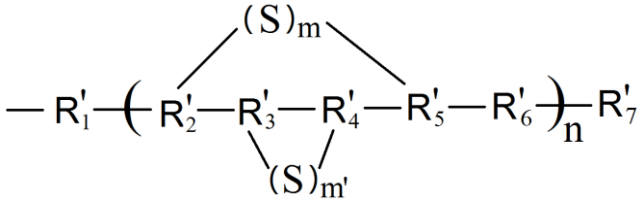
In the general formula (II-II), group R_1' is selected from single bond, C_1-C_{20} linear or branched alkylene (preferably selected from single bond and C_1-C_4 linear or branched alkylene); groups R_2' in n repeating units are, identical to or different from each other, each independently selected from single bond, C_1-C_{20} linear or branched alkylene (preferably each independently selected from single bond, C_1-C_4 linear or branched alkylene); groups R_3' in n repeating units are, identical to or different from each other, each independently selected from single bond, C_1-C_{20} linear or branched alkylene (preferably each independently selected from single bond, C_1-C_4 linear or branched alkylene); group R_4' is selected from hydrogen, C_1-C_{20} linear or branched alkyl (preferably selected from hydrogen, C_1-C_4 linear or branched alkyl); groups R_5' in n repeating units are, identical to or different from each other, each independently selected from hydrogen, C_1-C_{20} linear or branched alkyl (preferably each independently selected from hydrogen, C_1-C_4 linear or branched alkyl); groups R_6' in n repeating units are, identical to or different from each other, each independently selected from hydrogen, C_1-C_{20} linear or branched alkyl (preferably each independently selected from hydrogen, C_1-C_4 linear or branched alkyl); n is a positive integral number (preferably a positive integral number of 1-10, more preferably a positive integral number of 1-3).

~~30~~22. ~~The~~ An organophosphorus compound ~~according to claim 1~~, which has a structure as represented by the general formula (I-2):



(I-2)

In the general formula (I-2), the group R_Z is selected from H, C_1-C_{30} linear or branched alkyl, C_1-C_{30} linear or branched alkoxyl, C_6-C_{20} aryl, C_1-C_{20} linear or branched alkyl C_6-C_{20} aryl (preferably each independently selected from H, C_1-C_{10} linear or branched alkyl, C_1-C_{10} linear or branched alkoxyl, C_6-C_{10} aryl, C_1-C_{14} alkyl phenyl); groups R_1, R_2, R_3, R_4 and R_5 are, identical to or different from each other, each independently selected from H, C_1-C_{20} linear or branched alkyl, C_1-C_{20} linear or branched alkoxyl and a group represented by the formula (II-III), at least one group of groups R_1, R_2, R_3, R_4 and R_5 is a group represented by the formula (II-III);

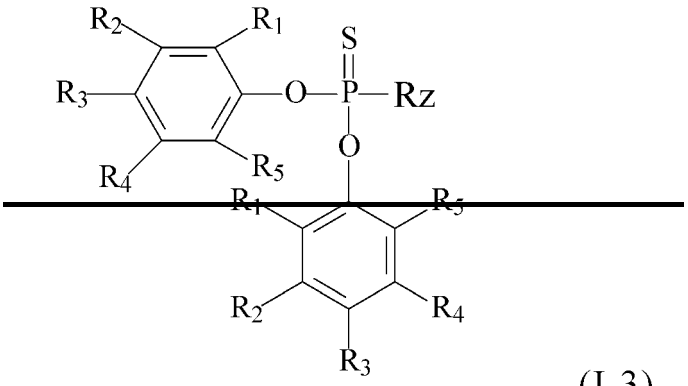


(II-III)

In the general formula (II-III), group R_1' is selected from single bond, C_1-C_{20} linear or branched alkylene (preferably selected from single bond and C_1-C_4 linear or branched alkylene); groups R_2' in n repeating units are, identical to or different from each other, each independently selected from divalent, tervalent or tetravalent C_1-C_{20} linear or branched alkyl (preferably each independently selected from divalent, tervalent or tetravalent C_1-C_4 linear or branched alkyl); groups R_3' in n repeating units are, identical to or different from each other, each independently selected from single bond, divalent or tervalent C_1-C_{20} linear or branched alkyl (preferably each independently selected from single bond, divalent or tervalent C_1-C_4 linear or branched alkyl); groups R_4' in n repeating units are, identical to or different from each other, each independently selected from single bond, divalent or tervalent C_1-C_{20} linear or branched alkyl (preferably each independently selected from single bond, divalent or tervalent C_1-C_4 linear or branched alkyl); groups R_5' in n repeating units are, identical to or different from each other, each independently selected from divalent, tervalent or tetravalent C_1-C_{20} linear or branched

alkyl (preferably each independently selected from divalent, tervalent or tetravalent C_1-C_4 linear or branched alkyl); groups R_6' in n repeating units are, identical to or different from each other, each independently selected from single bond, C_1-C_{20} linear or branched alkylene (preferably each independently selected from single bond, C_1-C_4 linear or branched alkylene); group R_7' is selected from hydrogen, C_1-C_{20} linear or branched alkyl (preferably selected from hydrogen, C_1-C_4 linear or branched alkyl); n is an integral number of 1-10 (preferably an integral number of 1-3); the numbers m in n repeating units are, identical to or different from each other, each independently selected from an integral number of 0-10 (preferably an integral number of 0-5); the numbers m' in n repeating units are, identical to or different from each other, each independently selected from an integral number of 0-10 (preferably an integral number of 0-5); in each repeating unit of the formula (II-III), when m is greater than 0, m sulfur atoms are bonded to groups R_2' and R_5'; when m' is greater than 0, m' sulfur atoms are bonded to groups R_3' and R_4'; in each repeating unit of the formula (II-III), when group R_3' is a single bond, m' sulfur atoms are bonded to group R_2', when group R_4' is a single bond, m' sulfur atoms are bonded to group R_5'.

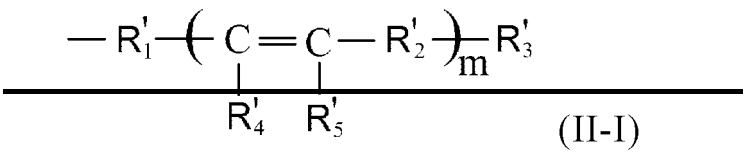
~~31. The organophosphorus compound according to claim 1, which has a structure as represented by the general formula (I-3):~~



(I-3)

~~In the general formula (I-3), group R_Z is selected from H, C_1-C_{30} linear or branched alkyl, C_1-C_{30} linear or branched alkoxyl, C_6-C_{20} aryl, C_1-C_{20} linear or branched alkyl C_6-C_{20} aryl (preferably each independently selected from H, C_1-C_{10} linear or branched alkyl, C_1-C_{10} linear or branched alkoxyl, C_6-C_{10} aryl, C_1-C_{14} alkyl phenyl); groups R_1, R_2, R_3, R_4 and R_5 are, identical to or different from each other, each independently selected from H, C_1-C_{20} linear or branched alkyl, C_1-C_{20} linear or branched alkoxyl and a group represented by the formula (II-I), at least one group of groups R_1, R_2, R_3, R_4 and R_5 is a group represented by the formula (II-~~

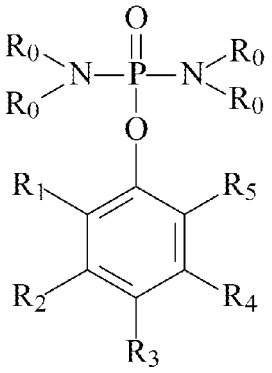
~~I);~~



(II-I)

~~In the general formula (II-I), group R_1' is selected from single bond, C_1-C_{20} linear or branched alkylene (preferably selected from single bond and C_1-C_4 linear or branched alkylene); groups R_2' in m repeating units are, identical to or different from each other, each independently selected from single bond, C_1-C_{20} linear or branched alkylene (preferably each independently selected from single bond, C_1-C_4 linear or branched alkylene); group R_3' is selected from hydrogen, C_1-C_{20} linear or branched alkyl (preferably selected from hydrogen, C_1-C_4 linear or branched alkyl); groups R_4' in m repeating units are, identical to or different from each other, each independently selected from hydrogen, C_1-C_{20} linear or branched alkyl (preferably each independently selected from hydrogen, C_1-C_4 linear or branched alkyl); groups R_5' in m repeating units are, identical to or different from each other, each independently selected from hydrogen, C_1-C_{20} linear or branched alkyl (preferably each independently selected from hydrogen, C_1-C_4 linear or branched alkyl); m is an integral number (preferably an integral number of 0-10, more preferably a positive integral number of 1-3).~~

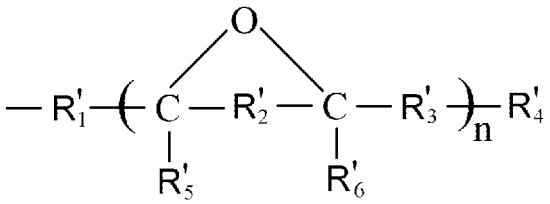
~~32~~23. ~~The~~ An organophosphorus compound ~~according to claim 1~~, which has a structure as represented by the general formula (I-4):



(I-4)

In the general formula (I-4), groups R_0 are each independently selected from H, C_6-C_{20} aryl, C_1-C_{20} linear or branched alkyl C_6-C_{20} aryl and C_1-C_{30} linear or branched alkyl (preferably each independently selected from phenyl, C_1-C_{14} alkyl phenyl and C_1-C_{20} linear or branched alkyl); groups R_1, R_2, R_3, R_4 and R_5 are, identical to or different from each other, each

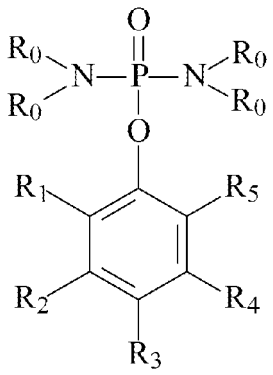
independently selected from H, C_1-C_{20} linear chain, C_1-C_{20} linear or branched alkoxyl or branched alkyl and a group represented by the formula (II-II), at least one group of groups R_1, R_2, R_3, R_4 and R_5 is a group represented by the formula (II-II);



(II-II)

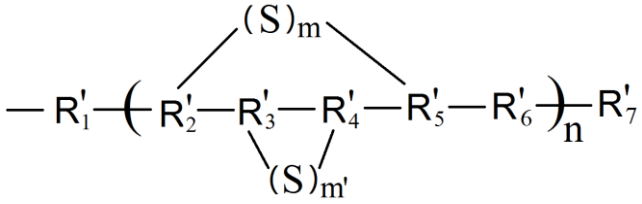
In the general formula (II-II), group R_1' is selected from single bond, C_1-C_{20} linear or branched alkylene (preferably selected from single bond and C_1-C_4 linear or branched alkylene); groups R_2' in n repeating units are, identical to or different from each other, each independently selected from single bond, C_1-C_{20} linear or branched alkylene (preferably each independently selected from single bond, C_1-C_4 linear or branched alkylene); groups R_3' in n repeating units are, identical to or different from each other, each independently selected from single bond, C_1-C_{20} linear or branched alkylene (preferably each independently selected from single bond, C_1-C_4 linear or branched alkylene); group R_4' is selected from hydrogen, C_1-C_{20} linear or branched alkyl (preferably selected from hydrogen, C_1-C_4 linear or branched alkyl); groups R_5' in n repeating units are, identical to or different from each other, each independently selected from hydrogen, C_1-C_{20} linear or branched alkyl (preferably each independently selected from hydrogen, C_1-C_4 linear or branched alkyl); groups R_6' in n repeating units are, identical to or different from each other, each independently selected from hydrogen, C_1-C_{20} linear or branched alkyl (preferably each independently selected from hydrogen, C_1-C_4 linear or branched alkyl); n is a positive integral number (preferably a positive integral number of 1-10, preferably a positive integral number of 1-3).

~~33~~24. ~~The~~ An organophosphorus compound ~~according to claim 1~~, which has a structure as represented by the general formula (I-5):



(I-5)

In the general formula (I-5), groups R_0 are each independently selected from H, C_6-C_{20} aryl, C_1-C_{20} linear or branched alkyl C_6-C_{20} aryl and C_1-C_{30} linear or branched alkyl (preferably each independently selected from phenyl, C_1-C_{14} alkyl phenyl and C_1-C_{20} linear or branched alkyl); groups R_1, R_2, R_3, R_4 and R_5 are, identical to or different from each other, each independently selected from H, C_1-C_{20} linear or branched alkyl, C_1-C_{20} linear or branched alkoxyl and a group represented by the formula (II-III), at least one group of groups R_1, R_2, R_3, R_4 and R_5 is a group represented by the formula (II-III);

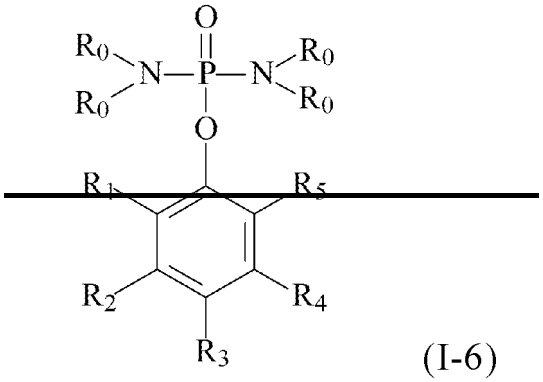


(II-III)

In the general formula (II-III), group R_1' is selected from single bond, C_1-C_{20} linear or branched alkylene (preferably selected from single bond and C_1-C_4 linear or branched alkylene); groups R_2' in n repeating units are, identical to or different from each other, each independently selected from divalent, tervalent or tetravalent C_1-C_{20} linear or branched alkyl (preferably each independently selected from divalent, tervalent or tetravalent C_1-C_4 linear or branched alkyl); groups R_3' in n repeating units are, identical to or different from each other, each independently selected from single bond, divalent or tervalent C_1-C_{20} linear or branched alkyl (preferably each independently selected from single bond, divalent or tervalent C_1-C_4 linear or branched alkyl); groups R_4' in n repeating units are, identical to or different from each other, each independently selected from single bond, divalent or tervalent C_1-C_{20} linear or branched alkyl (preferably each independently selected from single bond, divalent or tervalent C_1-C_4 linear or branched alkyl); groups R_5' in n repeating units are, identical to or different from each other, each independently selected from divalent, tervalent or tetravalent C_1-C_{20} linear or branched alkyl (preferably each independently selected from divalent, tervalent or tetravalent C_1-C_4

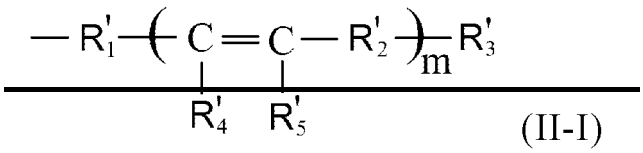
linear or branched alkyl); groups R_6' in n repeating units are, identical to or different from each other, each independently selected from single bond, C_1-C_{20} linear or branched alkylene (preferably each independently selected from single bond, C_1-C_4 linear or branched alkylene); group R_7' is selected from hydrogen, C_1-C_{20} linear or branched alkyl (preferably selected from hydrogen, C_1-C_4 linear or branched alkyl); n is an integral number of 1-10 (preferably an integral number of 1-3); the numbers m in n repeating units are, identical to or different from each other, each independently selected from an integral number of 0-10 (preferably an integral number of 1-5); the numbers m' in n repeating units are, identical to or different from each other, each independently selected from an integral number of 0-10 (preferably an integral number of 0-5); in each repeating unit of the formula (II-III), when m is greater than 0, m sulfur atoms are bonded to groups R_2' and R_5'; when m' is greater than 0, m' sulfur atoms are bonded to groups R_3' and R_4'; in each repeating unit of the formula (II-III), when group R_3' is a single bond, m' sulfur atoms are bonded to group R_2', when group R_4' is a single bond, m' sulfur atoms are bonded to group R_5'.

~~34. The organophosphorus compound according to claim 1, which has a structure as represented by the general formula (I-6):~~



(I-6)

~~In the general formula (I-6), groups R_0 are each independently selected from H, C_6-C_{20} aryl, C_1-C_{20} linear or branched alkyl C_6-C_{20} aryl and C_1-C_{30} linear or branched alkyl (preferably each independently selected from phenyl, C_1-C_{14} alkyl phenyl and C_1-C_{20} linear or branched alkyl); groups R_1, R_2, R_3, R_4 and R_5 are, identical to or different from each other, each independently selected from H, C_1-C_{20} linear or branched alkyl, C_1-C_{20} linear or branched alkoxyl and a group represented by the formula (II-I), at least one group of groups R_1, R_2, R_3, R_4 and R_5 is a group represented by the formula (II-I);~~



(II-I)

In the general formula (II-I), group R_1' is selected from single bond, C_1-C_{20} linear or branched alkylene (preferably selected from single bond and C_1-C_4 linear or branched alkylene); groups R_2' in m repeating units are, identical to or different from each other, each independently selected from single bond, C_1-C_{20} linear or branched alkylene (preferably each independently selected from single bond, C_1-C_4 linear or branched alkylene); group R_3' is selected from hydrogen, C_1-C_{20} linear or branched alkyl (preferably selected from hydrogen, C_1-C_4 linear or branched alkyl); groups R_4' in m repeating units are, identical to or different from each other, each independently selected from hydrogen, C_1-C_{20} linear or branched alkyl (preferably each independently selected from hydrogen, C_1-C_4 linear or branched alkyl); groups R_5' in m repeating units are, identical to or different from each other, each independently selected from hydrogen, C_1-C_{20} linear or branched alkyl (preferably each independently selected from hydrogen, C_1-C_4 linear or branched alkyl); m is an integral number (preferably an integral number of 0-10, more preferably a positive integral number of 1-3).

25. An organophosphorus compound prepared by the process according to any one of claims 1-20.

~~35~~26. A composition, which contains the organophosphorus compound according to any one of claims ~~1-5 and 29~~21-~~34~~24 or the organophosphorus compound prepared with the preparation process according to any one of claims ~~6~~1-~~28~~20.

~~36~~27. A lubricating oil, which contains a base oil and the organophosphorus compound according to any one of claims ~~1-5 and 29~~21-~~34~~24 or the organophosphorus compound prepared with the preparation process according to any one of claims ~~6~~1-~~28~~20.

~~37~~28. A lubricating grease, which contains a base oil and the organophosphorus compound according to any one of claims ~~1-5 and 29~~21-~~34~~24 or the organophosphorus compound prepared with the preparation process according to any one of claims ~~6~~1-~~28~~20.

~~38~~29. Use of the organophosphorus compound according to any one of claims ~~1-5 and 29~~21-~~34~~24 or the organophosphorus compound prepared with the preparation process according to any one of claims ~~6~~1-~~28~~20 as an extreme pressure antiwear additive, preferably as an extreme pressure antiwear additive for lubricating oil/lubricating grease.