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A process for the preparation and isolation of alkene oxides from alkenes

The present invention provides a process for the catalytic partial oxidation of hydrocarbons in the presence of oxygen and at least one reducing agent, characterised in that the reaction mixture is passed through a layer which contains a catalyst and a downstream layer which contains an aqueous absorption agent in which the partially oxidised hydrocarbons are absorbed quantitatively.

The catalytic gas phase partial oxidation of hydrocarbons in the presence of molecular oxygen and a reducing agent is known. (DE-A1-199 59 525, DE-A1-100 23 717, US-B-5 623 090, WO-98/00413-A1, WO-98/00415-A1, WO-98/00414-A1, WO-00/59632-A1, EP-A1-0827779, WO-99/43431-A1 which at the same time are included in the present application as reference material for the purposes of US patent practice). Compositions which contain, inter alia, nanoscale gold particles, are used as catalysts.

Methods for the selective separation of partial oxidation products from the reactants and secondary products produced by partial oxidation in the presence of reducing agents, as mentioned above, however, are not disclosed.

Methods for the purification of alkene oxides, such as adsorption, absorption, condensation etc., are known in principle.

To purify alkene oxides such as, for example, propene oxide, solid adsorption agents such as active carbon or zeolites, for example, may be used.

US-B-4,692,535 discloses, for example, the separation of high molecular weight poly(propene oxide) from propene oxide by contact with active carbon.



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US-B-4,187,287, US-B-5,352,807 and EP-A1-0 736 528 disclose the separation of various organic contaminants from alkene oxides, such as propene oxide and butene oxide, by treatment with solid active carbon.

- 5 The selective adsorption of the partial oxidation products of catalytic gas phase direct oxidation reactions with molecular oxygen and a reducing agent, however, is not described.

10 Likewise, the selective and quantitative separation of partial oxidation products of mixtures consisting of non-condensable gases such as hydrocarbons, oxygen, hydrogen, diluent gas and, on the other hand, water, water vapour and in particular acidic secondary products such as, inter alia, carboxylic acids and/or aldehydes, is not described.

15 In commercial processes for the synthesis of ethylene oxide from ethene and molecular oxygen without the use of a reducing agent, the preferred process parameters include temperatures well above 200°C and reaction pressures >15 bar. Ethene oxide, as the partial oxidation product, is produced with a selectivity of 80-85 %. Almost exclusively carbon dioxide and water are produced as virtually the
20 only secondary products using the extreme process parameters with high temperatures and high pressures, due to the preferred total oxidation of ethene. The epoxide, together with carbon dioxide, is separated from the feed exclusively by absorption in water.

25 In the case of ethene direct oxidation, therefore, apart from the epoxide and carbon dioxide, hardly any other partially oxidised hydrocarbons such as, inter alia, aldehydes, ketones, acids, esters or ethers, which could permanently reduce the pH of the absorption water, are produced and thus greatly lower the stability of the epoxide in water.

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The selective absorption of epoxides, such as propene oxide, arising from catalytic gas phase direct oxidation reactions with molecular oxygen and a reducing agent is not described.

5 On the other hand, partial oxidation with an oxygen/hydrogen mixture is performed in the temperature range from 140 to 210°C, which is thus much lower than the temperature for partial oxidation described above where only oxygen and no additional reducing agent, such as hydrogen, is used.

10 The low reaction temperature of $<210^{\circ}\text{C}$ in the process using oxygen and a reducing agent means that virtually no total oxidation takes place and therefore only traces of carbon dioxide are formed. Instead of carbon dioxide therefore, the product mixture contains, apart from an epoxide as the main product, many other partial oxidation products such as aldehydes, ketones, acids, esters, ethers, in low
15 concentrations. These secondary products can lower the pH in aqueous systems and thus reduce the stability of the epoxide (see Y. Pocker et al., J. Am. Chem. Soc., 1980, 102, 7725-7732: A Nuclear Magnetic Resonance Kinetic and Product Study of the Ring Opening of Propylene Oxide). Therefore there is a bias towards thinking that absorption in water in the presence of acidic secondary products cannot be
20 performed on an industrial scale.

Furthermore, all published applications for the selective oxidation of hydrocarbons in the presence of oxygen and a reducing agent achieve only a small hydrocarbon conversion of less than 10 %. All the processes are performed, on an industrial scale,
25 with very large amounts of circulating gas. The isolation of very small volumes of useful products (e.g. 2 vol.% of hydrocarbon oxide) from large amounts of gas (e.g. 98 vol.% of gas consisting of hydrocarbon, hydrogen, oxygen, water, acetaldehyde, propionaldehyde, acetone, acetic acid, formaldehyde, etc.) is very costly. The economic viability of the selective oxidation processes described is therefore
30 determined critically on the costs of useful product isolation.

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The object of the present invention is the provision of a process for the continuous synthesis of epoxides by partial catalytic gas phase oxidation of hydrocarbons in the presence of oxygen and a reducing agent and subsequent continuous quantitative isolation of the partial oxidation product by ab(de)sorption in/from water.

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Another object of the present invention is the provision of a process in which a high total conversion of alkene is produced.

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Another object of the present invention is the provision of a process in which the partially oxidised hydrocarbon can be isolated as quantitatively and as continuously as possible.

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According to the invention, this object is achieved by a process for the catalytic partial oxidation of hydrocarbons in the presence of oxygen and at least one reducing agent, characterised in that the reaction mixture is passed through a layer which contains a catalyst and a downstream absorption layer which contains water in which the partially oxidised hydrocarbons are absorbed.

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The expression hydrocarbon is understood to mean unsaturated or saturated hydrocarbons such as olefins or alkanes which may also contain heteroatoms such as N, O, P, S or halogens. The organic component to be oxidised may be acyclic, monocyclic, bicyclic or polycyclic and may be monoolefinic, diolefinic or polyolefinic.

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In the case of hydrocarbons with two or more double bonds, the double bonds may be conjugated or non-conjugated. Hydrocarbons from which those oxidation products are formed which have partial pressures low enough for the product to be constantly removed from the catalyst are preferably oxidised. Unsaturated and saturated hydrocarbons with 2 to 20, preferably 2 to 12 hydrocarbon atoms are preferred, in particular ethene, ethane, propene, propane, isobutane, isobutylene, 1-

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butene, 2-butene, cis-2-butene, trans-2-butene, 1,3-butadiene, pentenes, pentane, 1-hexene, hexenes, hexane, hexadiene, cyclohexene, benzene.

5 The oxygen may be used in a wide variety of forms, e.g. molecular oxygen, air and/or nitrogen oxide. Molecular oxygen is preferred.

10 Hydrogen in particular is suitable as a reducing agent. Any known source of hydrogen may be used such as e.g. pure hydrogen, cracker hydrogen, synthesis gas or hydrogen from the dehydrogenation of hydrocarbons and alcohols. In another embodiment of the invention, hydrogen may also be produced in situ in an upstream reactor, e.g. by the dehydrogenation of propane or isobutane or alcohols such as isobutanol. The hydrogen may also be introduced into the reaction system as a complex-bonded species, e.g. a catalyst/hydrogen complex.

15 A diluent gas such as nitrogen, helium, argon, methane, carbon dioxide, carbon monoxide or similar gases which are largely inert may also optionally be used in addition to the essential reactant gases described above. Mixtures of the inert components described may also be used. Addition of the inert component is often beneficial with regard to transport of the heat being released in this exothermic
20 oxidation reaction and from a safety point of view. If the process according to the invention is performed in the gas phase, gaseous diluent components such as e.g. nitrogen, helium, argon, methane and possibly water vapour and carbon dioxide are preferably used. Although water vapour and carbon dioxide are not completely inert, they often have a positive effect at low concentrations (<2 vol.%) of all the reaction
25 gases.

The relative molar ratios of hydrocarbon, oxygen, reducing agent (in particular hydrogen) and optionally a diluent gas can be varied between wide limits.

30 Oxygen is preferably used in the range 1-30 mol%, particularly preferably 5-25 mol%. (with reference to the feed gas or the circulating gas.)

An excess of hydrocarbon, with respect to the oxygen used (on a molar basis), is preferably used. The hydrocarbon concentration is typically greater than 1 mol% and less than 96 mol%. Hydrocarbon concentrations in the range of preferably 5 to 90 mol%, particularly preferably 20 to 85 mol% are used. The molar proportion of reducing agent (in particular the proportion of hydrogen), with respect to the total number of moles of hydrocarbon, oxygen, reducing agent and diluent gas, can be varied between wide limits. Typical reducing agent concentrations are greater than 0.1 mol%, preferably 2-80 mol%, particularly preferably 3-70 mol%.

Compositions which contain noble metal particles with a diameter less than 10 nm on a support material which contains metal oxide and silicon oxide are advantageously used as catalysts.

Gold and/or silver are preferably used as noble metal particles. The gold particles preferably have a diameter in the range 0.3 to 10 nm, preferably 0.9 to 9 nm and particularly preferably 1.0 to 8 nm. The silver particles preferably have a diameter in the range 0.5 to 50 nm, preferably 0.5 to 20 nm and particularly preferably 0.5 to 15 nm.

The hybrid support materials mentioned in DE-A1-199 59 525 and DE-A1-100 23 717, inter alia, may be used as catalyst support materials.

Organic-inorganic hybrid materials in the context of the invention are organically modified glasses which are preferably produced in a sol-gel process via the hydrolysis and condensation reactions of soluble precursor compounds and contain non-hydrolysable terminal and/or bridging organic groups in the network. These materials and the preparation thereof is disclosed, inter alia, in DE-A1-199 59 525, DE-A1-100 23 717, which are herewith included in the present application as reference material for the purposes of US patent practice.

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To generate gold particles on the support materials, the processes disclosed in documents US-A-5 623 090, WO-98/00413-A1, WO-98/00415-A1, WO-98/00414-A1, WO-00/59632-A1, EP-A1-0827779 and WO-99/43431-A1 are suitable, such as deposition-precipitation, coprecipitation, impregnation in a solution, incipient wetness, colloid processes, sputtering, CVD (chemical vapor deposition), PVD (physical vapor deposition) and microemulsion.

The methods of incipient wetness, solvent impregnation and a combination of impregnating the support materials with noble metal precursors and then immediately drying by a spray or fluidised bed technique are disclosed in applications DE-A1-199 59 525, DE-A1-100 23 717 and are particularly advantageous.

The support materials may also contain, as promoters, proportions of metals from group 5 of the Periodic System according to IUPAC (1985) such as vanadium, niobium, and tantalum, from group 3, preferably yttrium, from group 4, preferably zirconium, from group 8, preferably Fe, from group 15, preferably antimony, from group 13, preferably aluminium, boron, thallium and metals from group 14, preferably germanium and from groups 1 and 2, preferably sodium and/or caesium and/or magnesium and/or calcium. The additional metals (promoters) are frequently present in the oxidic form.

The noble metal-containing compositions according to the invention can be used at temperatures $>10^{\circ}\text{C}$, preferably in the range $80\text{-}230^{\circ}\text{C}$, particularly preferably in the range $120\text{-}210^{\circ}\text{C}$. At the higher temperatures, steam, as an energy carrier, may be produced in a coupled plant. With skilful process management, the steam can be used, for example, to work up the product.

The oxidation reaction is advantageously performed at elevated reaction pressures. Reaction pressures of >1 bar, particularly preferably $2\text{-}30$ bar are preferred.

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The catalyst loading can be varied between wide limits. Catalyst loadings of 0.5-100 l of gas (feed gas or circulating gas) per ml of catalyst per hour are preferably used, with catalyst loadings of 2-50 l of gas per ml of catalyst per hour being particularly preferably chosen.

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In the case of the catalytic oxidation of hydrocarbons in the presence of hydrogen, water is generally produced as a product coupled with the corresponding selective oxidation product.

10 Surprisingly, continuous separation of the partial oxidation products produced during direct oxidation in the presence of oxygen and a reducing agent from the reaction mixture is successful even in the presence of acidic secondary products by selective absorption in water **without** decomposition or the production of further products of these absorption products.

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Water is used as the preferred absorption agent.

In some cases, the absorption agent may also contain additives which, for example, increase the solubility of the partially oxidised hydrocarbon (solution promoter) or
20 inhibit further reaction of the partial oxidation products with water, possibly catalysed by acidic or basic secondary products (stabilisers).

Suitable additives to perform the function of "solution promoter" are, inter alia, functionalised hydrocarbons such as lower alcohols, ketones and ethers.

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Suitable additives to perform the function of "stabilisers" are, for example, bases, acids, buffer systems or salts. In some cases increasing the pH to e.g. a constant 7-9 results in a clear increase in stability of the epoxide in aqueous medium in the presence of reaction-typical secondary products such as aldehydes and/or carboxylic
30 acids.

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Hydrocarbon oxide absorption in water is favoured by increasing pressures and/or decreasing temperatures and reduced by heating and/or lowering the pressure.

Hydrocarbon oxide absorption advantageously takes place at the reaction pressure (e.g. at 5-30 bar). Subsequent hydrocarbon oxide desorption then advantageously takes place under reduced pressure. For economic reasons, a compromise has to be made between easier hydrocarbon oxide desorption at low pressures and the costs of subsequent gas compression. A pressure difference between absorption and desorption of ≤ 30 bar, particularly preferably < 25 bar, is used.

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A flow chart of an overall process for the partial oxidation of propene to propene oxide in the presence of oxygen and hydrogen with continuous ab(de)sorption in/from water is shown in figure 1. (Fig. 1: PO absorption/desorption in/from water).

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Here, 1 is the feed, 2 is the reactor, 3 is a heat-exchanger, 4 is the absorber, 5 is a blower, 6 is a reservoir, 7 is a heat-exchanger, 8 is the desorber, 9 is the enrichment section, 10 is a storage tank and 11 is fresh water and/or the removal of secondary products.

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During the catalytic partial oxidation of propene with an oxygen/hydrogen mixture a reaction mixture is obtained consisting, for example, of 1.5 vol.% propene oxide, 0.1 vol.% propionaldehyde, 0.1 vol.% acetaldehyde, 0.1 vol.% acetone, 0.02 vol.% acetic acid and 0.05 vol.% propylene glycol. The propene oxide can be virtually quantitatively and continuously isolated in accordance with figure 1.

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The organic partial oxidation products in the reaction gas stream are absorbed quantitatively in water. The entire reaction gas stream, at the reaction pressure, is advantageously passed from the bottom through an absorber column with a large number of plates, while water runs in counterflow from top to bottom.

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The gas stream depleted in partial oxidation products is preferably recycled to the reactor for repeated reaction, for example using a blower, optionally after further purification, e.g. drying. This gas stream consists substantially of unreacted hydrocarbons, reducing agent, oxygen and optionally a diluent gas. When using a
5 blower with moving parts, it has to be reckoned that there is always, in principle, a slightly increased risk of explosion. The risk of explosion in the compressor could, in some cases, be reduced by adding small amounts of water vapour.

Substantially increased total conversions can be achieved by using this circulating
10 mode of operation with regular separation of the reaction products. Concentrating the reaction products by absorption in water greatly lowers the processing costs for isolation of the hydrocarbon.

The absorption column is advantageously operated in counterflow, i.e. the reaction
15 gas mixture flows from the bottom to the top and the water flows in counterflow from the top to the bottom. This counterflow absorption process takes place continuously and preferably at the reaction pressure. A mode of operation in which the absorber pressure is 3-20 bar and the absorption temperature is 15-50°C is particularly preferred. As a cooling medium cooling water or brine, for example, is
20 used at, for example, 20°C in counterflow to the process medium.

The water enriched with propene oxide and other partial oxidation products then passes, for example, into a reservoir which is under the reaction pressure and which acts as a expansion vessel for a pump which feeds the contents of the reservoir
25 against a pressure retainer into a region in which the system pressure (0.5-10 bar) is lower than in the reactor and absorber. Here, the low-boiling components such as propene oxide, acetaldehyde, propionaldehyde and acetone, partly desorb. The desorption process is preferably increased still further by heating the laden water mixture in a heat-exchanger. Here, temperatures of 60 to 150°C are suitable.
30 Concentration of the propene oxide takes place in many cases directly in the enrichment section above the desorber column.

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Isolation of propene oxide from other highly-volatile partial oxidation products takes place in a downstream precision distillation section.

- 5 The heat of reaction produced during partial oxidation is advantageously used in the plant section *Desorption*, for example when operating the reactor as a circulation evaporator for the desorption column.

- 10 Particularly preferably, propene is oxidised to propene oxide in the process according to the invention.

The characteristic properties of the present invention are explained in the following examples using test reactions.

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Examples**Procedure used in the test for continuous absorption of catalytically prepared crude propene oxide and secondary products in water with subsequent desorption (test procedure)**

A metal tubular reactor with 15 mm internal diameter and 100 cm long was used and the temperature was kept constant with an oil thermostat. The reactor was provided with a set of four mass flow regulators (hydrocarbon, oxygen, hydrogen, nitrogen) for the reactant gases. A gas stream for performing oxidation reactions, always called the standard gas composition in the following, was chosen:

$\text{H}_2 / \text{O}_2 / \text{C}_3\text{H}_6 : 60 / 10 / 30 \text{ vol.}\%$

For reaction, 60 g of moulded items with an active substance content of 20 % (2x2 mm extrudates) were initially introduced at 165°C and 3 bar. The active substance loading was 10 l gas/(g active substance x h). Propene, for example, was used as a hydrocarbon. The catalyst productivity, when using propene as the hydrocarbon, was 400 g propene oxide/(kg active substance x h). The reaction gas stream was then cooled to 35°C using a heat-exchanger and passed into a downstream counterflow absorber (metal tube, 20 mm internal diameter and 100 cm long; filled with 3x3 netting wire rings) under the system pressure. Water (800 g/h) flowed from top to bottom against the gas stream. The water laden with organics passed into an expansion reservoir. From there the mixture passed into a heat-exchanger, was heated there to 95°C and the pressure was decreased to atmospheric pressure, downstream of a pressure retention valve, in the desorber held at 100°C (20 mm internal diameter; 100 cm long; filled with 3x3 netting wire rings).

The reflux ratio was, for example, 5-20. The low-boiling fraction consisting of, inter alia, propene oxide, propionaldehyde, acetone, acetaldehyde, passed to the head of the column, condensed and was condensed in the storage vessel cooled to 5°C.

The reaction gases were analysed by gas chromatography downstream of the reactor (sample 1) and above the absorber head (sample 2) (a combined FID/WLD method, in which the gas passed through three capillary columns). The water laden with organics was analysed upstream of the reservoir (sample 3) and at the base of the desorption column (sample 4), using gas chromatography (FID; FFAP column). The contents of the cooled storage vessel were also analysed using gas chromatography with FID (sample 5). (FID = Flamm-Ionisation-Detektor [= flame ionisation detector]; WLD = Wärme-Leitfähigkeits-Detektor [= heat conductivity detector])

10 **Catalyst preparation**

This example describes firstly the preparation of a powdered catalytically active organic-inorganic hybrid material consisting of a silicon and titanium-containing organic-inorganic hybrid material with free silane hydrogen units which has been coated with gold particles (0.04 wt.%) using the incipient wetness method. Then the finely powdered catalyst material is converted into an extrudate.

184.29 g of methyltrimethoxysilane (1.35 mol) and 25.24 g of triethoxysilane (153.6 mmol) were initially introduced. 44.79 g of p-toluenesulfonic acid (0.1 N) are added and then 17.14 g of tetrapropoxytitanium, dissolved in 40 g of ethanol, are also added. After an ageing period of 12 h, the gel was washed twice using 200 ml of hexane each time and then dried for 2 h at RT and for 8 hours at 120°C in air.

10.1 g of dried sol-gel material were impregnated with 5 g of a 0.16 % strength solution of $\text{HAuCl}_4 \times \text{H}_2\text{O}$ in methanol, with stirring (incipient wetness), dried at RT in a stream of air, then for 8 h at 120°C under air and then conditioned for 5 h at 400°C under an atmosphere of nitrogen. The catalytically active organic-inorganic hybrid material prepared in this way contained 0.04 wt.% of gold.

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Formation of an extrudate

8.5 g of organic-inorganic hybrid material, synthesised in accordance with the catalyst preparation described above, were intensively mixed with 5 g of silicon dioxide sol (Levasil, Bayer, 300 m²/g, 30 wt.% SiO₂ in water) and 1.0 g of SiO₂ powder (Ultrasil VN3, Degussa) for 2 h. 2 g of sodium silicate solution (Aldrich) were added to the plastic material obtained, the mixture was intensively homogenised for 5 min and then moulded in an extruder to form 2 mm strands. The strands prepared in this way were first dried for 8 h at room temperature and then for 5 h at 120°C and finally conditioned at 400°C for 4 h under an atmosphere of nitrogen. The mechanically stable moulded items had a high resistance to lateral pressure.

The conditioned 2x2 mm moulded items were used as a catalyst in the gas phase epoxidation of propene with molecular oxygen in the presence of hydrogen.

Example 1

The reaction gas (analysis at reactor outlet; before the adsorber; sample 1) contained 1.5 vol.% propene oxide, 2.5 vol.% water and 0.05 vol.% secondary products (including acetaldehyde, propionaldehyde, acetone, acetic acid) at the reactor outlet. The reaction gas was passed, at the reaction pressure (3 bar), from below into a counterflow absorber which was completely filled with netting wire rings (3 x 3 mm). The pressure of the non-absorbed gas is allowed to return to atmospheric pressure at the head of the absorber and is analysed by gas chromatography. The concentrations of propene oxide and the partial oxidation products produced as secondary products were below the limits of detection at this point. The absorption process for the condensable organic compounds had proceeded virtually quantitatively.

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The water laden with partial oxidation products is heated to 95°C in a heat-exchanger and decompressed into the desorption column (the desorption column had a temperature of 100°C at the lateral entry point). With a reflux ratio of 1 : 10, a temperature of 45°C is produced at the head of the column. The container, cooled to 5°C, contains 70 vol.% organic compounds and 30 vol.% water. The organic compounds, for their part, consist of >94 vol.% propene oxide, 2 vol.% propionaldehyde, 1 vol.% acetaldehyde and traces of acetone and butanedione. The base of the column contains no propene oxide or acetaldehyde or propionaldehyde. Only traces of glycol are detectable.

Overall, >95 vol.% of the propene oxide found in the reaction gas can be isolated in a single pass.

Example 2

Example 2 is similar to example 1, but the reflux ratio in the desorption column is 1 : 15.

With a reflux ratio of 1 : 15, a temperature of 40°C is produced at the head of the column. The container, cooled to 5°C, contains 78 vol.% organic compounds and 22 vol.% water. The organic compounds, for their part, consist of 94 vol.% propene oxide, 2 vol.% propionaldehyde, 1 vol.% acetaldehyde and traces of acetone and butanedione. The base of the column contains no propene oxide or acetaldehyde or propionaldehyde. Only traces of glycol and carboxylic acids are detectable.

Overall, 94 vol.% of the propene oxide found in the reaction gas can be isolated in a single pass.

Example 3

Example 3 proceeds in the same way as example 1, but the system pressure for reactor and absorber is 5 bar.

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With a reflux ratio of 1 : 10, a temperature of 37°C is produced at the head of the desorber column. The container, cooled to 5°C, contains 90 vol.% organic compounds and 10 vol.% water. The organic compounds, for their part, consist of 92 vol.% propene oxide, 2 vol.% propionaldehyde, 1.1 vol.% acetaldehyde and traces of acetone and butanedione. The base of the column contains no propene oxide or acetaldehyde or propionaldehyde. Only traces of glycol and carboxylic acids are detectable.

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Overall, 93 vol.% of the propene oxide found in the reaction gas can be isolated in a single pass.

Example 4

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Example 4 proceeds in the same way as example 1 but the unreacted feed gas, after the absorber, is returned to the reactor using a blower.

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The reaction gas, after passage through the absorber, downstream of the head of the desorber, has the following composition: 58 % H₂, 8.5 % O₂, 27.5 % C₃H₆, 0.2 % water, 0.005 % propene oxide, 0.001 % acetaldehyde. This gas was returned to the reactor using a blower.

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The reaction gas (analysis at the reactor outlet; before the absorber; sample 1) contained 1.4 vol.% propene oxide, 2.1 vol.% water and 0.05 vol.% secondary products (including acetaldehyde, propionaldehyde, acetone, acetic acid) at the reactor outlet.

Claims

1. A process for the catalytic partial oxidation of hydrocarbons in the presence of oxygen and at least one reducing agent, characterised in that the reaction mixture is passed through a layer which contains a catalyst and a downstream layer which contains an aqueous absorption agent in which the partially oxidised hydrocarbons are absorbed quantitatively.
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2. A process according to claim 1, characterised in that the reaction gas is recycled to the reaction after absorption of the partially oxidised hydrocarbons.
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3. A process according to claim 1 or 2, characterised in that absorption of the partially oxidised hydrocarbon is performed in the presence of non-condensable gases such as oxygen and hydrogen.
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4. A process according to claim 1 to 3, characterised in that the heat produced during reaction is used integrally during the working up procedure consisting, inter alia, of absorption in water and desorption from water.
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5. A process according to one of claims 1 to 4, characterised in that water is used as the absorption agent.
6. A process according to one of claims 1 to 4, characterised in that the pH of the water is held constant in the range 4-9 using bases and/or buffer systems.
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7. A process according to one of claims 1 to 5, characterised in that the absorbed partial oxidation products are separated into lights and heavies using a desorption column.
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8. A process according to claim 6, characterised in that desorption takes place with partial pressure release and elevated temperatures in the range 70-150°C.