The hydration of olefins is a reversible exothermic reaction consuming water as the reactant. Many prior art processes, however, use additional water to remove heat. Typical molar feed ratios water/olefin therefore range from 10 to 20 : 1, an example of which is described for IPA in US 4,340,769. The advantage of the process layout of US 4,340,769 is a high olefin conversion rate but the product alcohol IPA exits the reactor as a diluted aqueous solution with concentrations ranging from 5 to 15 wt.-%. To recover pure IPA costly distillation processes are required.

Object of the Invention

The hydration of olefins requires ion exchange resin catalysts with great mechanical strength in particular when high pressures and temperatures are involved. It has been found that many ion exchange resin catalysts deform due to the high pressure drop caused at high mass flow velocity. It is therefore one objective of the present invention to provide suitable catalyst arrangements for the hydration of olefins. A further object of the invention is to provide a new process for olefin hydration by arranging the acidic catalyst in structured packings.

Summary of the Invention

The invention is defined in the independent claims. Preferred embodiments are the subject matter of the dependent claims or are described herein below.

The invention relates to a process for the continuous production of a lower aliphatic alcohol having from 2 to 5 carbon atoms, preferably having 3 to 5 carbon, most preferably having 3 or 4 carbon atoms, by the catalytic hydration of lower aliphatic olefins having 2 to 5 carbon atoms, preferably 3 to 5 carbon atoms, most preferably having 3 or 4 carbon atoms, in the presence of water and an immobilized strongly acidic structured catalyst preferably at a temperature of 80 to 220°C, in particular from 130 to 190°C, and a pressure of about 40 to 200 bar, in particular from 60 to 120 bar. As starting material linear olefins are preferred. Preferably each the olefin, the water and the alcohol are predominantly (by weight) in the liquid state during the reaction. Elevated pressures are necessary to keep all components in a condensed state, liquid and/or supercritical, wherein olefins such as propylene and water show a large miscibility gap. Due to the hydrophilic behaviour of the acidic resins the catalyst surface is always well wetted with water even at low water hold-up. This demands high pressures to dissolve the olefin in water and to transport the olefin to the active sites of the catalyst.

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The hydration of olefins requires ion exchange resin catalysts with great mechanical strength in particular when high pressures and temperatures are involved. It has been found that many ion exchange resin catalysts deform due to the high pressure drop caused at high mass flow velocity. It is therefore one objective of the present invention to provide suitable catalyst arrangements for the hydration of olefins. A further object of the invention is to provide a new process for olefin hydratíon by arranging the acidic catalyst in structured packings.

Summary of the Invention

The invention is defined in the independent claims. Preferred embodiments are the subject matter of the dependent claims or are described herein below.

The invention relates to a process for the continuous production of a lower aliphatic alcohol having 3 or 4 carbon atoms, by the catalytic hydration of lower aliphatic olefins having 3 or 4 carbon atoms, in the presence of water and an immobilized strongly acidic structured catalyst at a temperature of 80 to 220°C, in particular from 130 to 190°C, and a pressure of about 40 to 200 bar, in particular from 60 to 120 bar. As starting material linear olefins are preferred. Preferably each the olefin, the water and the alcohol are predominantly (by weight) in the liquid state during the reaction. The elevated pressure keeps all above components in a condensed, liquid and/or super-critical state, wherein olefins such as propylene and water show a large miscibility gap. Due to the hydrophilic behaviour of the acidic resins the catalyst surface is always well wetted with water even at low water hold-up. This demands high pressures to dissolve the olefin in water and to transport the olefin to the active sites of the catalyst.

Claims

1. Process for the hydration of olefins to alcohols by heterogeneous reactive extraction bringing into contact in a reactor one or more ~~C2 to C5~~ olefins having 3 or 4 carbon atoms, water and an acidic catalyst, wherein the acidic catalyst is immobilized and selected from at least one member of the group consisting of the following structured catalysts:

a) a structured catalytic packing wherein the structured catalyst comprises multiple flow through channels wherein first multiple channels a orientated with an angle of + 20 to + 60° and second multiple channels with an angle of - 20 to - 60° towards the flow direction and the first and the second channels provide for multiple intersections to allow mass transfer in multiple directions;

b) a monolithic support having the shape of honeycombs or other parallel channel structures, impregnated or coated with the acidic catalyst;

c) acidic fibres as part of woven or non woven fabrics; and

d) catalytic elements aligned on wires or filaments.; ~~and~~

~~e) catalytic elements formed by foams or sponges.~~

2. The process according to claim 1 wherein in the reactor the water and the olefin are present in multiple condensed phases.

3. The process according to at least one of the preceding claims, wherein the olefin is propylene and the alcohol is isopropanol.

4. The process according to at least one of the preceding claims wherein the acidic catalyst is an ion exchange resin.

5. The process according to at least one of the preceding claims wherein the structured catalytic packing comprises multiple flow through channels and multiple cages permeable to the olefin and water but enclosing the acidic catalyst in the form of beads.

6. The process according to at least one of the preceding claims wherein a volumetric olefin/water hold-up ratio of from 10:1 to 20:1 is used and the hold-up ratio is maintained by a catalyst load of from 10 to 60 vol.-% in particular from 20 to 40 vol.-%.

7. The process according to at least one of the preceding claims wherein the flooding conditions affecting the hold-up ratio in the structured packing are controlled by the feed streams of olefin and water.

8. The process according to at least one of the preceding claims wherein the product alcohol, in particular isopropanol, is recovered from the aqueous phase by extraction with the olefinic phase.

9. The process according to at least one of the preceding claims wherein the hydration reaction is carried out at a temperature ranging from 80 to 220°C at pressures of 40 to 200 bar, in particular from 130 to 190°C and from 60 to 120 bar.

10. The process according to at least one of the preceding claims wherein the structured acidic catalyst a) to d) ~~e)~~ according to claim 1 is made of a corrosion resistant metal and/or glass preferably each with hydrophilic surface properties.

11. The process according to at least one of the preceding claims wherein said catalytic packing is used in combination with separation sections in the reactor.

12. The process according to at least one of the preceding claims wherein the molar feed ratio of the reactants is adjusted by variation of the feed streams into the reactor to maintain a volumetric olefin hold-up inside the hydration reactor ranging from 36 to 86 vol.-%, in particular ranging from 55 to 75 vol.-%.

13. The process according to at least one of the preceding claims wherein the reactor outlet mixture is separated by decantation into a condensed organic phase and a liquid aqueous phase wherein the aqueous phase can be recycled to the reactor inlet.

14. The process according to at least one of the preceding claims wherein unconverted olefins are recovered from the condensed organic phase by a separation process prior to azeotropic distillation used for alcohol purification.

15. The process according to claim 14 wherein the unconverted olefin is propylene and wherein the azeotropic distillation is used for isopropyl alcohol purification.

16. The process according to claim 14 or 15 wherein said separation process is a stripping process in particular a propylene stripping process.

17. The process according to at least one of claims 14 to 16 wherein said separation process separates gaseous propylene from the isopropyl alcohol containing inlet stream of the azeotropic distillation.

18. The process according to at least one of the preceding claims wherein the olefin is the stationary phase and water is the mobile phase preferably flowing downwards through the structured catalyst.

19. The process according to claim 9 ~~at least one of the preceding claims~~ wherein the space-time yield (STY) is above of 5 $mole_{IPA}/ltr_{cat}/hr$ when IPA is the product or wherein the space-time yield (STY) is above of 1.8 $mole_{SBA}/ltr_{cat}/hr$ when SBA is the product.

~~20. The process according to at least one of the preceding claims wherein the structured catalyst comprises multiple flow through channels wherein first multiple channels a orientated with an angle of + 20 to 60° and second multiple channels with an angle of - 20 to 60° towards the flow direction and the first and the second channels provide for multiple intersections to allow mass transfer in multiple directions, wherein the structured catalyst is preferably a structured catalytic packing.~~

Claims

1. Process for the hydration of olefins to alcohols at pressures of 40 to 200 bar and a temperature of 80 to 220°C by heterogeneous reactive extraction bringing into contact in a reactor one or more olefins having 3 or 4 carbon atoms, water and an acidic catalyst, wherein the olefin(s), the alcohol(s) and the water are in the condensed state, liquid state and/or supercritical state, the acidic catalyst is an ion exchange resin and is immobilized and selected from at least one member of the group consisting of the following structured catalysts:

a) a structured catalytic packing wherein the structured catalyst comprises multiple flow through channels wherein first multiple channels are orientated with an angle of + 20 to + 60° and second multiple channels with an angle of - 20 to - 60° towards the flow direction and the first and the second channels provide for multiple intersections to allow mass transfer in multiple directions;

b) a monolithic support having the shape of honeycombs or other parallel channel structures, impregnated or coated with the acidic catalyst;

c) acidic fibres as part of woven or non woven fabrics; and

d) catalytic elements aligned on wires or filaments.

2. The process according to claim 1 wherein in the reactor the water and the olefin are present in multiple condensed phases.

3. The process according to at least one of the preceding claims, wherein the olefin is propylene and the alcohol is isopropanol.

4. The process according to at least one of the preceding claims wherein the structured catalytic packing comprises multiple flow through channels and multiple cages permeable to the olefin and water but enclosing the acidic catalyst in the form of beads.

5. The process according to at least one of the preceding claims wherein a volumetric olefin/water hold-up ratio of from 10:1 to 20:1 is used and the hold-up ratio is maintained by a catalyst load of from 10 to 60 vol.-% in particular from 20 to 40 vol.-%.

6. The process according to at least one of the preceding claims wherein the flooding conditions affecting the hold-up ratio in the structured packing are controlled by the feed streams of olefin and water.

7. The process according to at least one of the preceding claims wherein the product alcohol, in particular isopropanol, is recovered from the aqueous phase by extraction with the olefinic phase.

8. The process according to at least one of the preceding claims wherein the hydration reaction is carried out at a temperature ranging from 130 to 190°C and from 60 to 120 bar.

9. The process according to at least one of the preceding claims wherein the structured acidic catalyst a) to d) according to claim 1 is made of a corrosion resistant metal and/or glass preferably each with hydrophilic surface properties.

10. The process according to at least one of the preceding claims wherein said catalytic packing is used in combination with separation sections in the reactor.

11. The process according to at least one of the preceding claims wherein the molar feed ratio of the reactants is adjusted by variation of the feed streams into the reactor to maintain a volumetric olefin hold-up inside the hydration reactor ranging from 36 to 86 vol.-%, in particular ranging from 55 to 75 vol.-%.

12. The process according to at least one of the preceding claims wherein the reactor outlet mixture is separated by decantation into a condensed organic phase and a liquid aqueous phase wherein the aqueous phase can be recycled to the reactor inlet.

13. The process according to at least one of the preceding claims wherein unconverted olefins are recovered from the condensed organic phase by a separation process prior to azeotropic distillation used for alcohol purification.

14. The process according to claim 13 wherein the unconverted olefin is propylene and wherein the azeotropic distillation is used for isopropyl alcohol purification.

15. The process according to claim 13 or 14 wherein said separation process is a stripping process in particular a propylene stripping process.

16. The process according to at least one of claims 13 to 15 wherein said separation process separates gaseous propylene from the isopropyl alcohol containing inlet stream of the azeotropic distillation.

17. The process according to at least one of the preceding claims wherein the olefin is the stationary phase and water is the mobile phase preferably flowing downwards through the structured catalyst.

18. The process according to claim 8 wherein the space-time yield (STY) is above of 5 $mole_{IPA}/ltr_{cat}/hr$ when IPA is the product or wherein the space-time yield (STY) is above of 1.8 $mole_{SBA}/ltr_{cat}/hr$ when SBA is the product.