the catalyst, to be carried out on an industrially-relevant scale economically.

This object is achieved by a device according to claim 1.

In an ~~embodiment first aspect~~, the disclosure relates to a device for the continuous homogeneous-catalytic reaction of a liquid with a gas and optionally a further fluid, wherein the device comprises at least one jet loop reactor having a pump-driven external liquid circuit, and wherein the device comprises at least one membrane separation stage that preferably retains the homogeneous catalyst, characterized in that the reactor is a jet loop reactor, and in that pump and membrane separation stage are arranged in the same external liquid circuit.

In a first aspect, there is provided a device for the continuous homogeneous-catalytic reaction of a liquid with a gas and optionally a further fluid, wherein the device comprises at least one reactor having a pump-driven external liquid circuit, and wherein the device comprises at least one membrane separation stage which have a molecular weight cutoff (MWCO) in the range from 150 g/mol to over 1 nm and that preferably retains the homogeneous catalyst, whereby the reactor is a jet loop reactor, and in that pump and membrane separation stage are arranged in the same external liquid circuit, characterized in that a permeate-side free volume is provided in the membrane separation stage, which free volume is at least 0.3 $dm^3$ per $m^2$ of membrane surface.

The disclosure is based on the knowledge that a jet loop reactor and nanofiltration may be combined to form a device which permits economic carrying out of a hydroformylation on a commercial format. Fundamental to the economic efficiency of the process is simple structure of the process with as few plant components as possible and also marked retention and recirculation of the active catalyst to the reaction. A process reduced to the essential components results from the direct integration of the membrane separation into the external circuit of the jet loop reactor. This additionally permits separation of the catalyst and optionally of the free ligand under reaction conditions.

In a second aspect, the disclosure relates to a process for the homogeneous-catalytic reaction of a liquid with a gas and optionally a further fluid,
characterized in that
the reaction is carried out in a device as defined above, and in that the target product of the reaction is discharged from the liquid circuit together with the permeate of the membrane separation stage.

In a third aspect, the disclosure relates to the use of a device as defined above for carrying out homogeneous-catalytic reactions, in particular for hydroformylation.

Use of commercially available membrane modules for reaction mixtures having dissolved and/or non-dissolved gas fractions is not possible, since they are not designed for adequate permeate-side gas removal and, depending on the amount of the permeate-side gas volumetric flow rate to be removed, build up a counterpressure on the permeate side which decreases the liquid permeate output or can even lead to destruction of the membrane. It has been found that using membrane modules which, per square meter of active membrane area, a permeate-side free volume of greater than 0.3 cubic decimeter ($dm^3$, equivalent to 1 liter) are necessary for gas streams occurring on the permeate side. The greater the permeate-side gas stream, the greater must the free permeate-side volume be. Surprisingly, it has additionally been found that the retention of the catalyst, in process streams containing a gas phase at the latest on the permeate side, is increased with the increase in permeate-side free volume.

## Claims

1. A device for the continuous homogeneous-catalytic reaction of a liquid with a gas and optionally a further fluid, wherein the device comprises at least one reactor having a pump-driven external liquid circuit, and wherein the device comprises at least one membrane separation stage which have a molecular weight cutoff (MWCO) in the range from 150 g/mol to over 1 nm and that preferably retains the homogeneous catalyst,
~~characterized in that~~
whereby the reactor is a jet loop reactor, and in that pump and membrane separation stage are arranged in the same external liquid circuit.~~,~~

~~2. The device as claimed in claim 1,~~
characterized in that
a permeate-side free volume is provided in the membrane separation stage, which free volume is at least 0.3 $dm^3$ per $m^2$ of membrane surface.

2~~3~~. The device as claimed in claim 1 ~~or 2~~,
characterized in that
the pump is equipped structurally for long-term pumping of fluids which contain liquid and gaseous phases.

3~~4~~. The device as claimed in claim 2~~3~~,
characterized in that
the pump is a peripheral impeller pump.

4~~5~~. The device as claimed in any one of the preceding claims, characterized by a permeate-side gas discharge arranged downstream of the membrane separation stage.

5~~6~~. The device as claimed in any one of the preceding claims,
characterized in that
a heat exchanger for heating or cooling the feed or the permeate of the membrane separation stage is arranged in the external liquid circuit, in particular upstream of the membrane separation stage.

6~~7~~. The device as claimed in any one of the preceding claims,
characterized in that

a tubular reaction space extends in the jet loop reactor, into which tubular reaction space a jet nozzle for injecting the liquid into the reaction space and also a suction tube for extracting the gas by suction both open out, and on which is provided a baffle plate-shielded takeoff for the external liquid circuit.

78. The device as claimed in any one of the preceding claims, characterized by at least one bypass conduit which is arranged in the external liquid circuit in parallel to the jet loop reactor or to the membrane separation stage.

89. The device as claimed in any one of the preceding claims, characterized in that
a multiplicity of jet loop reactors that are connectable in parallel and have a shared external liquid circuit are provided, wherein the membrane separation stage is arranged within the shared external liquid circuit.

910. The device as claimed in claim 98, characterized in that
the membrane separation stage comprises a multiplicity of membranes that are connectable in parallel in such a manner that the entire active membrane surface area of the membrane separation stage is adjustable by connecting and disconnecting the membranes.

101. A process for the homogeneous-catalytic reaction of a liquid with a gas and optionally a further fluid, characterized in that
the reaction is carried out in a device according to any one of claims 1 to 109, and in that the target product of the reaction is discharged from the liquid circuit together with the permeate of the membrane separation stage.

112. The process as claimed in claim 1110, characterized in that
the external liquid circuit upstream of the membrane separation stage is a mixture which comprises a liquid phase and a gaseous

phase dispersely distributed therein, wherein the volume fraction of the gaseous phase is between zero and thirty percent.

123. The process as claimed in claim 101 or 112, characterized in that oxidations, epoxidations, hydroformylations, hydroaminations, hydroaminomethylations, hydrocyanations, hydrocarboxyalkylation, aminations, ammonoxidation, oximations, hydrosilylations, ethoxylations, propoxylations, carbonylations, telomerizations, methatheses, Suzuki couplings or hydrogenations are carried out in the device.

134. The process as claimed in claim 1312, characterized in that compounds having olefinic double bonds are reacted with synthesis gas to form aldehydes and/or alcohols by hydroformylation.

145. The use of a device as claimed in any one of claims 1 to 10 9 for carrying out homogeneous-catalytic reactions, in particular for hydroformylation.