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DESCRIPTION

[0001] The invention relates to a process for the preparation of a triaryl phosphate ester composition.

[0002] Triaryl phosphate esters, in particular alkylated triaryl phosphate esters such as tert-butylphenyl phenyl phosphate esters, are often used as plasticizers or as flame retardants, for example in vinyl chloride polymers, polyolefins, cellulose esters, polyurethane foams, styrenic polymers, and other synthetic polymers. Triaryl phosphate esters are also used in fluids, for example for ignition control in hydraulic fluids or fuels, and as extreme pressure additives in lubricants. Triaryl phosphate esters are suitable for these applications due to their high resistivity to oxidative, thermal, and hydrolytic degradation. For the flame retardant properties of triaryl phosphate esters, a high phosphorous content is important.

[0003] Typically, triaryl phosphate esters also contain triphenyl phosphate (TPP). In fact, today's commercially available aryl phosphate ester products typically contain 30 to 45 wt.% triphenyl phosphate ester. TPP possesses a substantial toxicological and ecotoxicological potential and has therefore recently been classified as an environmental hazardous substance (UN 3082) as well as a marine pollutant. Besides, TPP is known to be a mild cholinesterase inhibitor. Analytical results show a statistically significant reduction in red blood cell cholinesterase activity in rats (Bingham, E.; Cohrssen, B.; Powell, C.H.; Patty's Toxicology Volumes 1-9, 5th ed., John Wiley & Sons New York, NY (2001), V6, p. 967). Therefore, triaryl phosphate esters with reduced TPP content are desirable.

[0004] Moreover, the physical properties of the triaryl phosphate esters are determined by the degree of alkylation of the aryl groups and the number of alkylated aryl groups in the triaryl phosphate ester or the phosphate ester composition. For example, a highly substituted triaryl phosphate ester, such as one with two or three alkylated aryl groups and/or more than one alkyl substituent per aryl group, is more viscous than a less substituted triaryl phosphate ester. Further, an increasing alkylation degree of the aryl groups decreases the phosphorous content of the product mixture, resulting in poorer flame retardant properties. JP 2013023580 A discloses a process for the preparation of a triaryl phosphate ester composition used for lubricating oils.

[0005] Triaryl phosphate esters can be formed by a number of methods commonly used in the art. US 2 275 041 describes the preparation of a mixed aromatic triaryl phosphate ester by reacting a phenol substituted with an allyl-type group with an aromatic phosphoric acid halide such as diphenyl phosphoric acid monochloride. However, the preparation of such defined triaryl phosphate ester compounds requires the use of expensive reagents and/or purification steps.

[0006] Other approaches aim at the preparation of mixtures of triaryl phosphate esters. In these approaches, phenol is alkylated with alkenes such as propylene or isobutylene to obtain a mixture of phenol and substituted phenols in a first step. According to US 4 093 680, this mixture of alkylated phenols is then reacted in a second step with phosphorous oxychloride to form a mixed triaryl phosphate ester. The product mix is a statistical mixture based on the composition of the starting alkylated phenol mixture and always includes some fraction of triphenyl phosphate, usually from 5 to 50 wt.%. A typical composition of a tert-butylphenyl phenyl phosphate ester composition contains

1 to 3 wt.% tris(tert-butylphenyl)phosphate, 12 to 18 wt.% bis(tert-butylphenyl)phenyl phosphate, 40 to 46 wt.% tert-butylphenyl diphenyl phosphate, and 30 to 45 wt.% TPP. Such high TPP contents are, however, undesirable for the above-mentioned reasons.

[0007] Attempts to reduce the amount of TPP in triaryl phosphate ester compositions have been undertaken. However, when attempting to decrease the levels of TPP in the triaryl phosphate ester composition by fractional distillation, the resulting products show discoloration and increased acidity levels, as described in US 5 206 404, which indicates partial degradation of the products.

[0008] US 5 206 404 describes an additional workup step of the crude reaction mixture by thin film evaporation at a temperature from 200 °C to 250 °C and a pressure of less than 5 kPa, such that 5 to 30% of the composition to be purified are evaporated as vapor. The resulting composition contains a high concentration of trialkylphenyl phosphate esters and dialkylphenyl phosphate esters. This, however, reduces the phosphorous content of the product mixture and increases the viscosity as described above.

[0009] US 6 242 631 describes two alternatives for the preparation of a mixed triaryl phosphate ester composition. In the first alternative, phosphorous oxychloride (POCl_3) is reacted with a high purity alkylated phenol in a quantity sufficient to exhaust at least one functionality of the POCl_3 followed by reaction with phenol. According to the examples, a slight excess of less than 0.1 equivalents of the alkylated phenol is used in the reaction with the POCl_3 . The resulting phosphate ester compositions contain 3.2 to 4.4 wt.% TPP, respectively, according to the examples and are obtained in yields of at most 94%. In the second alternative, diphenyl monochlorophosphate or a mixture of diphenyl monochlorophosphate and phenyl dichlorophosphate are reacted with a high purity alkylated phenol. While the second alternative can provide for compositions that are substantially free from TPP, the required phosphorous reagents, especially the phenylchlorophosphates are expensive and difficult to source in amounts of industrial scale.

[0010] US 2012/0004438 A1 also describes two alternatives for the preparation of triaryl phosphate ester compositions. In the first alternative, an excess of up to 100% of POCl_3 is reacted with an alkylated phenol, followed by distillation of the unreacted POCl_3 and subsequent reaction of the first reaction product with an alcohol such as an aryl alcohol. In the second alternative, an excess of an alkylated phenol is reacted with POCl_3 followed by reaction with another alcohol, preferably phenol. Additional refinement of the phosphate ester composition is optional and includes distillation as an alternative. According to the examples, multiple washing steps, including use of additional solvents (i.e. toluene), generating problematic waste streams, followed by an evaporation step and a flash distillation step are conducted in the second alternative. All operations decrease the yield to only 93% and increase the overall cost of the process.

[0011] The processes described so far all have drawbacks such as a high TPP content in the final product mixture, the use of expensive reagents or solvents, low overall yields, a low phosphorous content in the product mixture, and/or distillation and/or evaporation steps during the phosphorylation process and/or in the work-up.

[0012] Therefore, it was an object of the invention, to provide a process that yields a triaryl

phosphate ester composition with a low TPP content, in particular with a TPP content of 0.5 wt.% or less, based on the total weight of the triaryl phosphate ester composition, and/or with a high overall yield. It was another object of the invention to provide a process that relies on common starting materials, which are easily accessible on the market. It was another object of the invention to provide a process that yields a composition with a high phosphorous content. It was another object of the invention to provide a process with a reduced amount of waste streams and/or a reduced number of distillation and/or evaporation steps.

[0013] Some or all of these objects can be achieved by using the present invention. In particular, some or all of these objects can be achieved by the process of claim 1, the composition of claim 19, and the use of claim 20.

[0014] Further embodiments are described in the dependent claims and will be discussed in the following.

[0015] The invention provides for a process for the preparation of a triaryl phosphate ester composition comprising

1. a. reacting a phosphorous oxyhalide with a (C₁-C₁₅-alkyl)phenol to obtain a first product;
2. b. reacting the first product with phenol to obtain a triaryl phosphate ester composition;

wherein in step a., for every mol of phosphorous oxyhalide 1.3 to 1.6 mols of (C₁-C₁₅-alkyl)phenol are used, wherein the amount of phenol required in step b. is determined by analyzing the contents of the reaction mixture.

[0016] Surprisingly, it has been found that as a result of using 1.3 to 1.6 mols of (C₁-C₁₅-alkyl)phenol for every mol of phosphorous oxyhalide, a process was obtained that provides a triaryl phosphate ester composition in very good overall yields, in particular in yields above 95%, with a low TPP content and/or a low tris(alkylphenyl) phosphate ester content, in particular with a TPP content of 0.5 wt.% or less and/or a tris(alkylphenyl) phosphate ester content of 3 wt.% or less, in each case based on the total weight of the triaryl phosphate ester composition. Particularly, with the process according to the invention, common starting materials can be used and/or the number of evaporation and/or distillation steps can be reduced. Moreover, the use of solvents can be reduced.

[0017] Without wishing to be bound by a scientific theory, it appears that the use of 1.3 to 1.6 mols of (C₁-C₁₅-alkyl)phenol for every mol of phosphorous oxyhalide aids in achieving very good overall yields as well as in suppressing the formation of TPP. Surprisingly, it was also found that the resulting triaryl phosphate ester compositions had a good phosphorous content despite the use of up to 1.6 mols of (C₁-C₁₅-alkyl)phenol for every mol of phosphorous oxyhalide in the reaction. This was unexpected, since one would expect low phosphorous contents of the compositions due to the use of the excess of the (C₁-C₁₅-alkyl)phenol.

[0018] Phosphorous oxyhalides are also known as phosphoryl trihalides. Examples for phosphorous oxyhalides or phosphoryl trihalides are phosphorous oxychloride (phosphoryl trichloride, POCl₃), phosphorous oxybromide (phosphoryl tribromide, POBr₃), and phosphorous oxyiodide (phosphoryl triiodide, POI₃).

[0019] The steps a. and b. of the present invention may be catalyzed to accelerate the reaction. As catalysts, different compounds can be used. Preferably, steps a. and b. of the invention are catalyzed by a Lewis acid. Non-limiting examples of Lewis acids include aluminum halides, sodium halides, potassium halides, lithium halides, magnesium halides, calcium halides, iron halides, zinc halides, titanium halides, and antimony halides. Preferred Lewis acids include AlCl_3 , NaCl , KCl , LiCl , MgCl_2 , CaCl_2 , FeCl_3 , ZnCl_2 , TiCl_4 , and SbCl_5 . According to a preferred embodiment, steps a. and b. of the invention are catalyzed by a magnesium halide, preferably MgCl_2 . Mixtures of Lewis acids may also be used. It was discovered that these catalysts are particularly effective at accelerating the reaction. Moreover, these catalysts, in particular MgCl_2 , are inexpensive.

[0020] If a Lewis acid is used to catalyze steps a. and b. of the invention, it can be added as such or it can be prepared in situ. In particular, the Lewis acid can be added to the reaction vessel or be prepared in the reaction vessel before step a. According to an embodiment of the invention, the Lewis acid, in particular MgCl_2 , and the $(\text{C}_1\text{-C}_{15}\text{-alkyl})\text{phenol}$ are put into the reaction vessel first in a step before step a. In this embodiment, the Lewis acid can be put in first or the $(\text{C}_1\text{-C}_{15}\text{-alkyl})\text{phenol}$ can be put in first, which simplifies the handling significantly. According to another embodiment, a Lewis acid precursor, in particular magnesium, and the $(\text{C}_1\text{-C}_{15}\text{-alkyl})\text{phenol}$ are put into the reaction vessel first in a step before step a. Thereby, the Lewis acid can be formed in situ when adding the phosphorous oxyhalide. In this embodiment, the Lewis acid precursor can be added to the $(\text{C}_1\text{-C}_{15}\text{-alkyl})\text{phenol}$ or the $(\text{C}_1\text{-C}_{15}\text{-alkyl})\text{phenol}$ can be added to the Lewis acid precursor. Preferably, the Lewis acid precursor is added to the $(\text{C}_1\text{-C}_{15}\text{-alkyl})\text{phenol}$. According to a preferred embodiment, the magnesium halide is prepared by heating the reaction mixture, comprising magnesium and the $(\text{C}_1\text{-C}_{15}\text{-alkyl})\text{phenol}$ in the presence of an initial portion of phosphorous oxyhalide in a step prior to step a. This allows for an economic process.

[0021] The catalyst is preferably used in an amount of 0.001 to 0.1 mol%, more preferably 0.005 to 0.05 mol%, even more preferably 0.008 to 0.015 mol%, in each case based on the amount of phosphorous oxyhalide used. Removal of these amounts of the catalyst has been found to be simple.

[0022] As mentioned above, different phosphorous oxyhalides are known. Preferably, in the process according to the invention, the phosphorous oxyhalide is phosphorous oxychloride (POCl_3). This allows for an economic process.

[0023] In the process according to the invention, a $(\text{C}_1\text{-C}_{15}\text{-alkyl})\text{phenol}$ is reacted with a phosphorous oxyhalide to yield a first product. Advantageously, the $(\text{C}_1\text{-C}_{15}\text{-alkyl})\text{phenol}$ is a phenol substituted with a single $\text{C}_1\text{-C}_{15}$ alkyl group. The $\text{C}_1\text{-C}_{15}$ alkyl group of the $(\text{C}_1\text{-C}_{15}\text{-alkyl})\text{phenol}$ may be in ortho-position, meta-position, or para-position of the phenol ring. Preferably, the $\text{C}_1\text{-C}_{15}$ alkyl group of the $(\text{C}_1\text{-C}_{15}\text{-alkyl})\text{phenol}$ is in para-position of the phenol ring. Advantageously, the $\text{C}_1\text{-C}_{15}$ alkyl group of the $(\text{C}_1\text{-C}_{15}\text{-alkyl})\text{phenol}$ is a $\text{C}_1\text{-C}_{10}$ -alkyl group, more preferably a $\text{C}_1\text{-C}_7$ -alkyl group, more preferably a $\text{C}_1\text{-C}_5$ -alkyl group. More preferably the $\text{C}_1\text{-C}_{15}$ alkyl group of the $(\text{C}_1\text{-C}_{15}\text{-alkyl})\text{phenol}$ is selected from the group consisting of methyl-, ethyl-, propyl-, n-propyl-, iso-propyl-, butyl-, n-butyl-, iso-butyl-, tert-butyl-, pentyl-, n-pentyl-, tert-pentyl-, neopentyl-, isopentyl-, 1-

methylbutyl-, and 1-ethylpropyl. According to a preferred embodiment, the (C₁-C₁₅-alkyl)phenol is tert-butylphenol, in particular p-tert-butylphenol. It was discovered that with these (C₁-C₁₅-alkyl)phenols, in particular with p-tert-butylphenol, triaryl phosphate ester compositions with particularly good properties, in particular concerning their viscosities, can be obtained in an economical fashion.

[0024] In the process according to the invention, the reactants can be added in different order and/or fashion. For example for the reaction of step a., the reactants can be added in one portion or in smaller portions, for example dropwise. Further, the addition can be conducted at different temperatures, for example at room temperature or at higher temperatures such as from 75 to 105 °C. Preferably, the addition is conducted at 75 to 105 °C. Moreover, the phosphorous oxychloride can be added to the (C₁-C₁₅-alkyl)phenol or the (C₁-C₁₅-alkyl)phenol can be added to the phosphorous oxychloride. For the reaction of step a., the phosphorous oxychloride is preferably added dropwise to a mixture of the (C₁-C₁₅-alkyl)phenol and the catalyst at 75 to 105 °C, preferably at 85 to 95 °C. This allows for a good reaction control.

[0025] The amount of phenol required for a complete exhaustion of the halide functionalities of the phosphorous oxyhalide in step b. can be determined by calculating the stoichiometric amount based on the amount of (C₁-C₁₅-alkyl)phenol used in step a. According to a preferred embodiment of the invention, the amount of phenol required in step b. is determined by analyzing the chloride anion concentration of the reaction mixture. Different methods are known to the skilled person for analyzing the chloride anion concentration of a solution. For example, the chloride anion concentration of a solution can be analyzed using Mohr's method, in particular by titrating the solution in the presence of a chromate indicator with a silver nitrate solution of known concentration. According to the invention, the contents of the reaction mixture, in particular the chloride anion concentration in the reaction mixture, are preferably analyzed and/or determined after a first amount of phenol was added to the first reaction product. Preferably the first amount of phenol is a partial amount of the stoichiometric amount required for a complete exhaustion of the halide functionalities of the phosphorous oxyhalide and calculated based on the amount of (C₁-C₁₅-alkyl)phenol used in step a. It has been found that during step a., a part of the phosphorous oxyhalide may be carried away from the reaction mixture without having reacted together with the evolving hydrogen halide. For this reason, a substoichiometric amount of phenol may be sufficient in step b. By determining the chloride anion concentration, the amount of phenol required in step b. can be very precisely determined, which helps to reduce the amount of TPP formed and also to render the process more economic.

[0026] Step a. of the present invention can be conducted at different temperatures. Preferably, step a. is conducted at 90 to 145 °C, more preferably at 100 to 140 °C. This allows for a fast reaction.

[0027] The phenol can be added at different temperatures to the first reaction product. Preferably, phenol is added at 80 to 120 °C, more preferably at 90 to 110 °C. This may require cooling of the reaction mixture after step a. Preferably, the reaction mixture is cooled to 90 to 110 °C after step a. This allows for a better reaction control and may help to avoid side product formation.

[0028] Step b. of the present invention can be conducted at different temperatures. Preferably, step

b. is conducted at 120 to 180 °C, more preferably at 130 to 170 °C. This allows to achieve high overall yields without significant side product formation.

[0029] In order to ensure complete conversion in the steps of the process according to the invention, the reactions of the individual steps are conducted for a certain time. Advantageously, the reaction in step a. of the process of the invention is conducted for 0.5 to 7 hours, in particular 0.5 to 4 hours. This helps to achieve low TPP contents. Preferably the reaction in step b. of the process of the invention is conducted for 8 to 13 hours. This allows to achieve high overall yields.

[0030] The first reaction product of step a. can be used directly in step b. or it can be isolated, for example in combination with a workup and/or a purification step. Preferably, the first product of step a. is used without workup and/or purification in step b. This allows for an economic process and helps to reduce the amount of waste streams.

[0031] The triaryl phosphate ester composition obtained after step b. may be used as such or may be further refined, for example to remove undesired compounds, for example unreacted phenol and/or unreacted phenol derivatives. Undesired compounds may be removed by phase separation, stripping, such as steam stripping, and/or distillation. Further refinement of the triaryl phosphate ester composition may include contacting with an ion exchange resin, washing one or more times with an acid, a base, and/or water, pH adjustment, and/or evaporation steps such as passage through a wipe film evaporator.

[0032] According to an embodiment of the invention, the triaryl phosphate ester composition obtained after step b. is contacted with an ion exchange resin, preferably with a cationic exchange resin. In this step, demineralized water may be added to the phosphate ester composition in a weight ratio of water:phosphate ester composition of from 1:1 to 1:3, preferably 1:2.

[0033] According to another embodiment of the invention, the pH of the triaryl phosphate ester composition is adjusted to 8 to 10, in particular to 8.5 to 9, after it was contacted with the ion exchange resin. In this step, demineralized water may be added to the phosphate ester composition in a weight ratio of water:phosphate ester composition of from 1:1 to 1:3, preferably 1:2. The pH is preferably adjusted using a base, for example an alkali metal hydroxide. Preferably, the process according to the invention comprises only one pH adjustment step.

[0034] Additionally, the triaryl phosphate ester composition obtained after step b. may be subjected to an aqueous workup. In this aqueous workup step, demineralized water may be added to the phosphate ester composition in a weight ratio of water:phosphate ester composition of from 1:1 to 1:3, preferably 1:2. Phase separation may be conducted at a temperature from 40 to 80 °C, preferably from 50 to 70 °C. Preferably, the process according to the invention comprises only one aqueous workup step.

[0035] According to another embodiment of the invention, the triaryl phosphate ester composition obtained after step b. is subjected to an evaporation step in order to remove unreacted phenol and/or unreacted phenol derivatives. The evaporation step may be conducted as the last refinement step or earlier.

[0036] According to a preferred embodiment of the invention, the triaryl phosphate ester composition obtained after step b. is contacted with water at most three times before a final evaporation step.

[0037] According to another embodiment of the invention, the process according to the invention is conducted entirely solvent-free.

[0038] The invention also relates to a triaryl phosphate ester composition obtainable by a process according to the invention. In particular, the triaryl phosphate ester compositions obtainable according to the invention may contain 50 to 65 wt.% monoalkylphenyl diphenyl phosphate ester and 35 to 50 wt.% bis(alkylphenyl) phenyl phosphate ester, in each case based on the total weight of the triaryl phosphate ester composition. At the same time, the amount of tris(alkylphenyl) phosphate ester may be from 0.5 to 2 wt.%, based on the total weight of the triaryl phosphate ester composition.

[0039] The triaryl phosphate ester compositions according to the invention are useful in different applications. The invention also relates to the use of the triaryl phosphate ester compositions according to the invention as flame retardants in polymers, as extreme pressure additives in lubricants, and/or in functional fluids.

[0040] In the following, the invention shall be further explained by examples that are illustrative only and not to be construed as limiting in any way.

Materials:

[0041] Phosphorous oxychloride, POCl_3 (CAS: 10025-87-3, PCC Rokita S.A., purity >99.7%); p-tert-butylphenol, BP (CAS: 98-54-4, Sigma-Aldrich, purity 99%); phenol (CAS: 108-95-2, PKN Orlen S.A., purity >99.9%); magnesium chloride, MgCl_2 (CAS: 7786-30-3, Sigma-Aldrich, purity >95%); sodium hydroxide, NaOH (CAS: 1310-73-2, PCC Rokita S.A., 30% solution in water); cationic exchange resin (CAS: 69011-20-7, Purolite, Purolite C100MBH, 35-65%).

General procedures:

[0042]

Table 1: Procedures used to determine the density, dynamic viscosity, acid value and chloride anion concentration.

Density [g/cm^3] 25°C	PN-C-82057:2000
Dynamic viscosity [mPas] 25°C	PN-EN ISO 12058-1:2005
Acid value [mgKOH/g]	PN-EN ISO 2114:2005
	PN-81/C-06501
Mohr method to determine the chloride anion concentration [mgCl ⁻ /g]	PN-ISO 9297:1994

General workup procedure:

[0043] The general workup procedure consisted of the following three steps.

1. 1. Demineralization:

The raw product was stirred at 35 °C for 1 hour with 2 to 5 wt.%, based on the total weight of the raw product, of a cationic exchange resin and demineralized water at a weight ratio of water:raw product = 1:2. The cation exchange resin was filtered off at 60°C, and the remaining mixture was left for 0.5 hours to complete phase separation. The aqueous phase was discarded and the organic phase was kept.

2. 2. Neutralization:

The organic phase from step 1 was mixed anew with demineralized water at a weight ratio of water:raw product = 1:2 at 35 °C, and the pH of the mixture was adjusted with a 10% aqueous NaOH solution to 8.5 to 9.0. Then the temperature of the mixture was increased to 60 °C and left for 0.5 to 2.0 hours to complete the phase separation. The aqueous phase was discarded and the organic phase was kept.

3. 3. Aqueous workup:

The organic phase from step 2 was mixed anew with demineralized water at a weight ratio of water:raw product = 1:2, and the temperature of the mixture was increased to 60 °C. The mixture was left for 0.5 to 2.0 hours to complete the phase separation. Then, residual water and excess phenol were distilled off from the organic phase at 10 to 80 mbar at a temperature between 130 to 170 °C.

General procedure A:

[0044] BP and catalyst were mixed together in a 1L glass reactor, equipped with a mechanic stirrer, a nitrogen inlet tube, a thermometer, a reflux condenser with a gas outlet and a bubble counter under exclusion of air and moisture. POCl₃ was added dropwise over a period of 1.5 to 2.0 hours while the temperature was decreased constantly from initial 98°C to 88 °C. The temperature was increased to 115 °C over a period of 1.5 hours and then to 130 °C over a period of 0.5 hours. During these operations approximately 2.0-2.5% of the POCl₃ evaporates together with the HCl stream and can be detected in the gas washing liquid. Then the reaction mixture was cooled to 100 °C, phenol was added in one portion and then slowly heated again to 155 °C and kept at this temperature for 7.5 hours. After cooling of the mixture to 35 °C, the raw product was subjected to the general workup procedure.

General procedure B:

[0045] BP and catalyst were mixed together in a 1L glass reactor under exclusion of air and

moisture, equipped with a mechanic stirrer, a nitrogen inlet tube, a thermometer and a reflux condenser with a gas outlet and a bubble counter connected to a gas washing flask filled with 1L of water. HCl evolution starts immediately when adding POCl_3 dropwise over a period of 1.5 to 2.0 hours while the temperature was decreased constantly from initial 98°C to 88°C . The temperature was increased to 115°C over a period of 1.5 hours and then to 130°C over a period of 0.5 hours. During these operations approximately 2.0-2.5% of the POCl_3 evaporates together with the HCl stream and can be detected in the gas washing liquid. Then the reaction mixture was cooled to 100°C , 80 to 85% of the calculated amount of phenol was added in one portion and the resulting mixture was heated slowly to 155°C and kept at this temperature for 5.5 hours. Then, the reaction mixture was cooled again to 100°C , and after the chloride anion concentration in the reaction mixture was determined by titration of a sample of the reaction mixture using the Mohr method, the required amount of phenol for a complete exhaustion of the chloride functionalities of the POCl_3 was added in one portion. The resulting mixture was heated to 155°C and kept at this temperature for 4.5 hours. After cooling the mixture to 35°C , the raw product was subjected to the general workup procedure.

Example 1 (comparative):

[0046] BP (237.35 g, 1.58 mol) and MgCl_2 (1.9 g, 20 mmol) were mixed under exclusion of air and moisture in a 1L glass reactor, equipped with a mechanic stirrer, a nitrogen inlet tube, a thermometer and a reflux condenser with a gas outlet and a bubble counter, connected to a gas washing flask filled with 1L of water. After heating the reaction mixture to 105°C , a portion of POCl_3 (30.666 g, 0.2 mol) was added quickly and HCL evolution started immediately. The reaction mixture was stirred for another 10 minutes and then cooled down to 95°C . Another portion of POCl_3 (275.994 g, 1.8 mol) was added dropwise over a period of 2.5 hours while maintaining the temperature at 95°C . The temperature was increased to 115°C over 2 hours and then to 130°C over a period of another 2 hours. During these operations approximately 2.0-2.5% of the POCl_3 evaporates together with the HCl stream and can be detected in the gas washing liquid. Then the reaction mixture was cooled to 100°C , and phenol (417.85 g, 4.44 mol) was added in one portion. The resulting mixture was slowly heated to 155°C and kept at this temperature for 12 hours. After cooling of the mixture to 35°C , the raw product was subjected to the general workup procedure. The triaryl phosphate ester composition was isolated with a yield of 96.5 % and typically consisted of 43 wt.% p-tert-butylphenyl diphenyl phosphate, 16 wt.% bis(p-tert-butylphenyl) phenyl phosphate, 2 wt.% tris(p-tert-butylphenyl) phosphate, and 39 wt.% triphenyl phosphate.

Example 2:

[0047] Triaryl phosphate ester compositions were synthesized using the following amounts and general procedures.

Table 2: Amounts of starting materials and general procedures used

Synthesis No.	General Procedure	Amount POCl ₃ (mass, mols)	Amount BP (mass, mols)	Amount Phenol (mass, mols)	Catalyst (amount)
1	A	306.66 g, 2.00 mol	390.57 g, 2.60 mol	319.97 g, 3.39 mol	MgCl ₂ (20 mmol)
2	A	306.66 g, 2.00 mol	420.62 g, 2.80 mol	301.15 g, 3.20 mol	MgCl ₂ (20 mmol)
3	A	306.66 g, 2.00 mol	450.66 g, 3 mol	282.33 g, 2.99 mol	MgCl ₂ (20 mmol)
4	B	321.99 g, 2.10 mol	410.10 g, 2.73 mol	317.64 g, 3.38 mol	MgCl ₂ (20 mmol)
5	B	321.99 g, 2.10 mol	441.65 g, 2.94 mol	296.58 g, 3.15 mol	MgCl ₂ (20 mmol)

[0048] The reaction products obtained with the syntheses listed above were subsequently analysed concerning their composition as well as their viscosity at 25 °C, their density at 25 °C, and their acid value.

Table 3: Product compositions, viscosity, density, and acid value

Synthesis No.	Product composition [wt. %]				Viscosity at 25 °C mPa*s	Density 25 °C g/cm ³	Acid value mg KOH/g
	p-tert-butylphenyl diphenyl phosphate	bis(p-tert-butylphenyl) phenyl phosphate	tris(p-tert-butylphenyl) phosphate	Triphenyl phosphate			
1	61.1	37.8	0.7	0.4	180	1.14	0.02
2	56.9	41.7	1.1	0.3	210	1.13	0.01
3	51.0	47.2	1.6	0.2	253	1.13	0.01
4	62.9	35.8	1.1	0.2	175	1.14	0.01
5	52.4	45.5	2.0	0.1	207	1.13	0.01

[0049] The compositions were isolated with the following yields.

Table 4:

Synthesis No.	Yield
1	95.5%
2	97.0%
3	96.5%
4	97.5%
5	98.0%

[0050] Table 3 shows that using the process according to the invention, triaryl phosphate ester

compositions with a triphenyl phosphate content of less than 0.5 wt.% can be obtained from common starting materials that are easily accessible on the market. Moreover, using the chloride anion determination method allows to reduce the TPP content to values as low as 0.1 wt.%, based on the weight of the phosphate ester composition. Further, Table 3 shows that with the process according to the invention, triaryl phosphate ester compositions containing more than 50 wt.% of the monoalkylated aryl phosphate ester, in particular of p-tert-butylphenyl diphenyl phosphate, can be achieved. When compared to comparative Example 1, it can be seen that despite the use of an excess of BP in the syntheses of Example 2, the amount of tris(p-tert-butylphenyl) phosphate is at most as high as in Example 1. Also, using the invention, triaryl phosphate ester compositions can be prepared in essentially solvent-free processes that employ only one evaporation step. Further, Table 4 shows that using the process according to the invention, triaryl phosphate ester compositions can be obtained with more than 95% overall yield.

REFERENCES CITED IN THE DESCRIPTION

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P a t e n t k r a v

1. Fremgangsmåde til fremstilling af en triarylphosphatestersammensætning, omfattende

a. omsætning af et phosphoroxihalogenid med et (C₁-C₁₅-alkyl)phenol for at opnå et første produkt;

b. omsætning af det første produkt med phenol for at opnå en triarylphosphatestersammensætning;

kendetegnet ved, at

der under trin a. for hver mol phosphoroxihalogenid anvendes 1,3 til 1,6 mol af (C₁-C₁₅-alkyl)phenol,

hvor mængden af phenol, der kræves under trin b., bestemmes ved at analysere indholdet af reaktionsblandingen.

2. Fremgangsmåde ifølge krav 1, **kendetegnet ved, at** trin a. og b. katalyseres af en Lewis-syre, især af et magnesiumhalid.

3. Fremgangsmåde ifølge krav 2, **kendetegnet ved, at** magnesiumhalidet fremstilles ved at opvarme magnesium under nærvær af phosphoroxihalogenid i et trin, der ligger før trin a.

4. Fremgangsmåde ifølge et af de foregående krav, **kendetegnet ved, at** phosphoroxihalogenidet er phosphoroxychlorid (POCl₃).

5. Fremgangsmåde ifølge et af de foregående krav, **kendetegnet ved, at** alkylphenolet er tert-butylphenol.

6. Fremgangsmåde ifølge et af de foregående krav, **kendetegnet ved, at** trin a. udføres ved 90 til 145 °C, især ved 100 til 140 °C.

7. Fremgangsmåde ifølge et af de foregående krav, **kendetegnet ved, at** trin b. udføres ved 120 til 180 °C, især ved 130 til 170 °C.

8. Fremgangsmåde ifølge et af de foregående krav, **kendetegnet ved, at** reaktionsblandingen afkøles til 90 til 110 °C efter trin a.

9. Fremgangsmåde ifølge et af de foregående krav, **kendetegnet ved, at** omsætningen under trin a. udføres i 0,5 til 7 timer, især i 0,5 til 4 timer.
- 5 10. Fremgangsmåde ifølge et af de foregående krav, **kendetegnet ved, at** omsætningen under trin b. udføres i 8 til 13 timer.
- 10 11. Fremgangsmåde ifølge et af de foregående krav **kendetegnet ved, at** det første produkt af trin a. anvendes uden oparbejdning og/eller oprensning under trin b.
12. fremgangsmåde ifølge et af de foregående krav **kendetegnet ved, at** den krævede mængde phenol under trin b. bestemmes ved at analysere chlorid-anionkoncentrationen i reaktionsblandingen.
- 15 13. Fremgangsmåde ifølge krav 12 **kendetegnet ved, at** indholdet af reaktionsblandingen, især chloridanionkoncentrationen af reaktionsblandingen, analyseres og/eller bestemmes efter en første mængde phenol er tilsat til det første reaktionsprodukt.
- 20 14. Fremgangsmåde ifølge et af de foregående krav **kendetegnet ved, at** triarylfosphatestersammensætningen, der opnås efter trin b., er bragt i kontakt med en ionbytningsharpiks.
- 25 15. Fremgangsmåde ifølge krav 14 **kendetegnet ved, at** pH-værdien af triarylfosphatestersammensætningen justeres til 8 til 10, især til 8,5 til 9, efter den er bragt i kontakt med ionbytningsharpiksen.
- 30 16. Fremgangsmåde ifølge et af de foregående krav **kendetegnet ved, at** triarylfosphatestersammensætningen, der opnås efter trin b., udsættes for en vandig oparbejdning.
- 35 17. Fremgangsmåde ifølge et af de foregående krav **kendetegnet ved, at** triarylfosphatestersammensætningen, der opnås efter trin b., udsættes for et fordampningstrin for at fjerne ikke-omsat phenol og/eller ikke-omsatte phenol-derivater.

18. Fremgangsmåde ifølge et af de foregående krav, **kendetegnet ved, at** fremgangsmåden udføres fuldstændig opløsningsmiddelfrit.

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19. Triarylphosphatestersammensætning, som kan opnås ved en fremgangsmåde ifølge et af kravene 1 til 18.

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20. Anvendelse af triarylphosphatestersammensætning ifølge krav 19 som flammehæmmer i polymerer, som tilsætningsstof til ekstremt tryk i smøremidler og/eller i funktionelle fluida.