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

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

~~The invention therefore~~In a 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, ~~which~~ wherein the device comprises at least one jet loop reactor having a pump-driven external liquid circuit, and ~~which~~ 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 ~~which~~ that pump and membrane separation stage are arranged in the same external liquid circuit.

The ~~invention~~ 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.

A particularly preferred development of the ~~invention~~ disclosure therefore provides 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.

Permeate-side volume is taken to mean the volume following on the permeate side perpendicular to the active membrane surface. The permeate-side free volume is the fraction of the permeate-side volume which is not filled with material apart from the permeate.

In a preferred embodiment of the ~~invention~~disclosure, the pump is equipped structurally for long-term pumping of fluids which contain liquid and gaseous phases. Particularly preferably, pumps should be used which in addition can also transport a small solids fraction.

For this purpose, peripheral impeller pumps are particularly suitable. They can transport in the long term fluid mixtures which contain a liquid phase and a gaseous phase. Small solids fractions are not a problem. A peripheral impeller pump is a particular type of a centrifugal pump having an annular peripheral channel in which the pump rotor rotates. The pump rotor is usually constructed as a circular disk having a multiplicity of radially extending projections on the disk. The projections run in the region of the peripheral channel. The fluid is drawn in by suction through a suction port and passed through the annular channel in which the pump rotor rotates. This consists of straight paddles which place the fluid into a rotary motion. In the peripheral channel, therefore, the energy of motion is transferred from the paddles to the medium, as a result of which the pressure is increased. The fluid leaves the peripheral impeller pump through an outlet port after it has flowed through the peripheral channel. Peripheral impeller pumps are commercially available from K-ENGINEERING Mischtechnik und Maschinenbau, 26871 Papenburg (Germany) or from SPECK PUMPEN Verkaufsgesellschaft GmbH, 91231 Neunkirchen a. Sand (Germany).

In order to avoid deactivation of the catalyst and damage of the membrane due to degassing, and also to achieve an improved membrane retention, the permeate of the membrane separation stage needs to be degassed in a controlled manner. In addition to the permeate-side free volume dimensioned as above, a permeate-side gas discharge needs to be

provided arranged downstream of the membrane separation stage. Such a gas discharge should be constructed as follows:

The core piece of the gas discharge is a compensating vessel in which liquid and gaseous phases are separated from one another. The two-phase permeate stream is fed to the vessel in order that liquid phase and gas phase can separate. A pressure maintaining device which removes gas until the preset pressure is reached is connected to the gas phase. In addition, a compressed gas feed is mounted on the vessel, which compressed gas feed permits the preset gas pressure to be held constant, for instance when the liquid level in the vessel is falling.

The suitable membrane material must be selected with respect to the catalyst complex that is to be separated off: Since the permeability of a membrane for the various components of the feed that is to be separated is ultimately a function of time (the membrane is not absolutely impermeable to a catalyst, its passage velocity is rather markedly slower in relation to the other reaction participants), the membrane must be selected in such a manner that the catalyst complex that is to be separated off is retained preferentially.

In the process according to the ~~invention~~ disclosed membranes can be used which, owing to their chemical or physical properties, are suitable for retaining organophosphorus metal-complex catalyst and/or free organophosphorus ligand preferably to an extent of at least 50%.

Corresponding membranes belong to the class of nanofiltration membranes. The expression nanofiltration is applied to membrane separation processes which have a separation limit or molecular weight cutoff (MWCO) in the range from 150 g/mol to over 1 nm. The magnitude of the separation limit or MWCO indicates the molecular or particle size of a component that has a membrane retention of 90%.
A usual method of determination for the separation limit is given in Y.H. See Toh, X.X. Loh, K. Li, A. Bismarck, A.G. Livingston, In search of a standard method for the characterisation of organic solvent nanofiltration membranes, J. Membr. Sci., 291 (2007) 120-125.