Claims

1. Process for the production of ethanol from~~conversion of~~ ethanoic acid, ~~into ethanol~~ characterised by the following steps:

1. introducing ethanoic acid and H_2 into a primary hydrogenation unit in the presence of a precious metal-based catalyst to produce ethanol and ethyl ethanoate,
2. introducing ethyl ethanoate, from step 1, together with H_2, into a secondary hydrogenation unit in the presence of a copper-based catalyst to produce ethanol, and
3. recovering ethanol from step 2.

2. A process for the production of ethanol from~~conversion of~~ methanol ~~into ethanol~~, characterised by the following steps:

1. introducing methanol, together with CO, into a carbonylation reactor to produce ethanoic acid,
2. introducing ethanoic acid, from step 1, together with H_2, into a primary hydrogenation unit in the presence of a precious metal-based catalyst to produce ethanol and ethyl ethanoate,
3. introducing ethyl ethanoate from step 2, together with H_2, into a secondary hydrogenation unit in the presence of a copper based catalyst to produce ethanol, and
4. recovering ethanol from step 3.

3. Process for the production of ethanol from~~conversion of~~ a carbonaceous feedstock ~~into ethanol~~, whereby the carbonaceous feedstock is first converted into synthesis gas, which is subsequently converted into ethanol, characterised by the following consecutive steps:

1. introducing a carbonaceous feedstock, into a synthesis gas generation unit to produce synthesis gas,
2. introducing synthesis gas, produced in step 1, into a methanol synthesis reactor, to produce methanol,
3. introducing methanol, from step 2, together with CO, into a carbonylation reactor, to produce ethanoic acid,
4. introducing ethanoic acid, from step 3, together with H_2, into a primary hydrogenation unit in the presence of a precious metal-based catalyst, to produce ethanol and ethyl ethanoate,
5. introducing ethyl ethanoate, from step 4, together with H_2, into a secondary hydrogenation unit in the presence of a copper-based catalyst, to produce ethanol, and
6. recovering ethanol from step 5.

4. Process according to any one of the preceding claims, ~~2 or 3~~ wherein the precious metal based catalyst is a palladium based catalyst~~step of producing ethanoic acid by carbonylation of methanol comprises contacting methanol with CO, in the liquid reaction composition, in a carbonylation reactor wherein, the liquid reaction composition comprises:~~

~~(a) ethanoic acid, (b) an iridium catalyst, (c) methyl iodide, (d) water and (e) a promoter~~.

5. Process according to any one of the preceding claims~~,–4~~ wherein the precious metal based catalyst~~promoter~~ is a supported catalyst which comprises palladium~~selected from ruthenium~~ and rhenium and/or silver~~osmium~~.

~~6. Process according to claim 5 wherein the concentration of water in the liquid reaction composition of the carbonylation reactor is in the range 0.1 to 15 wt %, more preferably 1 to 10 wt %, most preferably 1 to 6.5 wt %.~~

6~~7~~. Process according to any one of the preceding claims, wherein the secondary hydrogenation unit is operated in a gas phase regime.

7~~8~~. Process according to any one of the preceding claims, wherein the secondary hydrogenation unit is operated at a temperature of at least 10 °C~~, preferably at least 20 °C,~~ lower than the operating temperature of the primary hydrogenation unit.

8~~9~~. Process according to any one of the preceding claims, wherein more than 50% and less than 90% ~~and most preferably more than 60% and less than 80%~~ of the ethanoic acid introduced into the primary hydrogenation unit is converted into ethanol and ethyl ethanoate per pass.

9~~10~~. Process according to any one of the preceding claims, wherein at least 50%~~, preferably at least 75%, more preferably at least 90% and most preferably at least 95%~~ of the ethyl ethanoate introduced into the secondary hydrogenation unit is converted into ethanol per pass.

10~~11~~. Process according to any one of the preceding claims, wherein the stream exiting the secondary hydrogenation unit, which stream ~~which~~ comprises ethanol, ethanoic acid, ethyl ethanoate and H_2, is passed through a separation unit, and wherein the separated ethanoic acid is recycled to the primary hydrogenation unit and the separated ethyl ethanoate is recycled to the secondary hydrogenation unit.

11~~12~~. Process according to any one of the preceding claims, wherein the stream exiting the primary hydrogenation unit, which stream comprises ethanol, ethanoic acid, ethyl ethanoate and H_2, is passed through a separation unit, and wherein the separated ethanoic acid is recycled to the primary hydrogenation unit and the separated ethyl ethanoate is introduced into the secondary hydrogenation unit.

12~~13~~. Process according to ~~any of~~ claims 10~~11~~ or 11~~12~~, wherein the separated H_2 is recycled into ~~either~~ the primary hydrogenation unit and/or the secondary hydrogenation unit.

13~~14~~. Process according to any one of the preceding claims, wherein the molar ratio of H_2 to ethanoic acid that is introduced into the primary hydrogenation unit is greater than 2:1~~, preferably the molar ratio is greater than 4:1 and most preferably the molar ratio is~~

~~greater than 5:1;~~ and is less than 100:1~~, preferably less than 50:1 and most preferably less than 15:1~~.

1~~4~~15. Process according to any one of the preceding claims, wherein the molar ratio of H_2 to [ethyl ethanoate and ethanoic acid] that is introduced into the secondary hydrogenation unit is greater than 2:1~~, preferably the molar ratio is greater than 4:1 and most preferably the molar ratio is greater than 5:1~~; and is less than 100:1~~, preferably less than 50:1 and most preferably less than 15:1~~.