

PROCESS FOR THE PRODUCTION OF ACETIC ACID

This invention relates to a process for the production of acetic acid and in particular to a process for the production of acetic acid by the carbonylation of methanol and/or a reactive derivative thereof in the presence of a promoted iridium catalyst.

The production of acetic acid by the carbonylation of methanol in the presence of an iridium catalyst and a promoter such as ruthenium is described, for example, in EP-A-0752406, EP-A-0849248, EP-A-0849249, and EP-A-1002785.

EP-A-0643034 describes a process for the carbonylation of methanol and/or a reactive derivative thereof in the presence of acetic acid, an iridium catalyst, methyl iodide, at least a finite concentration of water, methyl acetate and a promoter selected from ruthenium and osmium.

EP-A-0 749 948 describes a process for the carbonylation of an alkyl alcohol such as methanol and/or a reactive derivative thereof to produce the corresponding carboxylic acid and/or ester in the presence of an iridium catalyst, an alkyl halide, water and at least one promoter selected from cadmium, mercury, zinc, gallium, indium and tungsten, optionally with a co-promoter selected from ruthenium, osmium and rhenium.

The technical problem to be solved is to provide an improved carbonylation process for the production of acetic acid. It has now been surprisingly found that by using niobium in an iridium-catalysed carbonylation process for the production of acetic acid, the quantities of liquid and gaseous by-products are reduced and hence selectivity to the desired acetic acid is increased whilst maintaining the reaction rate.

Accordingly, the present invention provides a process for the production of acetic acid by carbonylating methanol and/or a reactive derivative thereof with carbon monoxide in at least one carbonylation reaction zone containing a liquid reaction composition comprising an iridium carbonylation catalyst, methyl iodide co-catalyst, a finite concentration of water, acetic acid, methyl acetate, and as promoters ruthenium and at least one of niobium and tantalum.

In the process of the present invention, suitable reactive derivatives of methanol include methyl acetate, dimethyl ether and methyl iodide. A mixture of methanol and reactive derivatives thereof may be used as reactants in the process of the present invention. Water is required as co-reactant for ether or ester reactants. Preferably, methanol

and/or methyl acetate are used as reactants.

At least some of the methanol and/or reactive derivative thereof will be converted to, and hence present as, methyl acetate in the liquid reaction composition by reaction with the carboxylic acid product or solvent. Preferably, the concentration of methyl acetate in the liquid reaction composition is in the range 1 to 70% by weight, more preferably 2 to 50% by weight, most preferably 3 to 35% by weight

Water may be formed in situ in the liquid reaction compositions, for example, by the esterification reaction between methanol reactant and acetic acid product. Water may be introduced to the carbonylation reaction zone together with or separately from other components of the liquid reaction composition. Water may be separated from other components of the liquid reaction composition withdrawn from the reaction zone and may be recycled in controlled amounts to maintain the required concentration of water in the liquid reaction composition. Preferably, the concentration of water in the liquid reaction composition is in the range 0.1 to 20% by weight, more preferably 1 to 15% by weight, yet more preferably 1 to 10% by weight.

Preferably, the concentration of methyl iodide co-catalyst in the liquid reaction composition is in the range 1 to 20% by weight, preferably 2 to 16% by weight.

The iridium catalyst in the liquid reaction composition may comprise any iridium-containing compound which is soluble in the liquid reaction composition. The iridium catalyst may be added to the liquid reaction composition in any suitable form which dissolves in the liquid reaction composition or is convertible to a soluble form. Preferably the iridium may be used as a chloride free compound such as acetates which are soluble in one or more of the liquid reaction composition components, for example water and/or acetic acid and so may be added to the reaction as solutions therein. Examples of suitable iridium-containing compounds which may be added to the liquid reaction composition include IrCl_3 , IrI_3 , IrBr_3 , $[\text{Ir}(\text{CO})_2\text{I}]_2$, $[\text{Ir}(\text{CO})_2\text{Cl}]_2$, $[\text{Ir}(\text{CO})_2\text{Br}]_2$, $[\text{Ir}(\text{CO})_4\text{I}_2]^{-}\text{H}^{+}$, $[\text{Ir}(\text{CO})_2\text{Br}_2]^{-}\text{H}^{+}$, $[\text{Ir}(\text{CO})_2\text{I}_2]^{-}\text{H}^{+}$, $[\text{Ir}(\text{CH}_3)\text{I}_3(\text{CO})_2]^{-}\text{H}^{+}$, $\text{Ir}_4(\text{CO})_{12}$, $\text{IrCl}_3 \cdot 4\text{H}_2\text{O}$, $\text{IrBr}_3 \cdot 4\text{H}_2\text{O}$, $\text{Ir}_3(\text{CO})_{12}$, iridium metal, Ir_2O_3 , IrO_2 , $\text{Ir}(\text{acac})(\text{CO})_2$, $\text{Ir}(\text{acac})_3$, iridium acetate, $[\text{Ir}_3\text{O}(\text{OAc})_6(\text{H}_2\text{O})_3][\text{OAc}]$, and hexachloroiridic acid $\text{H}_2[\text{IrCl}_6]$, preferably, chloride-free complexes of iridium such as acetates, oxalates and acetoacetates.

Preferably, the concentration of the iridium catalyst in the liquid reaction composition is in the range 100 to 6000 ppm by weight of iridium. The liquid reaction composition additionally comprises ruthenium and at least one of niobium and tantalum promoters. The promoters may be added to the liquid reaction composition for the carbonylation reaction in any suitable form which dissolves in the liquid reaction composition or is convertible to soluble form.

Examples of suitable ruthenium-containing compounds which may be used as sources of promoter include ruthenium (III) chloride, ruthenium (III) chloride trihydrate, ruthenium (IV) chloride, ruthenium (III) bromide, ruthenium metal, ruthenium oxides, ruthenium (III) formate, $[\text{Ru}(\text{CO})_3\text{I}_3]\text{-H}^+$, $[\text{Ru}(\text{CO})_2\text{I}_2]_n$, $[\text{Ru}(\text{CO})_4\text{I}_2]$, $[\text{Ru}(\text{CO})_3\text{I}_2]_2$, tetra(aceto)chlororuthenium(II,III), ruthenium (III) acetate, ruthenium (III) propionate, ruthenium (III) butyrate, ruthenium pentacarbonyl, trirutheniumdodecacarbonyl and mixed ruthenium halocarbonyls such as dichlorotricarbonylruthenium (II) dimer, dibromotricarbonylruthenium (II) dimer, and other organoruthenium complexes such as tetrachlorobis (4-cymene)diruthenium(II), tetrachlorobis(benzene)diruthenium(II), dichloro(cycloocta-1,5diene) ruthenium (II) polymer and tris(acetylacetonate)ruthenium (III).

Examples of suitable niobium-containing compounds which may be used include niobium (V) chloride, niobium (V) iodide and niobium (V) bromide.

Examples of suitable tantalum-containing compounds which may be used include tantalum (V) chloride, tantalum (V) iodide and tantalum (V) bromide.

Preferably, each promoter is present in an effective amount up to the limit of its solubility in the liquid reaction composition and/or any liquid process streams recycled to the carbonylation reactor from the acetic acid recovery stage. Each promoter is suitably present in the liquid reaction compositions at a molar ratio of promoter to iridium of [greater than 0 to 15]:1 such as in the range [1 to 10] : 1, for example, in the range [2 to 6] : 1. Each promoter is suitably present in the liquid reaction composition in a concentration less than 8000 ppm.

Suitably, the molar ratio of iridium : ruthenium : niobium may be in the range 1 : [greater than 0 to 15] : [greater than 0 to 15], such as 1 : [1 to 10] : [1 to 10], for example, 1 : [2 to 6] : [2 to 6].

Suitably, the molar ratio of iridium : ruthenium : tantalum may be in the range 1 : [greater than 0 to 15] : [greater than 0 to 15], such as 1 : [1 to 10] : [1 to 10], for example 1 : [2 to 6] : [2 to 6].

Preferably, the iridium, ruthenium, niobium and tantalum containing compounds
5 are free of impurities which provide or generate in situ ionic iodides which may inhibit the reaction, for example, alkali or alkaline earth metal or other metal salts.

Ionic contaminants such as, for example, (a) corrosion metals, particularly nickel, iron and chromium and (b) phosphines or nitrogen containing compounds or ligands which may quaternise in situ; should be kept to a minimum in the liquid reaction composition as
10 these will have an adverse effect on the reaction by generating I^- in the liquid reaction composition which has an adverse effect on the reaction rate. Some corrosion metal contaminants such as for example molybdenum have been found to be less susceptible to the generation of I^- . Corrosion metals which have an adverse affect on the reaction rate may be minimised by using suitable corrosion resistant materials of construction.
15 Similarly, contaminants such as alkali metal iodides, for example lithium iodide, should be kept to a minimum. Corrosion metal and other ionic impurities may be reduced by the use of a suitable ion exchange resin bed to treat the reaction composition, or preferably a catalyst recycle stream. Such a corrosion metal removal process is described in US 4007130. Preferably, ionic contaminants are kept below a concentration at which they
20 would generate 500 ppm I^- , preferably less than 250 ppm I^- in the liquid reaction composition.

The carbon monoxide reactant for the carbonylation reaction may be essentially pure or may contain inert impurities such as carbon dioxide, methane, nitrogen, noble gases, water and C_1 to C_4 paraffinic hydrocarbons. The presence of hydrogen in the
25 carbon monoxide and generated in situ by the water gas shift reaction is preferably kept low, for example, less than 1 bar partial pressure, as its presence may result in the formation of hydrogenation products. The partial pressure of carbon monoxide is suitably in the range 1 to 70 bar, preferably 1 to 35 bar and more preferably 1 to 15 bar.

The total pressure of the carbonylation reaction is suitably in the range 1.0 to 20.0
30 Mpag (10 to 200 barg), preferably 1.0 to 10.0 Mpag (10 to 100 barg), more preferably 1.5 to 5.0 Mpag (15 to 50 barg). The carbonylation reaction temperature is preferably in the range 150 to 220 °C.

The process of the present invention may be performed as a batch or a continuous process, preferably as a continuous process.

The acetic acid product may be removed from the carbonylation reaction zone by withdrawing liquid reaction composition and separating the acetic acid product by one or more flash and/or fractional distillation stages from the other components of the liquid reaction composition such as iridium catalyst, ruthenium, and at least one of niobium and tantalum promoter, methyl iodide, water and unconsumed reactants which may be recycled to the carbonylation reaction zone to maintain their concentrations in the liquid reaction composition.

The process of the present invention may be carried out in a single carbonylation reaction zone or it may be carried out in two or more reaction zones. Where two or more reaction zones are employed, the liquid reaction composition and reaction conditions in each reaction zone may be the same or different.

The invention will now be illustrated by way of example only by reference to the following examples.

General Reaction Method

All experiments were performed in a 300 cm³ zirconium autoclave equipped with a stirrer and a liquid injection facility. The autoclave was pressure tested to a minimum of 30 barg with nitrogen and then flushed three times with carbon monoxide up to 3 barg. A charge consisting of methyl acetate, acetic acid, methyl iodide, water and promoters was placed in the autoclave and a small amount of carbon monoxide was placed over the charge. A ballast vessel was charged with an overpressure of carbon monoxide.

The autoclave was heated with stirring (1500 rpm) to 190 °C. The catalyst injection system was primed with an iridium acetate solution (approx 5% iridium, 26% water, 62.7% acetic acid) and acetic acid and injected with carbon monoxide to bring the autoclave pressure to 28 barg.

The reaction rate was monitored by a drop in the carbon monoxide pressure from the ballast vessel. The autoclave was maintained at a constant temperature of 190 °C and pressure of 28 barg throughout the reaction. After uptake of carbon monoxide from the ballast vessel had ceased, the autoclave was isolated from the gas supply and cooled. After cooling, a gas analysis sample was taken and the autoclave vented. The liquid components were discharged, and analysed for liquid by-products by known established gas

chromatography methods. Detected components were quantified by integration of the component peaks relative to an external standard and expressed as parts per million (ppm) by weight. The major product obtained in each carbonylation experiment was acetic acid.

The rate of gas uptake at a certain point in a reaction run was used to calculate the carbonylation rate, as number of moles of reactant consumed per litre of cold degassed reactor composition per hour ($\text{mol.l}^{-1}.\text{h}^{-1}$) at a particular reactor composition (total reactor composition based on a cold degassed volume)

The methyl acetate concentration was calculated during the course of the reaction from the starting composition, assuming that one mole of methyl acetate was consumed for every mole of carbon monoxide that was consumed. No allowance was made for organic components in the autoclave headspace. The gaseous by-products were analysed by conventional gas chromatography methods of the cooled head space gas and the selectivity to methane was calculated based on the methyl acetate consumption and the selectivity to carbon dioxide was calculated based on carbon monoxide consumption.

Examples

Experiment A

A baseline experiment was performed with the autoclave charged with an iridium acetate solution and a ruthenium acetate solution (5% ruthenium, 18% water, 72% acetic acid).. The amounts of the components charged to the autoclave are given in Table 1 below. The rate of reaction at a calculated reaction composition of 12% methyl acetate is shown in Table 2.

Experiment B

Experiment A was repeated except that the autoclave was also charged with a vanadium acetate solution. The amounts charged to the autoclave are given in Table 1 and the results of the experiment are given in Table 2.

Example 1

Experiment A was repeated except that the autoclave was also charged with a niobium (v) chloride solution. The amounts charged to the autoclave are given in Table 1 and the results of the experiment are given in Table 2.

The results in Table 2 show that a combination of ruthenium and niobium promotes an iridium catalysed methanol carbonylation process with reduced by-product make whilst maintaining the reaction rate. However, a combination of vanadium (same Group of the

Periodic Table as niobium and tantalum) and ruthenium does not maintain the carbonylation rate compared to the use of ruthenium alone.

Example 2

5 Experiment A was repeated except that the autoclave was also charged with a tantalum (v) chloride solution. The amounts charged to the autoclave are given in Table 1 and the results of the experiment are given in Table 2.

The results in Table 2 show that a combination of ruthenium and tantalum promotes an iridium catalysed methanol carbonylation process with a significant reduction in by-products whilst maintaining an acceptable reaction rate.

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Table 1 Autoclave Charges

Experiment	Catalyst System (molar ratio)	Ir Acetate (g)	Ru acetate (g)	Nb/Ta salt (g)	Methyl Acetate (g)	Water (g)	Methyl iodide (g)	Acetic Acid (g)
Experiment A	Ir/Ru (1:2)	0.33	0.35	0	48.0	15.58	13.33	70.28
Experiment B	Ir/Ru/V (1:2:2)	0.33	0.35	1.21	48.0	15.56	16.30	68.08
Example 1	Ir/Ru/Nb (1:2:2)	0.33	0.35	0.94	48.0	16.74	15.78	68.89
Example 2	Ir/Ru/Ta (1:2:2)	0.33		2.84	48.0	15.56	13.30	66.44

Table 2 Rate and By-product data

Experiment	Rate at 12 wt% MeOAc Mol.l ⁻¹ .h ⁻¹	Propionic Acid (ppm)	Methane Selectivity	CO ₂ Selectivity
Experiment A (Ir/Ru)	19	400	1.4	0.9
Experiment B (Ir/Ru/V)	13.7	325	1.8	1.3
Example 1 (Ir/Ru/Nb)	19	250	0.8	0.5
Example 2 (Ir/Ru/Ta)	17.1	240	0.8	1.0

Claims

1. A process for the production of acetic acid by carbonylating methanol and/or a reactive derivative thereof with carbon monoxide in at least one carbonylation reaction zone containing a liquid reaction composition comprising an iridium carbonylation catalyst, methyl iodide co-catalyst, a finite concentration of water, acetic acid, methyl acetate and as promoters ruthenium and at least one of niobium and tantalum.
2. A process according to claim 1 wherein the promoters ruthenium and at least one of niobium and tantalum are each present in the liquid reaction composition at a molar ratio of promoter to iridium of [greater than 0 to 15] : 1.
3. A process according to claim 1 wherein the molar ratio of iridium : ruthenium : (niobium or tantalum) is in the range 1 : [1 to 10] : [1 to 10].
4. A process according to claim 3 wherein the molar ratio of iridium : ruthenium : (niobium or tantalum) is in the range 1 : [2 to 6] : [2 to 6].
5. A process according to any one of claims 1 to 4 wherein the concentration of each promoter in the liquid reaction composition is less than 8000 ppm.
6. A process according to any one of claims 1 to 5 wherein the concentration of iridium in the liquid reaction composition is in the range 100 to 6000 ppm.
7. A process according to any one of claims 1 to 6 wherein water is present in the liquid reaction composition at a concentration in the range 0.1 to 20% by weight.
8. A process according to claim 7 where the water concentration is in the range 1 to 15% by weight.
9. A process according to claim 8 wherein the water concentration is in the range 1 to 10% by weight.
10. A process according to any one of claims 1 to 9 wherein the methyl acetate is present in the liquid reaction composition at a concentration in the range 1 to 70% by weight.
11. A process according to any one of claims 1 to 10 wherein the methyl iodide is present in the liquid reaction composition at a concentration in the range 1 to 20% by weight.
12. A process according to any one of claim 1 to 11 wherein the carbonylation reaction is carried out at a total pressure in the range 1 to 20 Mpag.

13. A process according to any one of claims 1 to 12 wherein the carbonylation reaction is carried out at a temperature in the range 150 to 220 °C.

14. A process according to any one of claims 1 to 13 wherein the carbonylation reaction is carried out in a single carbonylation reaction zone.

5 15. A process according to any one of claims 1 to 13 wherein the carbonylation reaction is carried out in at least two carbonylation reaction zones.

16. A process according to any one of claims 1 to 15 wherein the process is carried out as a continuous process.

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