Claims

1. Process for preparing methyl methacrylate and/or methacrylic acid, comprising the process steps of:

a. the reacting of acetone cyanohydrin and sulfuric acid in one or more reactors I in a first reaction stage at a temperature in the range from 70°C to 130°C to obtain a first reaction mixture comprising sulfoxyisobutyramide and methacrylamide;

b. the converting of the first reaction mixture, comprising heating to a temperature in the range from 130 to 200°C, in one or more reactors II in a second reaction stage to obtain a second reaction mixture comprising predominantly methacrylamide and sulfuric acid; and

c. the reacting of the second reaction mixture with water and optionally methanol in one or more reactors III in a third reaction stage to obtain a third reaction mixture comprising methacrylic acid and/or methyl methacrylate;

wherein

(i) the sulfuric acid used in the first reaction stage, which is fed in at one or more points in the reactors I, has a concentration in the range from 98.0% by weight to 100.5% by weight,

(ii) the dwell time of the first reaction mixture in the second reaction stage is in the range from 2 to 15 min,

(iii) the heating in the second reaction stage is performed in one or more reactors II, wherein at least one reactor II comprises at least one preheater segment comprising one or more linear pipeline elements that are heated by means of a heating medium spatially separate from the reaction mixture, wherein the reaction mixture is heated by 10 to 100°C,

(iv) the converting in the second reaction stage is performed in one or more reactors II, wherein at least one reactor II comprises at least

one delay segment which is operated under virtually adiabatic conditions,

(v) the preheater segment and/or the delay segment are implemented in a combination of linear pipeline elements and deflections, wherein the linear pipeline elements and the deflections are connected to one another via reducing flanges,

(vi) the second reaction mixture obtained in step b, comprising predominantly methacrylamide and sulfuric acid, is optionally cooled down to a temperature below 120°C, and/or optionally intermediately buffered in an intermediate vessel, before the reaction mixture is guided into the third reaction stage.

2. Process according to Claim 1, characterized in that the superficial volume of the linear pipeline elements relative to the superficial volume of the deflections in the preheater segment and/or in the delay segment corresponds to a ratio in the range from 1.0 to 75.0.

3. Process according to Claim 1 or 2, characterized in that, in the preheater segment, the linear pipeline elements are executed in one or more straight pipelines having an internal diameter in the range from 8 mm to 200 mm, wherein the pipelines of the linear pipeline elements in the preheater segment have a smaller internal diameter than the pipelines of the linear pipeline elements in the delay segment.

4. Process according to at least one of Claims 1 to 3, characterized in that the linear pipeline elements in the preheater segment and/or in the delay segment of the at least one reactor II are executed in parallel bundles of tubes, and these bundles of tubes are connected by means of at least one deflection, wherein the deflection is configured as a pipeline comprising a first section having an internal cross section that runs convergently in flow direction, a second section having an essentially constant internal cross-sectional area, and a third section having an internal cross section that runs divergently in flow direction.

5. Process according to at least one of Claims 1 to 4, characterized in that at least one preheater segment comprises linear pipeline elements and deflections, wherein the linear pipeline elements of the preheater segment comprise 1 to 50 separate straight

pipelines that are secondarily heated with a heating medium and are arranged parallel to one another, and wherein the deflections that connect the linear pipeline elements to one another comprise at least one pipeline.

6. Process according to at least one of Claims 1 to 5, characterized in that the deflections are formed from pipeline elements having an inflection of 90° to 180°.

7. Process according to at least one of Claims 1 to 6, characterized in that an average speed of the reaction mixture of 0.2 to 3 m/sec is established within the deflections and the variance in the local speed at any point within the deflections from the average conveying speed is not more than 30%.

8. Process according to at least one of Claims 1 to 7, characterized in that at least one intermediate conversion between at least two first reaction stages takes place in the performance of the first reaction stage and the second reaction stage, wherein the at least two reactors II for the conversion are implemented by at least one shell-and-tube heat exchanger as preheater segment, combined with at least one delay zone as delay segment.

9. Process according to Claim 8, characterized in that at least two reactors I are used, wherein at least one reactor II comprising at least one preheater segment and/or delay segment between the reactors I, and at least one reactor II comprising at least one preheater segment and/or delay segment at the exit from the first reaction stage are used.

10. Process according to at least one of Claims 1 to 9, characterized in that at least 60% of the static dwell time of at least one second reaction stage is implemented in a dwell segment executed as a pipeline.

11. Process according to at least one of Claims 1 to 10, characterized in that the first reaction mixture resulting from the first reaction stage, proceeding from at least one reactor I, is conveyed through at least one reactor II at a constantly controlled mass flow rate by means of a discharge pump.

12. Process according to at least one of Claims 1 to 11, characterized in that at least one preheater segment in at least one reactor II is configured as a shell-and-tube heat exchanger, wherein the reaction mixture flows through the shell-and-tube heat

~~exchanger on the tube side, and the free cross-sectional area of the tubes used in the shell-and-tube heat exchanger ensures an average flow rate of at least 0.2 m/s in the tubes.~~

~~13. Apparatus for performance of the process according to any of Claims 1 to 12, wherein the apparatus in each case comprises one or more reactors I, II and III that are connected to one another by pipeline elements, and wherein at least one reactor II comprises at least one preheater segment and at least one delay segment, wherein the preheater segment comprises one or more linear pipeline elements that are heated by means of a heating medium spatially separate from the reaction mixture, and wherein the delay segment is operated under virtually adiabatic conditions, and wherein the preheater segment and/or the delay segment are implemented in a combination of linear pipeline elements and deflections, wherein the linear pipeline elements and the deflections are connected to one another via reducing flanges.~~

~~14. Apparatus according to Claim 13, characterized in that the superficial volume of the linear pipeline elements relative to the superficial volume of the deflections in the preheater segment and/or in the delay segment corresponds to a ratio in the range from 1.0 to 75.0.~~

~~15. Apparatus according to Claim 14 or 15, characterized in that, in the preheater segment, the linear pipeline elements are executed in one or more straight pipelines having an internal diameter in the range from 8 mm to 200 mm, wherein the pipelines of the linear pipeline elements in the preheater segment have a smaller internal diameter than the pipelines of the linear pipeline elements in the delay segment.~~

~~16. Apparatus according to at least one of Claims 13 to 15, characterized in that the deflections are formed from pipeline elements having an inflection of 90° to 180°.~~

~~17. Apparatus according to at least one of Claims 13 to 16, characterized in that the linear pipeline elements of the preheater segment and/or of the delay segment are connected by deflections, wherein the deflections are an element that causes deflection by 180°, formed from two 90° pipeline deflections and one linear pipeline element preferably disposed between the 90° pipeline deflections.~~

Amended claims in accordance with Art. 34 (2) b) PCT (clean copy)

1. Process for preparing methyl methacrylate and/or methacrylic acid, comprising the process steps of:

a. the reacting of acetone cyanohydrin and sulfuric acid in one or more reactors I in a first reaction stage at a temperature in the range from 70°C to 130°C to obtain a first reaction mixture comprising sulfoxyisobutyramide and methacrylamide;

b. the converting of the first reaction mixture, comprising heating to a temperature in the range from 130 to 200°C, in one or more reactors II in a second reaction stage to obtain a second reaction mixture comprising predominantly methacrylamide and sulfuric acid; and

c. the reacting of the second reaction mixture with water and optionally methanol in one or more reactors III in a third reaction stage to obtain a third reaction mixture comprising methacrylic acid and/or methyl methacrylate;

wherein

(i) the sulfuric acid used in the first reaction stage, which is fed in at one or more points in the reactors I, has a concentration in the range from 98.0% by weight to 100.5% by weight,

(ii) the dwell time of the first reaction mixture in the second reaction stage is in the range from 2 to 15 min,

(iii) the heating in the second reaction stage is performed in one or more reactors II, wherein at least one reactor II comprises at least one preheater segment comprising one or more linear pipeline elements that are heated by means of a heating medium spatially separate from the reaction mixture, wherein the reaction mixture is heated by 10 to 100°C,

(iv) the converting in the second reaction stage is performed in one or more reactors II, wherein at least one reactor II comprises at least

one delay segment which is operated under virtually adiabatic conditions,

(v) the preheater segment and/or the delay segment are implemented in a combination of linear pipeline elements and deflections, wherein the linear pipeline elements and the deflections are connected to one another via reducing flanges,

(vi) the second reaction mixture obtained in step b, comprising predominantly methacrylamide and sulfuric acid, is optionally cooled down to a temperature below 120°C, and/or optionally intermediately buffered in an intermediate vessel, before the reaction mixture is guided into the third reaction stage,

wherein the superficial volume of the linear pipeline elements relative to the superficial volume of the deflections in at least one preheater segment corresponds to a ratio in the range from 2.0 to 75.0.

2. Process according to Claim 1, characterized in that, in the preheater segment, the linear pipeline elements are executed in one or more straight pipelines having an internal diameter in the range from 8 mm to 200 mm, wherein the pipelines of the linear pipeline elements in the preheater segment have a smaller internal diameter than the pipelines of the linear pipeline elements in the delay segment.

3. Process according to at least one of Claims 1 to 2, characterized in that the linear pipeline elements in the preheater segment and/or in the delay segment of the at least one reactor II are executed in parallel bundles of tubes, and these bundles of tubes are connected by means of at least one deflection, wherein the deflection is configured as a pipeline comprising a first section having an internal cross section that runs convergently in flow direction, a second section having an essentially constant internal cross-sectional area, and a third section having an internal cross section that runs divergently in flow direction.

4. Process according to at least one of Claims 1 to 3, characterized in that at least one preheater segment comprises linear pipeline elements and deflections, wherein the linear pipeline elements of the preheater segment comprise 1 to 50 separate straight pipelines that are secondarily heated with a heating medium and are arranged

parallel to one another, and wherein the deflections that connect the linear pipeline elements to one another comprise at least one pipeline.

5. Process according to at least one of Claims 1 to 4, characterized in that the deflections are formed from pipeline elements having an inflection of 90° to 180°.

6. Process according to at least one of Claims 1 to 5, characterized in that an average speed of the reaction mixture of 0.2 to 3 m/sec is established within the deflections and the variance in the local speed at any point within the deflections from the average conveying speed is not more than 30%.

7. Process according to at least one of Claims 1 to 6, characterized in that at least one intermediate conversion between at least two first reaction stages takes place in the performance of the first reaction stage and the second reaction stage, wherein the at least two reactors II for the conversion are implemented by at least one shell-and-tube heat exchanger as preheater segment, combined with at least one delay zone as delay segment.

8. Process according to Claim 7, characterized in that at least two reactors I are used, wherein at least one reactor II comprising at least one preheater segment and/or delay segment between the reactors I, and at least one reactor II comprising at least one preheater segment and/or delay segment at the exit from the first reaction stage are used.

9. Process according to at least one of Claims 1 to 8, characterized in that at least 60% of the static dwell time of at least one second reaction stage is implemented in a dwell segment executed as a pipeline.

10. Process according to at least one of Claims 1 to 9, characterized in that the first reaction mixture resulting from the first reaction stage, proceeding from at least one reactor I, is conveyed through at least one reactor II at a constantly controlled mass flow rate by means of a discharge pump.

11. Process according to at least one of Claims 1 to 10, characterized in that at least one preheater segment in at least one reactor II is configured as a shell-and-tube heat exchanger, wherein the reaction mixture flows through the shell-and-tube heat exchanger on the tube side, and the free cross-sectional area of the tubes used in

~~the shell-and-tube heat exchanger ensures an average flow rate of at least 0.2 m/s in the tubes.~~

~~12. Apparatus for performance of the process according to any of Claims 1 to 11, wherein the apparatus in each case comprises one or more reactors I, II and III that are connected to one another by pipeline elements, and wherein at least one reactor II comprises at least one preheater segment and at least one delay segment, wherein the preheater segment comprises one or more linear pipeline elements that are heated by means of a heating medium spatially separate from the reaction mixture, and wherein the delay segment is operated under virtually adiabatic conditions,~~
~~wherein the preheater segment and/or the delay segment are implemented in a combination of linear pipeline elements and deflections, wherein the linear pipeline elements and the deflections are connected to one another via reducing flanges, and wherein~~

~~the superficial volume of the linear pipeline elements relative to the superficial volume of the deflections in at least one preheater segment corresponds to a ratio in the range from 2.0 to 75.0.~~

~~13. Apparatus according to Claim 12, characterized in that, in the preheater segment, the linear pipeline elements are executed in one or more straight pipelines having an internal diameter in the range from 8 mm to 200 mm, wherein the pipelines of the linear pipeline elements in the preheater segment have a smaller internal diameter than the pipelines of the linear pipeline elements in the delay segment.~~

~~14. Apparatus according to at least one of Claims 12 or 13, characterized in that the deflections are formed from pipeline elements having an inflection of 90° to 180°.~~

~~15. Apparatus according to at least one of Claims 12 to 14, characterized in that the linear pipeline elements of the preheater segment and/or of the delay segment are connected by deflections, wherein the deflections are an element that causes deflection by 180°, formed from two 90° pipeline deflections and one linear pipeline element preferably disposed between the 90° pipeline deflections.~~

1. Process for preparing methyl methacrylate and/or methacrylic acid, comprising the process steps of:

a. the reacting of acetone cyanohydrin and sulfuric acid in one or more reactors I in a first reaction stage at a temperature in the range from 70°C to 130°C to obtain a first reaction mixture comprising sulfoxyisobutyramide and methacrylamide;

b. the converting of the first reaction mixture, comprising heating to a temperature in the range from 130 to 200°C, in one or more reactors II in a second reaction stage to obtain a second reaction mixture comprising predominantly methacrylamide and sulfuric acid; and

c. the reacting of the second reaction mixture with water and optionally methanol in one or more reactors III in a third reaction stage to obtain a third reaction mixture comprising methacrylic acid and/or methyl methacrylate;

wherein

(i) the sulfuric acid used in the first reaction stage, which is fed in at one or more points in the reactors I, has a concentration in the range from 98.0% by weight to 100.5% by weight,

(ii) the dwell time of the first reaction mixture in the second reaction stage is in the range from 2 to 15 min,

(iii) the heating in the second reaction stage is performed in one or more reactors II, wherein at least one reactor II comprises at least one preheater segment comprising one or more linear pipeline elements that are heated by means of a heating medium spatially separate from the reaction mixture, wherein the reaction mixture is heated by 10 to 100°C,

(iv) the converting in the second reaction stage is performed in one or more reactors II, wherein at least one reactor II comprises at least

one delay segment which is operated under virtually adiabatic conditions,

(v) the preheater segment and/or the delay segment are implemented in a combination of linear pipeline elements and deflections, wherein the linear pipeline elements and the deflections are connected to one another via reducing flanges,

(vi) the second reaction mixture obtained in step b, comprising predominantly methacrylamide and sulfuric acid, is optionally cooled down to a temperature below 120°C, and/or optionally intermediately buffered in an intermediate vessel, before the reaction mixture is guided into the third reaction stage,

wherein the superficial volume of the linear pipeline elements relative to the superficial volume of the deflections in at least one preheater segment corresponds to a ratio in the range from 2.0 to 75.0.

2. Process according to Claim 1, characterized in that, in the preheater segment, the linear pipeline elements are executed in one or more straight pipelines having an internal diameter in the range from 8 mm to 200 mm, wherein the pipelines of the linear pipeline elements in the preheater segment have a smaller internal diameter than the pipelines of the linear pipeline elements in the delay segment.

3. Process according to at least one of Claims 1 to 2, characterized in that the linear pipeline elements in the preheater segment and/or in the delay segment of the at least one reactor II are executed in parallel bundles of tubes, and these bundles of tubes are connected by means of at least one deflection, wherein the deflection is configured as a pipeline comprising a first section having an internal cross section that runs convergently in flow direction, a second section having an essentially constant internal cross-sectional area, and a third section having an internal cross section that runs divergently in flow direction.

4. Process according to at least one of Claims 1 to 3, characterized in that at least one preheater segment comprises linear pipeline elements and deflections, wherein the linear pipeline elements of the preheater segment comprise 1 to 50 separate straight pipelines that are secondarily heated with a heating medium and are arranged

parallel to one another, and wherein the deflections that connect the linear pipeline elements to one another comprise at least one pipeline.

5. Process according to at least one of Claims 1 to 4, characterized in that the deflections are formed from pipeline elements having an inflection of 90° to 180°.

6. Process according to at least one of Claims 1 to 5, characterized in that an average speed of the reaction mixture of 0.2 to 3 m/sec is established within the deflections and the variance in the local speed at any point within the deflections from the average conveying speed is not more than 30%.

7. Process according to at least one of Claims 1 to 6, characterized in that at least one intermediate conversion between at least two first reaction stages takes place in the performance of the first reaction stage and the second reaction stage, wherein the at least two reactors II for the conversion are implemented by at least one shell-and-tube heat exchanger as preheater segment, combined with at least one delay zone as delay segment.

8. Process according to Claim 7, characterized in that at least two reactors I are used, wherein at least one reactor II comprising at least one preheater segment and/or delay segment between the reactors I, and at least one reactor II comprising at least one preheater segment and/or delay segment at the exit from the first reaction stage are used.

9. Process according to at least one of Claims 1 to 8, characterized in that at least 60% of the static dwell time of at least one second reaction stage is implemented in a dwell segment executed as a pipeline.

10. Process according to at least one of Claims 1 to 9, characterized in that the first reaction mixture resulting from the first reaction stage, proceeding from at least one reactor I, is conveyed through at least one reactor II at a constantly controlled mass flow rate by means of a discharge pump.

11. Process according to at least one of Claims 1 to 10, characterized in that at least one preheater segment in at least one reactor II is configured as a shell-and-tube heat exchanger, wherein the reaction mixture flows through the shell-and-tube heat exchanger on the tube side, and the free cross-sectional area of the tubes used in

the shell-and-tube heat exchanger ensures an average flow rate of at least 0.2 m/s in the tubes.

12. Apparatus for performance of the process according to any of Claims 1 to 11, wherein the apparatus in each case comprises one or more reactors I, II and III that are connected to one another by pipeline elements, and wherein at least one reactor II comprises at least one preheater segment and at least one delay segment, wherein the preheater segment comprises one or more linear pipeline elements that are heated by means of a heating medium spatially separate from the reaction mixture, and wherein the delay segment is operated under virtually adiabatic conditions,
wherein the preheater segment and/or the delay segment are implemented in a combination of linear pipeline elements and deflections, wherein the linear pipeline elements and the deflections are connected to one another via reducing flanges, and wherein

the superficial volume of the linear pipeline elements relative to the superficial volume of the deflections in at least one preheater segment corresponds to a ratio in the range from 2.0 to 75.0.

13. Apparatus according to Claim 12, characterized in that, in the preheater segment, the linear pipeline elements are executed in one or more straight pipelines having an internal diameter in the range from 8 mm to 200 mm, wherein the pipelines of the linear pipeline elements in the preheater segment have a smaller internal diameter than the pipelines of the linear pipeline elements in the delay segment.

14. Apparatus according to at least one of Claims 12 or 13, characterized in that the deflections are formed from pipeline elements having an inflection of 90° to 180°.

15. Apparatus according to at least one of Claims 12 to 14, characterized in that the linear pipeline elements of the preheater segment and/or of the delay segment are connected by deflections, wherein the deflections are an element that causes deflection by 180°, formed from two 90° pipeline deflections and one linear pipeline element preferably disposed between the 90° pipeline deflections.