

added to the reactor and in which the product(s) remain in the reactor until the end of the run. However, such process is only useful if the desired reaction products are stable in the reactor. However, it is not uncommon that the reaction is reversible, thus leading to a too high concentration of substrate which may result in the formation of unwanted side products.

US20040211729 discloses a process and system for recovering oligomers and/or acid catalyst from wash streams using filter membranes, wherein the product stream is removed via a settler. The preferred operation of the process is a batch operation, and in case of a continuous operation there is no recycling of retentate. In addition, the reaction is not performed in dilute conditions.

WO88/05444 discloses a process and system for separation of synthetic water soluble polymers, wherein the polymerization reaction is performed as a batch reaction and wherein the product stream is charged to a membrane unit with recirculation of the permeate obtained after filtration to the reactor.

Thus, there is a need for processes and systems suitable for carrying out reactions which require maintaining one or more of the substrates at a low concentration, more particularly which are equally suitable for reactions wherein the reaction product is not stable in the reactor.

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SUMMARY

It is an aim of the present disclosure to provide a process for carrying out a chemical reaction of a substrate in a diluted reaction mixture which, compared to a batch process, requires significantly less solvent for the same amount of reaction product. It is a further aim of the present disclosure to provide such processes which are suitable for carrying out reactions wherein the reaction product is unstable under the applied reaction conditions.

In one aspect of the present disclosure, there is provided a continuous process for carrying out a chemical reaction of a substrate in a diluted reaction mixture comprising a solvent, the process comprising the steps of:

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- (a) simultaneously adding a substrate feed and a solvent for diluting said substrate feed to form a reaction mixture in a reactor; and causing said substrate to form a reaction product in said reaction mixture;

- (b) discharging, from an outlet of the reactor, reaction mixture comprising reaction product and solvent;
- (c) conducting the entire reaction mixture discharged in step (b) to a filtration membrane, whereby the filtration membrane is permeable to the solvent and
5 provided to be impermeable to the reaction product;
- (d) recycling solvent which permeates the filtration membrane for diluting said substrate feed in step (a); and
- (e) conducting the retentate from said filtration membrane to a reservoir other than said reactor, said retentate comprising reaction product.

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More particularly, provided herein is a continuous process for carrying out a chemical reaction of a substrate in a diluted reaction mixture comprising a solvent, the process comprising the steps of:

- (a) (simultaneously) adding a substrate feed and a solvent for diluting said substrate feed
15 to form a reaction mixture in a reactor; and causing said substrate to form a reaction product in said reaction mixture;
- (b) discharging, from an outlet of the reactor, reaction mixture comprising reaction product and solvent;

In certain embodiments, said filtration membrane has a reaction product rejection of at least 90%.

In particular embodiments, said filtration membrane has a substrate rejection of at least 95%.

- 5 In certain embodiments, said filtration membrane is selected from the group consisting of a nanofiltration membrane, a microfiltration membrane, an ultrafiltration membrane, a reverse osmosis filtration membrane, and combinations thereof.

In particular embodiments, the temperature within the filtration loop and reaction vessel may be different. More particularly, the temperature within the filtration loop feed tank and
10 the reaction vessel may be different. Most particularly, the temperature within the filtration loop feed tank may be lower than the temperature within the reaction vessel.

In another aspect of the present disclosure, there is provided a system for carrying out a chemical reaction of a substrate in a diluted reaction mixture comprising a solvent, comprising:

- 15 (i) a reactor comprising:
- a first, second, and third inlet; and
- a reactor outlet;
(ii) a first feed tank connected to said reactor via said first inlet;
(iii) a second feed tank connected to said reactor via said second inlet;
20 (iv) a filtration loop feed tank comprising:
- a first filtration loop feed tank inlet which is connected to said reactor via said reactor outlet;
- a second filtration loop feed tank inlet; and
- a filtration loop feed tank outlet;
25 and
(v) a filtration membrane configured for receiving a solution from said filtration loop feed tank outlet, said filtration membrane having a retentate side and a permeate side, whereby the filtration membrane is further configured for returning the permeate to said reactor via said third inlet, and for returning the retentate to said
30 filtration loop feed tank via said second filtration loop feed tank inlet.

In a further aspect of the present disclosure, there is provided a system for carrying out a chemical reaction of a substrate in a diluted reaction mixture comprising a solvent, comprising:

- (i) a reactor comprising:
 - a first and second inlet; and
 - a reactor outlet;
- (ii) a mixing vessel having an inlet and connected to said reactor via said first inlet;
- 5 (iii) a first feed tank connected to said mixing vessel;
- (iv) a second feed tank connected to said reactor via said second inlet;
- (v) a filtration loop feed tank comprising:
 - a first filtration loop feed tank inlet which is connected to said reactor via said reactor outlet;
 - 10 - a second filtration loop feed tank inlet; and
 - a filtration loop feed tank outlet;
 and
- (vi) a filtration membrane configured for receiving a solution from said filtration loop feed tank outlet, said filtration membrane having a retentate side and a permeate side, whereby the filtration membrane is further configured for returning the permeate to said mixing vessel via said inlet, and for returning the retentate to said filtration loop feed tank via said second filtration loop feed tank inlet.
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Further provided herein is a system for carrying out a chemical reaction of a substrate in a diluted reaction mixture comprising a solvent, comprising:

- 20 (i) a reactor (3) comprising:
 - a first, second, and third inlet (7, 8, 9); and
 - a reactor outlet (13);
- (ii) a first feed tank (1) connected to said reactor (3) via said first inlet (7);
- (iii) optionally, a second feed tank (2) connected to said reactor (3) via said second inlet
- 25 (8);
- (iv) a filtration loop feed tank (4) comprising:
 - a first filtration loop feed tank inlet (10) which is connected to said reactor (3) via said reactor outlet (13);
 - a second filtration loop feed tank inlet (11); and
 - 30 - a filtration loop feed tank outlet (14);
 and
- (v) a filtration membrane (5) configured for receiving a solution from said filtration loop feed tank outlet (14), said filtration membrane having a retentate side (15) and a permeate side (16), whereby the filtration membrane is further configured for returning the permeate to said reactor (3) via said third inlet (9), and for returning the
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retentate to said filtration loop feed tank (4) via said second filtration loop feed tank inlet (11).

In particular embodiments, said reactor (3) is a continuously stirred reactor.

- 5 Further provided herein is a system for carrying out a chemical reaction of a substrate in a diluted reaction mixture comprising a solvent, comprising:

- (i) a reactor (3) comprising:
 - a first and second inlet (7, 8); and
 - a reactor outlet (13);
- (ii) a mixing vessel (6) having an inlet (12) and connected to said reactor (3) via said first inlet (7);
- (iii) a first feed tank (1) connected to said mixing vessel (6);
- (iv) optionally, a second feed tank (2) connected to said reactor (3) via said second inlet (8);
- (v) a filtration loop feed tank (4) comprising:
 - a first filtration loop feed tank inlet (10) which is connected to said reactor (3) via said reactor outlet (13);
 - a second filtration loop feed tank inlet (11); and
 - a filtration loop feed tank outlet (14);and
- (vi) a filtration membrane (5) configured for receiving a solution from said filtration loop feed tank outlet (14), said filtration membrane having a retentate side (15) and a permeate side (16), whereby the filtration membrane is further configured for returning the permeate to said mixing vessel (6) via said inlet (12), and for returning the retentate to said filtration loop feed tank (4) via said second filtration loop feed tank inlet (11).

In particular embodiments, said reactor (3) is a continuously stirred reactor.

The inventors have found that the processes and systems described herein allow for obtaining similar or increased reaction product yield and/or product purity compared to a batch process at high dilution, while providing a much lower Process Mass Intensity (PMI). Accordingly, the present processes may assist the chemical industry in its efforts towards higher sustainability. The above and other characteristics, features and advantages of the concepts described herein will become apparent from the following detailed description, which illustrates, by way of example, the principles of the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

The following description of the figures of specific embodiments of the methods and instruments described herein is merely exemplary in nature and is not intended to limit the present teachings, their application or uses. Throughout the drawings, corresponding reference numerals indicate like or corresponding parts and features.

14. A system for carrying out a chemical reaction of a substrate in a diluted reaction mixture comprising a solvent, comprising:
- (i) a reactor comprising:
 - a first, second, and third inlet; and
 - 5 - a reactor outlet;
 - (ii) a first feed tank connected to said reactor via said first inlet;
 - (iii) a second feed tank connected to said reactor via said second inlet;
 - (iv) a filtration loop feed tank comprising:
 - 10 - a first filtration loop feed tank inlet which is connected to said reactor via said reactor outlet;
 - a second filtration loop feed tank inlet; and
 - a filtration loop feed tank outlet;
- and
- (v) a filtration membrane configured for receiving a solution from said filtration loop feed tank outlet, said filtration membrane having a retentate side and a permeate side, whereby the filtration membrane is further configured for returning the permeate to said reactor via said third inlet, and for returning the retentate to said filtration loop feed tank via said second filtration loop feed tank inlet.
15. A system for carrying out a chemical reaction of a substrate in a diluted reaction mixture comprising a solvent, comprising:
- (i) a reactor comprising:
 - a first and second inlet; and
 - 20 - a reactor outlet;
 - 25 (ii) a mixing vessel having an inlet and connected to said reactor via said first inlet;
 - (iii) a first feed tank connected to said mixing vessel;
 - (iv) a second feed tank connected to said reactor via said second inlet;
 - (v) a filtration loop feed tank comprising:
 - 30 - a first filtration loop feed tank inlet which is connected to said reactor via said reactor outlet;
 - a second filtration loop feed tank inlet; and
 - a filtration loop feed tank outlet;
- and

- (vi) a filtration membrane configured for receiving a solution from said filtration loop feed tank outlet , said filtration membrane having a retentate side and a permeate side, whereby the filtration membrane is further configured for returning the permeate to said mixing vessel via said inlet, and for returning the retentate to said filtration loop feed tank via said second filtration loop feed tank inlet.
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16. The system according to claims 14 or 15 wherein the reactor is provided with a mixing means.
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17. The system according to any of claims 14 to 16, further comprising means for adjusting the rate at which reaction mixture is discharged from the filtration loop feed tank and the substrate addition rate, in function of the membrane flux.