

Process for preparing compounds containing nitrile functions

[0001] The present invention relates to the preparation of compounds
5 containing nitrile functions, more preferably of compounds containing two
nitrile functions, such as succinonitrile and adiponitrile.

[0002] It relates more particularly to the preparation of compounds
containing nitrile functions from compounds containing carboxyl functions
10 which are, advantageously, present in fermentation media or fermentation
liquors.

[0003] Compounds containing nitrile functions, and especially dinitrile
compounds such as adiponitrile and succinonitrile, are products which are
15 important in the manufacture of amine compounds or polymers, for example.

[0004] For instance, adiponitrile is an important compound used as an
intermediate in the manufacture of hexamethylenediamine, or of epsilon-
caprolactam. These two compounds are monomers which are used in the
20 manufacture of polyamides, especially polyhexamethylenediamine adipamide
(PA 6,6) or polycaproatamide (PA 6). Hexamethylenediamine is also used for the
synthesis of diisocyanates, which are important monomers in the manufacture
of polyurethanes.

25 [0005] Adiponitrile and succinonitrile may also be used in processes for
manufacturing polyamides by condensation reaction with diacid monomers.

[0006] Numerous processes have been proposed for synthesis of
adiponitrile. These processes principally use, as their starting material,
30 hydrocarbon compounds obtained from the refining of petroleum. Thus the
main processes for synthesis of adiponitrile are the hydrocyanation of
butadiene, and the ammoxidation of propane or of propene.

[0007] Also exploited has been a process for preparing adiponitrile by
35 converting adipic acid into adiponitrile in the presence of ammonium
hydroxide. This process is described particularly in French patents 2028842,
2132849 and 2144340.

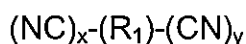
[0008] In this process, the adipic acid used as starting material was obtained from a hydrocarbon, such as cyclohexane, which was obtained during the refining of petroleum.

5 [0009] In view of the exhaustion of petroleum resources, many research studies have been undertaken with the aim of developing processes for synthesizing these important compounds in the manufacture of materials that are used in numerous applications, starting from renewable raw materials or resources. Generally speaking, these renewable resources are composed of
10 cultivated or uncultivated plant material, such as trees and plants such as sugar cane, maize, manioc, wheat or the like.

[0010] This plant material is converted by processes which generally comprise a plurality of mechanical, chemical and biological steps into
15 compounds which belong to the class of sugars, such as glucose, sucrose, fructose or the like. The resulting sugars are then converted, advantageously, by processes such as fermentation into compounds containing particular organic functions. Hence, by a process of biological fermentation, it is possible to convert the sugars into compounds containing carboxyl functions. These
20 fermentation processes produce aqueous solutions of organic compounds that are referred to as fermentation liquors.

[0011] One of the objects of the invention is to provide a process for preparing compounds comprising at least one nitrile function, using as starting
25 material, preferably, an aqueous solution of a carboxyl compound, and, even more advantageously, the aqueous solutions referred to as fermentation liquors that are obtained by fermentation of sugars produced by the transformation of renewable resources.

30 [0012] For this purpose, the invention provides a process for preparing compounds of general formula I:



in which

35 R_1 represents a saturated or unsaturated, linear or branched hydrocarbon group containing 1 to 20 carbon atoms and possibly containing heteroatoms, and
x and y represent 0 or 1, with (x+y) being 1 or 2.

[0013] This process involves reacting ammonia with a salt of an organic diacid of general formula II



in which x, y and R₁ have the meaning indicated above, in the presence of a catalyst comprising a crystalline silicon orthophosphate.

10 [0014] The process is implemented at a temperature of between 300°C and 450°C, preferably between 350°C and 425°C.

[0015] The aqueous solution of compounds of formula II is evaporated before being contacted with the catalyst, either in an evaporation device or by
15 spraying into the stream of superheated ammonia. These two means of evaporating the aqueous solution are given solely as indicators.

[0016] In another feature of the invention, the catalyst comprises less than 5% by weight of amorphous silicon orthophosphate.

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[0017] In another feature of the invention, the compound of general formula II is an aqueous solution. This aqueous solution is obtained more advantageously in a process of biological transformation of a solution containing sugars that is itself obtained from a process of transformation or
25 extraction using, as starting materials, essentially plant materials which constitute a renewable resource.

[0018] This aqueous solution obtained from a process of biological transformation is obtained, for example, by a sugar fermentation process. This
30 medium is referred to generally as "fermentation liquor".

[0019] These fermentation liquors may be used directly or after filtration to separate the biological material or biomass from the medium. As an example of a process for preparing fermentation liquors that are suitable as starting
35 material for the process of the invention, mention may be made of the processes described in the article by Varadarajan et al. that appeared in Biotechnol. Pro. 1999, 15, 845-854, or the article by Olson et al. that appeared in Applied Biochemistry and Biotechnology 2003, Vol. 105-108, 843-851.

[0020] The aqueous solutions and/or fermentation liquors that are suitable for the process of the invention have a weight concentration of compounds of general formula II that is generally greater than 1% by weight, preferably
5 between 1% by weight and 30% by weight, advantageously between 5% by weight and 25% by weight. However, the maximum concentration suitable is fixed by the solubility limit of the compound of formula II in water at the temperature at which the solution is fed into the evaporation device used to feed the solution onto the catalyst.

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[0021] This concentration may be obtained directly by the process of biological fermentation, or by concentration of the fermentation liquor or of the aqueous solution, for example, by evaporation of water. The compound of general formula II is advantageously selected from the group consisting of
15 ammonium succinate, ammonium adipate, ammonium glutamate, ammonium glutarate, ammonium salts of difunctional fatty acids, ammonium hexadecanedioate or the like.

[0022] A catalyst suitable for the invention may be obtained
20 advantageously by impregnating a silica with phosphoric acid in aqueous solution, then calcining in air, to form silicon orthophosphate. The calcining temperature is advantageously between 450°C and 800°C, for example between 450°C and 550°C. A preparation process of this kind is described more particularly in French patent application 2810317.

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[0023] It is also possible to use catalysts which are sold by a number of companies such as the company UOP. However, it may be necessary to treat these commercial catalysts in order to increase the level of crystalline form, by a heat treatment, for example.

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[0024] The catalyst is generally in solid form, for example in the form of beads, cylindrical extrudates, honeycomb or the like. The catalyst is disposed in a reactor in the form of a fixed bed through which the fermentation liquor and the ammonia in vapour form are passed.

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[0025] The catalyst of the invention may further comprise dopant elements or cocatalysts.

[0026] In another feature of the invention, the catalyst used for implementing the process of the invention may be regenerated by treating the catalyst bed with air at a temperature of between 450 and 500°C for 10 to 20 hours. The regeneration treatment may be monitored by detecting the presence of CO₂ in the air at the reactor outlet. Treatment is halted when the absence of CO₂ in the air is found. The catalyst thus regenerated may be used for further implementation of the process of the invention, with equivalent catalytic performance.

[0027] The vapours recovered at the reactor outlet are condensed for the purpose of recovering the compound containing the nitrile functions. These compounds may be subsequently purified, by conventional techniques such as distillation, crystallization, extraction or the like.

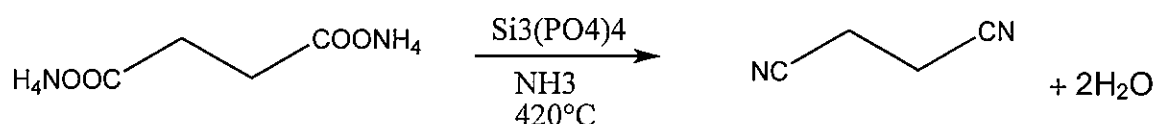
[0028] The catalyst is advantageously activated in particular by treatment with gaseous ammonia at a temperature of between 350°C and 500°C, before the feeding of the aqueous solution of compound II.

[0029] Further details and advantages of the invention will emerge more clearly from a reading of the examples which are given below solely by way of indication.

[0030] The reaction is implemented in gaseous phase at a temperature in the region of 400°C and under atmospheric pressure. The catalyst used is composed of silicon orthophosphate of formula Si₃(PO₄)₄.

[0031] This catalyst is prepared by impregnating a silica with 85% phosphoric acid and then calcining in air at 500°C.

[0032] Example 1: Preparation of succinonitrile



[0033] The starting material is an aqueous solution containing approximately 10% to 20% by weight of ammonium succinate in solution in

water.

[0034] This aqueous solution contains other acids and diacids containing fewer carbon atoms, which are referred to as "lower acids".

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[0035] The composition of the aqueous solution used corresponds to the composition of a solution or fermentation liquor obtained from a process of fermentation of a medium containing sugars obtained from the treatment of a plant material.

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[0036] The solubility of the ammonium salts of these acids increases greatly with temperature, and so it may be of advantage to use a hot solution in order to prevent crystallization problems.

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[0037] A glass reactor with a diameter of 22 mm is supplied in succession with

3 ml of glass powder

5 ml (4.0 g) of $\text{Si}_3(\text{PO}_4)_4$ catalyst in the form of extrudates

3 ml of glass powder.

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[0038] The catalyst bed is activated first by treatment at 500°C in a stream of air of 3 l/h for approximately 15 hours, followed, after lowering of the temperature to 420°C, by replacement of the air by a stream of NH_3 at a rate of 1.5 l/h.

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[0039] Using a syringe driver, an aqueous solution of ammonium succinate at a concentration of 15% by weight is injected at a rate of 6 ml/h.

Under these conditions, the molar NH_3 /ammonium succinate ratio is 10.

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[0040] The condensates are recovered and analysed by gas chromatography (GC).

[0041] After injection of aqueous solution for 4 hours, the yield of

conversion to succinonitrile relative to the ammonium succinate introduced is 65%.

Example 2: Preparation of succinonitrile from succinic acid

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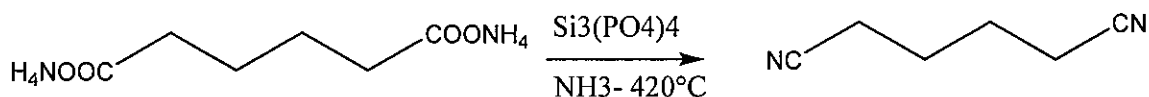
[0042] Example 1 is repeated, but using a 20% strength by weight aqueous solution of succinic acid.

The catalyst bed is identical to that of the preceding test. Following activation, a stream of ammonia at 2 l/h is passed over the catalyst bed, and, at the same time, the aqueous solution of succinic acid is injected at a rate of 4 ml/h.

10 Under these conditions, the molar NH_3 /succinic acid ratio is 10. The condensates are recovered and analysed by GC.

After 5 hours of injection, the yield of succinonitrile is 70%.

15 [0043] Example 3: Preparation of adiponitrile



[0044] Example 1 is repeated, replacing the ammonium succinate solution with a 15% strength by weight ammonium adipate solution. A stream of NH_3 at 20 1.5 l/h is injected into the catalyst bed, and the hot aqueous ammonium adipate solution is injected at a rate of 4 ml/h.

[0045] After 4 hours of injection, the yield of conversion of ammonium 25 adipate to adiponitrile is 72%.

Example 4: Preparation of succinonitrile with regenerated catalyst

[0046] When the performance of the catalyst bed falls below the economic optimum, the bed can be regenerated in accordance with the following 30 procedure, which is described solely by way of example.

[0047] The feed to the catalyst bed of ammonia and aqueous ammonium

carboxylate solution is halted. The catalyst bed, maintained under a stream of nitrogen, is cooled to ambient temperature. The stream of nitrogen is replaced with a stream of 3 l/h of air, and the catalyst bed is heated gradually to 500°C. Treatment in air at 500°C is maintained for approximately 15 hours. The
5 presence of CO₂ in the exiting air is detected, and the treatment is continued until CO₂ is no longer detected in the outgoing flow.

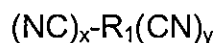
[0048] The temperature of the catalyst bed is brought to 420°C, the flow of air being replaced by a stream of nitrogen at 3 l/h. At 420°C, the stream of
10 nitrogen is replaced gradually by ammonia. The catalyst is then regenerated, and a succinonitrile production test was carried out in accordance with the procedure described in Example 1. The conversion yield obtained is identical.

Claims

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1. Process for preparing compounds of general formula I

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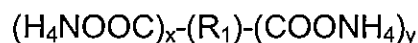
in which:

R₁ represents a saturated or unsaturated, linear or branched hydrocarbon group containing 1 to 20 carbon atoms and possibly containing hetero-atoms,

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x and y are 0 or 1, with (x+y) being 1 or 2,

which comprises reacting ammoniac with a compound of general formula II



in vapour phase in the presence of a catalyst comprising a silicon ortho-phosphate of formula Si₃(PO₄)₄, at a temperature of between 300°C and

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450°C.

2. Process according to Claim 1, characterized in that the compound of general formula II is in aqueous solution.

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3. Process according to Claim 2, characterized in that the concentration of the compound of general formula II in the aqueous solution is greater than 1% by weight.

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4. Process according to Claim 3, characterized in that the concentration of the compound of general formula II in the aqueous solution is between 1% and 30% by weight, preferably between 1% and 25% by weight.

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5. Process according to any of Claims 2 to 4, characterized in that the aqueous solution of the compound of general formula II is a medium resulting from the biological transformation of compounds belonging to the class of sugars.

6. Process according to Claim 5, characterized in that the medium obtained from the biological transformation that is used is obtained after separation from the biomass.
7. Process according to any of Claims 1 to 6, characterized in that the compound of general formula II is selected from the group consisting of ammonium succinate, ammonium adipate, ammonium glutamate, ammonium glutarate, ammonium salts of fatty diacids, ammonium hexadecanedioate or the like.
8. Process according to any of Claims 1 to 7, characterized in that the reaction is performed in a reactor comprising a fixed catalyst bed.
9. Process according to any of Claims 1 to 8, characterized in that the catalyst is obtained by impregnating a silica with phosphoric acid and calcining in air.
10. Process according to Claim 9, characterized in that the calcining is performed at a temperature of between 400°C and 800°C.
11. Process according to any of the preceding claims, characterized in that the compound of general formula I is selected from the group consisting of adiponitrile and succinonitrile.