

Process for the preparation of water-soluble
diphosphines

The invention relates to the preparation of diphosphines which are derived from biaryl compounds and are soluble in water as a result of the presence of sulfonic acid radicals in the molecule.

Complex compounds which contain, as the central atom, a metal of group VIII of the periodic table of the elements and, as ligands, P(III) compounds such as phosphines and phosphites and in addition optionally other groups suited for complex formation, have recently become increasingly important as catalysts. Thus, the reaction of olefins with synthesis gas to give aldehydes (hydroformylation) practiced industrially on a large scale is carried out in the presence of catalyst systems which are composed of cobalt and, in particular, rhodium and triphenylphosphine. Catalysts based on complex compounds containing phosphines have also proved suitable for the reaction of methanol with synthesis gas to give higher alcohols, in particular ethanol and propanol (homologization). In accordance with the solubility of these catalysts in organic media, the reactions are carried out in the homogeneous phase.

Instead of in the homogeneous phase, the reactions can also be carried out in heterogeneous reaction systems. The advantage of this process variant is the simple and gentle separation of the catalyst, which is present dissolved in water, from the water-insoluble reaction product. For example, the process described in DE 2,700,904 C2 for the addition of hydrogen cyanide to an unsaturated organic compound having at least one ethylenic double bond works according to this principle. Suitable catalysts for this reaction are the systems nickel/TPPTS [TPPTS is tri(sulfohenyl)phosphine], palladium/TPPTS or iron/TPPTS. For the preparation of aldehydes by reaction of olefins with carbon monoxide and hydrogen, according to the process of DE 2,627,354 C2

REPLACED SHEETS SG

☒	Description	: paged 1 to paged 1
☒	Claim(s)	: paged 1/3 to paged 1/3
☒	Drawing(s)	: paged - to paged -
☒	Abstract	: paged 1/1 to paged -
DATE OF RECEIPT		

This Sheet Has Been Replaced



22. Feb. 15:23

Print Time

22. Feb. 15:27



rhodium is employed in metallic form or in the form of one of its compounds together with a water-soluble phosphine, for example TPPTS, as the catalyst.

5 Diphosphines, which as bidentate ligands are able to form chelates with metal ions, are only used rarely, in contrast to the monophosphines, and then exclusively as constituents of homogeneously dissolved catalysts. Thus, according to the teaching of DE 2,904,782 C2, aldehydes are obtained by hydroformylation of a lower olefinic
10 compound in an organic solvent in the presence of a rhodium complex, a trisubstituted monophosphine and a diphosphinoalkane.

DE 2,909,041 A1 describes a process for the preparation of aldehydes by hydroformylation of olefins in which
15 platinum is present as the catalyst, the halide of at least one metal of group IVB of the periodic table of the elements ("carbon group") is present as the auxiliary catalyst and a two-bonded ligand of the formula $R_2X-Z-Y-Z-XR'_2$ (R or R' is an alkyl, aryl or aralkyl group, X is phosphorus, arsenic or antimony, Y is an
20 alkylene, arylene or aralkylene group and Z is a methylene group or an oxygen atom) is present as the reaction promoter. 2,2'-Bis(diphenylphosphinomethyl)-1,1'-binaphthyl is used in combination with a rhodium or
25 nickel compound as a ligand for asymmetric hydrogenation catalysts according to Laid-open Japanese Patent Application 79/39,059.

30 A reason for the comparatively rare use of diphosphines as a constituent of catalysts may be the difficulties which stand in the way of their preparation on an industrial scale. A number of laboratory processes for obtaining diphosphines are indeed known, but their application to industrial production processes is not without problems, either technically or economically.

35 A process which inter alia relates to the preparation of

- 3 -

diphosphines - they are used as bidentate phosphorus ligands - is the subject of EP 0,326,286 A1. Biaryl compounds are employed as starting substances which are substituted in each of the two aryl groups by the radical
5 -CH(R₃)(R₄) and optionally by other radicals. They are converted by the action of proton-eliminating reagents into biaryldianions, which are reacted with phosphorus compounds of the formulae X-P(R₁)(R₂) or X-PO(R₁)(R₂) (X is preferably a halogen atom). In this manner, diphosphines
10 are obtained directly or, if the phosphorus compound X-PO(R₁)(R₂) was employed, after reduction.

The process described above is suitable only for the preparation of diphosphines which are not substituted or contain substituents which are inert to compounds having
15 reducing action. In this connection, it has to be taken into account that a reduction step is not only necessary when using reactants of the type X-P(O)(R₁)(R₂). The formation of the biaryldianion also takes place under reducing conditions, as the reagents employed for eliminating the proton, such as alkali metal hydrides or
20 alkali metal alkyls, have reducing action. A direct preparation of biarylphosphines containing sulfonic acid groups is therefore not possible in the way described above, because the sulfonic acid groups are not retained
25 in the reaction of biaryl and phosphorus compound.

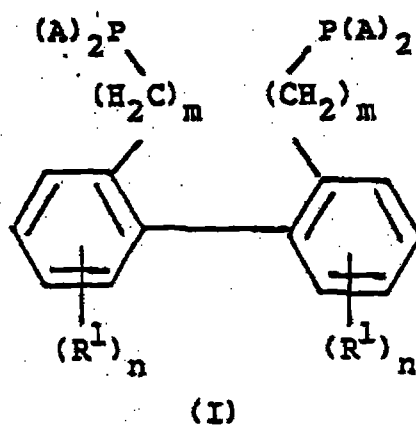
The object was therefore to develop a process for the preparation of sulfonated diphosphines which not only solves the problems described, but is also simple to carry out industrially and moreover economical.

30 The object described above is achieved by a process for the preparation of water-soluble diphosphines. It comprises treating biaryl compounds of the formula (I)

This Sheet Has Been Replaced



- 4 -



This Sheet Has Been Replaced



in which A is identical or different and is alkyl, cycloalkyl, phenyl, tolyl or naphthyl radicals, R¹ is identical or different and is hydrogen or alkyl or alkoxy radicals having 1 to 14 carbon atoms, furthermore cycloalkyl, aryl or aroxy radicals having 6 to 14 carbon atoms or a fused benzene ring, m is identical or different and is an integer from 0 to 5 and n is likewise identical or different and is integers from 0 to 4, at temperatures from 0 to 50°C with a solution of sulfur trioxide in sulfuric acid and then allowing the mixture to react subsequently with vigorous stirring at 20 to 50°C, in particular 20 to 30°C, over a period of 1 to 60 h, diluting the reaction mixture with water while maintaining a temperature of from 0 to 20°C, in particular 0 to 10°C, followed by working up.

It is surprisingly possible by the process according to the invention to sulfonate biaryls substituted by diorganoalkylenephosphine groups under mild conditions (where organo is an abbreviation for alkyl, cycloalkyl, phenyl, tolyl or naphthyl radicals). It is particularly remarkable that the formation of oxidation products such as phosphine oxides is largely suppressed. The progress of the sulfonation can be monitored and checked in a simple manner by ³¹P-NMR spectroscopy.

The biaryls employed as starting compounds in each case contain a $-(CH_2)_mP(A)_2$ -radical in the 2- and 2'-position.

- 5 -

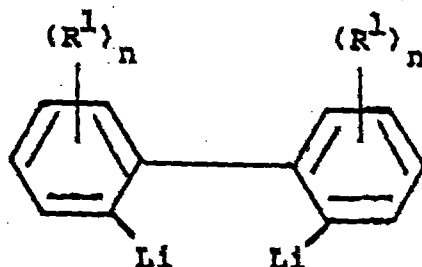
A and m in this case have the meanings described above. A is preferably a phenyl, tolyl or naphthyl radical. The biaryl molecule can furthermore be substituted by one or more identical or different radicals R^1 . The meaning of R^1 is described above. R^1 is in particular hydrogen, a methyl, isopropyl, isobutyl, t-butyl, phenyl or naphthyl radical or a fused benzene ring. m is preferably 1 and n is 0 or 1.

Sulfonated biaryl derivatives which are substituted in the 6- and 6'-position by R^1 radicals (excepting fused benzene ring from the meaning) are of particular significance. Their presence prevents the rotation of the two substituted phenyl radicals. Complex compounds which contain molecules of this type as ligands can therefore be employed as catalysts for enantioselective reactions.

For the preparation of the biaryl derivatives containing phosphorus, the biaryls on which they are based are advantageously used as starting materials.

The biaryls are obtained according to prior art processes, for example by coupling aryl Grignard reagents with aryl chloride, bromide or iodide in the presence of nickel catalysts. Another route to obtain them is the dehalogenation of aryl bromides and iodides in the presence of powdered active nickel oxides.

For the introduction of the phosphine radical into the biaryl and thus for the preparation of the intermediate for obtaining the sulfonated compound, a novel procedure which starts from easily accessible starting substances has proved very suitable. It comprises the reaction of 2,2'-dilithiobiphenyl or its derivatives of the formula



This Sheet Has Been Replaced



This Sheet Has Been Replaced



- 6 -

with a diarylphosphine halide of the formula $(A)_2P(CH_2)_nX$ (where in the formulae R^1 , A, m and n have the meanings described above and X is halogen). For the reaction, the two reactants are suspended in stoichiometric amounts or with a small excess of one of the two components in an inert organic solvent, for example an aliphatic hydrocarbon or hydrocarbon mixture such as hexane or light petroleum, in an aromatic hydrocarbon such as toluene or in an ether such as tetrahydrofuran, and the mixture is stirred at temperatures of from -50 to 100°C , preferably from -20 to 50°C . The reaction product dissolved in the organic medium is hydrolyzed using water. The diphosphine can be obtained in high yields from the organic phase after removal of the solvent by distillation and an optionally added purification step.

The diphosphine can be employed for the sulfonation without prior purification. The sulfonating agent used according to the invention is oleum, i.e. a solution of SO_3 in sulfuric acid. It is advantageous to employ oleum having an SO_3 concentration of 20 to 65 % by weight, relative to the solution. An essential feature of the novel procedure is the maintenance of specific reaction temperatures. These are 0 to 60°C and low temperatures in the range from 0 to 20°C are preferred. In order to ensure that the temperature ranges mentioned are not exceeded, it is recommended that the diphosphine is first dissolved in concentrated sulfuric acid and the solution is then treated with oleum in portions with stirring and intensive cooling. It is then allowed to react with vigorous stirring at 20 to 60°C , in particular 20 to 30°C , over a period of 1 to 60 h. SO_3 concentrations in the oleum and the period of stirring determine the degree of sulfonation of the diphosphine. The higher the supply of SO_3 and the longer the mixture is stirred, the more sulfonic acid groups enter the diphosphine molecule. As soon as the reaction is complete, the reaction mixture is worked up by dilution with water. There are several processes available for this. According to an approved

This Sheet Has Been Replaced



- 7 -

procedure, the sulfuric acid solution is first neutralized. Both during dilution of the reaction mixture and during neutralization, care is to be taken that overheating does not occur and it has proved suitable to maintain temperatures of from 0 to 20°C, in particular from 0 to 10°C. The aqueous solution of an alkali metal hydroxide, preferably sodium hydroxide, is used for neutralization. Alkali metal hydroxide concentrations of 20 to 60 % by weight, relative to the solution, have proved suitable. In order to achieve precipitation which is as complete as possible of the alkali metal sulfate formed from the sulfuric acid and alkali metal hydroxide, it is recommended to work at not too great a dilution. Alkali metal sulfate precipitates from the neutralized reaction mixture. It is filtered off and washed several times with a lower alcohol, preferably a C₁- to C₄-alcohol, in particular methanol. The sulfonated diphosphine is obtained from the filtrate by removal of the solvent under mild conditions, for example by distillation in the vacuum of an oil pump. For purification, the crystalline product obtained is dissolved in a little water, the solution is mixed with a lower alcohol, preferably a C₁- to C₄-alcohol, in particular methanol, and filtered, and the solvent is again removed gently.

According to another process, the subject of European Patent 0,107,006, the acidic aqueous solution of the sulfonation product is extracted with the solution of a water-insoluble amine in a water-insoluble organic solvent. The organic phase is removed and brought into intimate contact with the aqueous solution of a base. The sulfonated diphosphine can then be isolated from the aqueous phase removed.

The sulfonated diphosphines are colorless to yellowish-colored powders. Depending on the sulfonation conditions, they contain 4 to 6 sulfonic acid groups. They dissolve very easily in water and the solubility is 0.5 to 1.5 kg of sulfonation product/l of water according to the degree

- 8 -

of sulfonation. The free acids and also the salts of other metals can be prepared from the alkali metal salts, for example by ion exchange.

The novel process is illustrated in the subsequent example, but it is not restricted to the embodiments described.

This Sheet Has Been Replaced



Example

1. Preparation of 2,2'-bis(diphenylphosphinomethyl)-biphenyl ("BISBI")

2.34 g (10 mmol) of $\text{ClCH}_2\text{PPh}_2$, obtained according to Langhans et al., Chem. Ber. 123 (1990), 995-999, are suspended in 30 ml of hexane in a 250 ml three-necked flask provided with a reflux condenser, dropping funnel and magnetic stirrer and treated dropwise with vigorous stirring with a suspension of 0.83 g (5 mmol) of 2,2'-dilithiobiphenyl, obtained according to J. Organomet. Chem. 228 (1982), 107-118, in 30 ml of hexane. The mixture is then heated at 60°C for about 30 min and the solution is cooled by addition of 20 ml of toluene. After stirring for 20 minutes, it is cautiously hydrolyzed with 10 ml of water. The organic phase is removed in a separating funnel, washed three times with 5 ml portions of water and freed of solvent in an oil pump vacuum at a maximum of 30°C. BISBI is precipitated from the residual viscous oil as a white solid by addition of 15 ml of ethanol and filtered off through a G3 glass frit.

Yield: 70 % of theory. The batch size can be increased 100-fold without disadvantages or losses in yield if reaction vessels and reaction times are increased.

2. Sulfonation of BISBI

1 mmol of BISBI are dissolved in 2 ml of concentrated sulfuric acid and treated dropwise at 0°C with 5 ml of

- 9 -

oleum (SO₃ content: 20 to 65 % by weight, relative to the solution). After warming to room temperature (about 20°C), the reaction mixture is stirred vigorously for several hours, then poured cautiously onto about 100 g of ice and neutralized at temperatures below 5°C using an aqueous NaOH solution (NaOH content: 50 % by weight, relative to the solution). The resulting suspension is filtered and the filtrate is added to 25 ml of methanol. The filter cake is washed twice with 25 ml portions of methanol. The combined fractions are concentrated to dryness in an oil pump vacuum and the residue is taken up in very little water. The clear, amber-colored solution is injected into 30 ml of methanol, the suspension is stirred and filtered, and the filtrate is concentrated to dryness in an oil pump vacuum. The sulfonation period depends on the progress of the reaction, which is monitored by ³¹P-nuclear magnetic resonance spectroscopy at intervals of about 2 h.

Characterization of the reaction product

The reaction product described below was obtained from BISBI, after reaction for 17 h, by reaction with 65 % strength oleum.

³¹P-NMR (161.8 MHz, CD₂Cl₂, 20°C): δ = -6.8 (s), -7.1 (s), -9.5 (s), -9.6 (s)

IR (KBr, cm⁻¹) ν = 993 (m), 1040 (st), 1098 (m), 1127 (m), 1146 (m), 1195 (sst)

P/S ratio = 2 : 5.7 (elemental analysis)

Solubility: greater than 1 g/ml of water

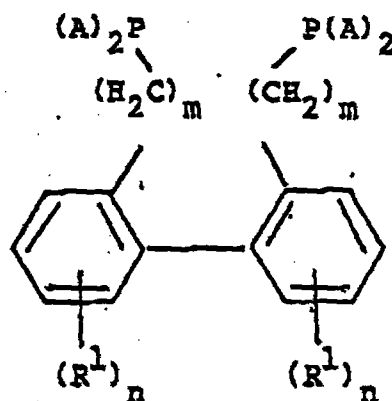
Appearance: yellowish powder

This Sheet Has Been Replaced

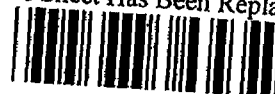


Patent claims

1. A process for the preparation of water-soluble diphosphines, which comprises treating biaryl compounds of the formula



This Sheet Has Been Replaced



5 in which A is identical or different and is alkyl, cycloalkyl, phenyl, tolyl or naphthyl radicals, R¹ is identical or different and is hydrogen or alkyl or alkoxy radicals having 1 to 14 carbon atoms, furthermore cyclo-
 10 alkyl, aryl or aroxy radicals having 6 to 14 carbon atoms or a fused benzene ring, m is identical or different and is an integer from 0 to 5 and n is likewise identical or different and is integers from 0 to 4, at temperatures from 0 to 60°C with a solution of sulfur trioxide in sulfuric acid and then allowing the mixture to react
 15 subsequently with vigorous stirring at 20 to 60°C, in particular 20 to 30°C, over a period of 1 to 60 h, diluting the reaction mixture with water while maintaining a temperature of from 0 to 20°C, in particular 0 to 10°C, followed by working up.

20 2. The process as claimed in claim 1, wherein the concentration of the sulfur trioxide dissolved in the sulfuric acid is 20 to 65 % by weight, relative to the solution.

25 3. The process as claimed in claim 1 or 2, wherein the reaction mixture is allowed to react subsequently at 20 to 30°C.



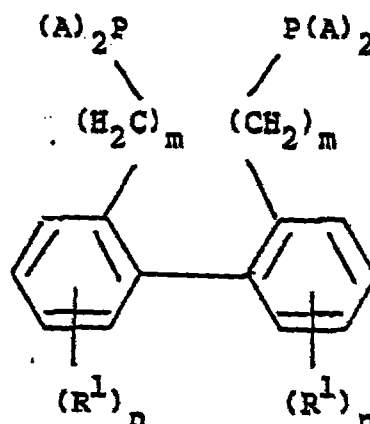
- 2 -



4. The process as claimed in one or more of claims 1 to 3, wherein the reaction mixture diluted with water is neutralized using an aqueous alkali metal hydroxide solution while maintaining a temperature of from 0 to 20°C, in particular from 0 to 10°C, precipitated alkali metal sulfate is filtered off, the aqueous solution is concentrated under mild conditions, the crystalline product is dissolved in a little water, the solution is mixed with a lower alcohol, preferably a C₁- to C₄-alcohol, in particular methanol, and filtered and the water-soluble diphosphine is isolated by removal of the solvent under mild conditions.

5. The process as claimed in one or more of claims 1 to 3, wherein the reaction mixture diluted with water is extracted with the solution of a water-insoluble amine in a water-insoluble organic solvent, the organic phase is removed and brought into intimate contact with the aqueous solution of a base, and the water-soluble diphosphine is isolated from the aqueous phase removed.

6. The process as claimed in one or more of claims 1 to 4, wherein the biaryl compounds of the formula



employed for the sulfonation are obtained by reaction of a dilithium compound of the formula

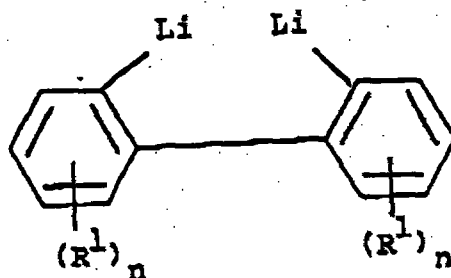
This Sheet Has Been Replaced



Received Time 22. Feb. 15:28

Print Time 22. Feb. 15:31

- 3 -



with a halogenated diarylalkylenephosphine of the formula



where X is chlorine, bromine or iodine.

- 5 7. The product obtained by sulfonation of 2,2'-bis-(diphenylphosphinomethyl)biphenyl as claimed in claim 1.

This Sheet Has Been Replaced

