Claims

1. Process for producing alkyl methacrylate and optionally methacrylic acid in which, in a first reaction step in a reactor 1, methacrolein is produced through a partial oxidation of isobutene and/or tert-butyl alcohol in the gas phase and, in a second reaction step in a reactor 2, this is converted by a partial oxidation in the gas phase to methacrylic acid, wherein

   the unreacted methacrolein in reactor 2 is, in the second reaction step, separated from the methacrylic acid formed and, in a further oxidation step in a reactor 4, is oxidatively esterified in the liquid phase in the presence of an alcohol and

   the crude methacrylic acid formed in reactor 2 is purified by distillation and/or extraction and, in a further step, optionally reacted with an alcohol in a reactor 3 under acid catalysis to form the alkyl methacrylate.

2. Process for producing alkyl methacrylate and optionally methacrylic acid, comprising the steps:

   A) producing methacrolein from isobutene and/or tert-butanol in the presence of steam and an oxygen-containing gas in a reactor 1, wherein the reaction takes place in the gas phase on a heterogeneous contact I, and wherein a methacrolein-containing process gas 1 is obtained,

   B) transferring the process gas 1, which contains methacrolein and steam, from reactor 1, with supply of an oxygen-containing gas and optionally additional steam, to a reactor 2, wherein a reaction on a heterogeneous contact II takes place and a process gas 2 containing methacrylic acid and methacrolein is obtained,

   C) separating the process gas 2 from step B) by condensation or quenching, extraction and/or distillation into a phase 3a comprising methacrylic acid and a phase 3b comprising methacrolein,

D1) oxidatively esterifying the methacrolein in the phase 3b obtained from step C) in a reactor 4 with an alcohol in the presence of an oxygen-containing gas and a heterogeneous noble metal-containing oxidation catalyst comprising metals and/or metal oxides, wherein a mixture comprising an alkyl methacrylate, unreacted alcohol, methacrylic acid and unreacted methacrolein is obtained as a liquid process stream 4,

D2) esterifying, under acid catalysis, the methacrylic acid in the optionally additionally purified phase 3a obtained from step C) with an alcohol in a reactor 3 on a contact III and

D3) cleaning steps for isolating the methacrylic acid obtained in phase 3a, including at least one distillation.

3. Process according to Claim 2, wherein the methacrolein-containing process gas 1 is after step A) purified by means of at least one distillation and/or extraction before it is used as purified condensate and, after evaporation, as a component of the process gas 1 in process step B).

4. Process according to Claim 2 or 3, wherein the oxygen-containing gas stream in process step B) and/or D1) is a partially recycled gas stream.

5. Process according to at least one of Claims 2 to 4, wherein the heterogeneous oxidation catalyst used in the oxidative esterification reaction according to step D1) comprises one or more ultrafinely divided metals having an average particle size of < 20 nm that is selected from the group consisting of gold, palladium, ruthenium, rhodium and silver, and wherein the reaction in step D1) is carried out in the liquid phase at a pressure of 1 to 100 bar.

6. Process according to at least one of Claims 2 to 5, wherein the heterogeneous oxidation catalyst used in the oxidative esterification reaction according to step D1) comprises one or more noble metals on one or more support materials based on silica, alumina, titanium dioxide, magnesium oxide, bismuth oxide, tellurium oxide, or other basic oxides from the groups of the alkali metals and alkaline earth metals, wherein the resulting support material has a diameter from 10 µm to 10 mm.

7. Process according to Claim 6, wherein, in addition to the noble metal component, the catalyst includes one or more further elements or oxides thereof selected from the group consisting of manganese, iron, cobalt, nickel, copper, zinc, lead, the lanthanoids, tellurium, antimony and bismuth.

8. Process according to at least one of Claims 2 to 7, wherein steps A) to D1) and also D2) and optionally D3) are carried out in a continuous process.

9. Process according to at least one of Claims 2 to 8, wherein the alcohol in process step D1) is methanol, and wherein the oxidative esterification reaction according to step D1) is carried out with a molar ratio of methanol to methacrolein in the stationary reaction phase in the range from 1:1 to 50:1.

10. Process according to at least one of Claims 2 to 9, wherein the reaction according to step D1) is carried out in the liquid phase at a pressure in the range from 2 to 50 bar, a pH in the range from 3 to 10 and at a temperature in the range from 10 to 200°C.

11. Process according to at least one of Claims 2 to 10, wherein the alcohol in process steps D1) and D2) is in each case methanol.

12. Process according to at least one of Claims 2 to 11, wherein the crude products of process steps D1) and D2) are purified directly from reactors 4 and 3 or are combined and purified together after in each case one or two optional separate purification steps.

13. Process according to at least one of Claims 2 to 12, wherein the respective organic phases from process steps D1) and D2) are purified separately in at least one distillation step and/or one extraction step before they are combined.