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TITLE: PREPARATION PROCESS OF CATALYST FOR PRODUCING ALKENYL ACETATES AND CATALYST PREPARED BY THIS PROCESS

FIELD OF THE INVENTION

This invention relates to a preparation process of a catalyst which comprises a noble metal, a metal for assisting catalysis, and an alkali or alkali earth metal compound, all of which are supported on the outer layer of a supporting material, and also relates to a catalyst prepared according to the process of the present invention, which is suitable for producing alkenyl acetates through reaction of olefins, acetic acid and oxygen in vapor phase.

BACKGROUND OF THE INVENTION

The industrial production of alkenyl acetates through reaction of olefins, oxygen and acetic acid in vapor phase has been performed in the presence of a heterophase catalyst, which comprises a noble metal, a metal for assisting catalysis, and an alkali or alkali earth metal compound supported on the outer layer of a supporting material. This preparation process has been known for a long time and the key point of this process, the metal components-supporting catalyst, has been widely discussed and studied, mostly based on changing the kind or relative composition of the metal components. However, no matter what changes the metal composition or its structure has undergone, the basic structure of all catalysts for producing alkenyl acetates is essentially in egg-shell form which was produced by impregnating on a supporting material the metal components, which are palladium metal, a metal for assisting catalysis, and an alkali or alkali earth metal compound, wherein the metal for assisting catalysis is preferably gold and copper, and wherein the alkali or alkali earth metal compound is preferably a potassium compound (USP 3939199, EP 0361484 and USP 4668819).

Earlier, the catalyst employed to produce vinyl acetate was prepared by depositing palladium, gold and the like noble metals on the whole supporting material (USP 3725680, 3743607); the catalyst employed to produce propenyl acetate was prepared by depositing palladium, copper and the like noble metals on the whole supporting material (USP 3917676). That is, the active noble metals were supported on the interiors and outer layers of a

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supporting material. However, while the catalyst was prepared in this way, it was found in actual reaction that the reactants were scarcely able to efficiently diffuse into inner regions of the supporting material, so that the interior active palladium and gold or copper metals were not able to be sufficiently utilized. In order to improve this drawback, in the preparation process of the catalyst for producing alkenyl acetates, usually, instead of depositing palladium metal and a metal for assisting catalysis on the whole supporting material, only a homogeneously impregnated layer was formed on the surface of a supporting material. That is, the impregnation of palladium metal and the metal for assisting catalysis was only performed on the surface layer of a supporting material, so that a supported catalyst in the form of egg-shell was produced (USP 4087622). The preparation method was that the active metallic materials were impregnated first, then these metal salts were precipitated through utilizing alkali or alkali earth metal salts (USP 4048096, USP A3775342).

Further, it was known that when preparing the metal components-supporting catalyst, a special supporting substance was used. The supporting substance was cleaned with acids before the impregnation and treated with bases after the impregnation (EP-A-0519435).

Since palladium and the metal for assisting catalysis were heterogeneous during the impregnation, therefore, the distribution of them on the surface of a supporting material was heterogeneous as well. Many researches have been made to investigate this problem (USP4087622, USP 3822308 and British Patent 1521652). As a result, in the preparation of the catalyst for producing alkenyl acetates, the catalyst was essentially based on an egg-shell composition and structure formed by supporting palladium, a metal for assisting catalysis, and an alkali or alkali earth metal compound at the surface layer of a supporting material. The preparation process generally was comprised of the following steps: (1) a supporting material was impregnated with an aqueous solution of soluble palladium ions and metal ions for assisting catalysis; (2) the impregnated supporting material was contacted with an alkali solution, so that the soluble palladium ions and metal ions for assisting catalysis were precipitated on the surface layer of the supporting material and formed into nonsoluble oxidative state palladium and metal for assisting catalysis; (3) the treated supporting material was washed with water to remove soluble ions produced during the precipitation; (4) the oxidative state palladium and metal for assisting catalysis supported on the treated

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supporting material were reduced to the metallic state; (5) the treated supporting material in (4) was impregnated with a solution of an alkali or alkali earth metal compound; and (6) the impregnated supporting material in (5) was dried. Among these steps, conventionally, the reducing step (4) was performed by a reducing process using liquid reducing agents in liquid phase. However, since heterogeneity of the distribution of palladium and the metal for assisting catalysis on the surface of the supporting material still existed, the catalyst produced was not satisfactory.

In order to resolve the above problem, in the preparation process of the catalyst for producing alkenyl acetates according to the present invention, the conventional reducing process utilizing liquid reducing agents in liquid phase is changed into a reducing process utilizing gaseous reducing agents in vapor phase. As a result, the prepared metal components-supporting catalyst has a high surface area and exhibits high catalytic activity, so that the catalytic ability and life of this heterophase catalyst are improved.

SUMMARY OF THE INVENTION

This invention relates to a preparation process of a catalyst which comprises a noble metal, a metal for assisting catalysis, and an alkali or alkali earth metal compound, all of which are supported on the outer layer of a supporting material. The preparation process comprises impregnating the supporting material with a solution containing an oxidative state noble metal as the main catalyst and an oxidative state metal for assisting catalysis, reducing the oxidative state metals into the metallic state in vapor phase with a gaseous reducing agent under constant temperature, constant pressure and constant gas concentration, then impregnating the treated supporting material with a solution of an alkali or alkali earth metal compound. The metal components-supporting catalyst prepared by the process according to the present invention has a high surface area and exhibits high catalytic activity, so that the catalytic ability and life of this heterophase catalyst can be improved. The catalyst prepared in the present invention is suitable for producing alkenyl acetates through reaction of olefins, acetic acid and oxygen in vapor phase.

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DETAILED DESCRIPTION OF THE INVENTION

This invention relates to a preparation process of a catalyst which comprises a noble metal, a metal for assisting catalysis, and an alkali or alkali earth metal compound, all of which are supported on the outer layer of a supporting material. The examples of the suitable supporting material are alumina, silica gel, silica, active carbon, silicon carbide, diatomaceous earth, pumice and the like, while among them silica is preferable. The example of the noble metal is palladium; the examples of the metal for assisting catalysis are gold, copper, molybdenum, cadmium and magnesium, while among them gold and copper are preferable. The examples of the alkali or alkali earth metal compounds are the hydroxides, acetates, nitrates and bicarbonates of potassium, sodium, cesium, magnesium, barium and the like, while among them potassium salts are preferable, and potassium acetate is even more preferable.

The distinctive feature of the process according to the present invention is, in preparing the catalyst for producing alkenyl acetates, the conventional reducing process utilizing liquid reducing agents in liquid phase is changed into a reducing process utilizing gaseous reducing agents in vapor phase to carry out the reduction of the oxidative state metals. After treatment with an alkali solution to translate the oxidative state noble metal and metal for assisting catalysis (which are supported on the supporting material after the impregnation) into hydroxide state, these are reduced with suitable gaseous reducing agents in specific reductive conditions and translated into the metallic state.

The term "oxidative state" used herein according to the present invention means a metal in cationic state, for example, oxidative state palladium means Pd^{2+}.

In the preparation process according to the present invention, after the metal components are supported on the surface layer of a supporting material by means of conventionally well-known method, the heretofore non-reduced catalyst is placed in a reactor, and a gaseous reducing agent is used under suitable reductive conditions in vapor phase to reduce the oxidative state metals into free metals. While the examples of gaseous reducing agents used in the present invention are hydrogen and ethylene, hydrogen is preferable. In the reducing process, it is preferable to dilute the gaseous reducing agent with inert gas (such as nitrogen gas). The volume percentage of the reducing agent after dilution is in the range of 0.05 to 75%, and preferably, 5 to 30%. The amount of the reducing

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agent used depends on the amounts of the noble metal and the metal for assisting catalysis, so that the equivalents thereof usually should be at least 1 to 1.5 times the equivalents required to reduce the catalyst; if necessary, more reducing agents can be used. The reducing temperature is usually between 100 to 300 °C, and preferably, between 150 to 250 °C. The reducing pressure is usually between 0 to 5 kg/cm^2 (gauge pressure), and preferably, between 1.5 to 3.5 kg/cm^2 (gauge pressure).

After the reducing process, the treated catalyst is washed with deionized water until the chloride ions are completely removed. After drying, it is impregnated with an aqueous solution containing an alkali or alkali earth metal compound. Finally, the catalyst is dried at a temperature between 80 to 150 °C until the water content is between 0 to 6% by weight, and preferably, 1 to 3% by weight.

The metal components-supporting catalyst prepared in the present invention is suitable for producing alkenyl acetates through reaction of olefins, acetic acid and oxygen in vapor phase. Said olefinic compounds include ethylene, propylene, isobutylene and the like. For example, the catalyst prepared in the present invention can be used in the presence of ethylene, acetic acid and oxygen in vapor phase to produce vinyl acetate. The catalyst employed in this producing process comprises palladium, gold and an alkali or alkali earth metal compound (a potassium compound is preferred). Also, the catalyst prepared in the present invention may be used in the presence of propylene, acetic acid and oxygen in vapor phase to produce propenyl acetate. The catalyst employed in this producing process comprises palladium, copper (barium and lead can further be added), and an alkali or alkali earth metal compound (a potassium compound is preferred).

A certain amount of the above prepared catalyst for producing alkenyl acetates is placed in a reacting tube with an inner diameter of 20mm and a length of 2.0 m. Under a specific pressure at the entrance of the reacting tube, the reacting gases are introduced into the tube at a reacting temperature set according to the activity of the catalyst. These reacting gases comprises 30 to 45 volume % of olefin, 30 to 50 volume % of nitrogen gas, 5 to 15 volume % of acetic acid and 3 to 7 volume % of oxygen. Analysis of the yield of alkenyl acetate in the composition at the exit of the tube is performed in a definite time.

Generally, the selection of a catalyst in the industry is based on the catalytic activity. The catalytic activity can be calculated basically according to the following formula:

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The activity of a catalyst:

$$\text{STY(space time yield)} = \frac{\text{weight of alkenyl acetates produced(g)}}{\text{volume(l) of catalyst x sampling time(hr)}}$$

The selectivity of a catalyst:

$$C_2 \text{ selectivity} = \frac{\text{moles of vinyl acetate produced}}{\text{moles of vinyl acetate produced+1/2 moles of } CO_2 \text{ produced}}$$

$$C_3 \text{ selectivity} = \frac{\text{moles of propenyl acetate produced}}{\text{moles of propenyl acetate produced+1/3moles of } CO_2 \text{ produced}}$$

As the surface area of metals in the catalyst prepared according to the present invention is higher compared to those of the catalyst prepared by the reducing process using liquid reducing agents, so is the efficiency of the catalyst in the present invention higher. It is confirmed from the evaluation of the catalytic activity that when the catalyst is used to produce alkenyl acetates, the catalyst prepared in the present invention not only provides higher activity of the whole reaction of olefins, acetic acid and oxygen, but also lengthens its own life. That is, compared to the conventional catalyst,the catalyst of the present invention is able to yield more alkenyl acetates per unit volume of the reactor and per unit time when the conditions of the synthetic reaction (such as pressure, temperature, oxygen concentration) remain constant. Moreover, if the productive yield remains constant, then the reacting temperature can be decreased. Therefore, since the selectivity of the reaction is variable under the same output, the cost of the starting materials is lower. The amount of carbon dioxide by-product turns out to be less, and the products lost during the exclusion of carbon dioxide is also less.

The present invention will be further described with reference to the following Examples and Comparative Examples, but the scope of the present invention is by no means limited.

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Example 1

The supporting material employed in this Example was a porous carrier of alumina/silica with an outer diameter of 5 mm and was available from SUD-CHEMIE AG. This supporting material had a surface area of 100 to 120 m^2/g, a pore volume of 0.7 to 0.9 ml/g and a volume density of 600 g/l. The metal component-supporting catalyst was prepared according to the following steps:

Step 1): An aqueous Na_2PdCl_4 solution with weight of 2.2 kg containing 15 weight % of palladium was added into an aqueous $HAuCl_4$ solution with weight of 0.5 kg containing 30 weight % of gold. The mixture was then diluted with deionized water till total volume was 37.2 l. 100 l of alumina/silica carrier was placed in an impregnating tank with rotation rate of 24 turns per minute. The mixture was added rapidly in 10 minutes.

Step 2): Hot air was passed through to dry the carrier until the remained moisture was less than 4 %. The temperature of the hot air was lower than 120 °C.

Step 3): 28 weight % NaOH solution with weight of 160 % the amount absorbed by the carrier (about 60 kg) was added to the dried catalyst. The impregnating time was over 20 hours. The originally soluble chloride state palladium and gold were translated into insoluble hydroxide state palladium and gold.

Step 4): The impregnated catalyst carrier after drying was placed in a reducing reactor with temperature controlled at 165 °C and pressure set at 2 kg/cm^2 (gaure pressure). The reducing gases were passed into the reactor with a flow rate of 15 cm/sec, wherein the composition of the reducing gases was hydrogen : nitrogen = 1 : 3. The hydroxide state palladium and gold were reduced into metallic state palladium and gold.

Step 5): The above catalyst was washed to remove chloride ions with the amount of 15 to 16 liters of deionized water per liter of the catalyst until the catalyst was free of

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chloride ions.

Step 6): The catalyst carrier was dried as in step 2).

Step 7): An adequate amount of potassium acetate was added into the dried catalyst carrier, so that each liter of the catalyst contained 30 g weight of potassium acetate.

Step 8): The catalyst carrier was dried as in step 2).

After the above steps, a catalyst contained 3.3 g/l of palladium, 1.5 g/l of gold and 30 g/l of potassium acetate was obtained, wherein all palladium and gold were well distributed on the shell of the carrier.

Nine hundred milliliters of the catalyst thus obtained was charged into a reacting tube with an inner diameter of 20 mm and a length of 2.0 m. Under a pressure of 8 kg/cm^2 (gauge pressure) at the entrance of the reactor, the reacting gaseous mixture was introduced into the reactor at a temperature of 140 ℃. The gaseous mixture was comprised of 41 volume % of ethylene, 43 volume % of nitrogen gas, 10 volume % of acetic acid and 6 volume % of oxygen. While the composition at the exit was analyzed in a definite time, the activity and the selectivity of the catalyst were calculated, and the surface area of metals was determined. The results are listed in Table 1.

When the activity and the selectivity of the catalyst were evaluated, the crude product at the exit of the reactor was cooled with chilled water, and the composition was analyzed by Shimadzu Gas Chromatography. The flow rate of the gases was determined by Shinagawa Dry Gas Meter and the surface area of metals was determined according to ChemiSorp Method as in ASTM D3908.

Example 2

This is a repetition of Example 1 except that, an aqueous Na_2PdCl_4 solution with weight of 2.2 kg containing 18 weight % of palladium and an aqueous $HAuCl_4$ solution with weight of 0.5 kg containing 36 weight % of gold were prepared. As well, a catalyst was obtained that contained 4.0 g/l of palladium, 1.8 g/l of gold and 30 g /l of potassium acetate, wherein all

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palladium and gold were well distributed on the shell of the carrier.

This catalyst was evaluated by the same methods as in Example 1, and the results are listed in Table 1.

Example 3

This is a repetition of Example 1 except that, an aqueous Na_2PdCl_4 solution with weight of 2.2 kg containing 22.5 weight % of palladium and an aqueous $HAuCl_4$ solution with weight of 0.5 kg containing 45 weight % of gold were prepared. As well, a catalyst was obtained that contained 5.0 g/l of palladium, 2.25 g/l of gold and 30 g/l of potassium acetate , wherein all palladium and gold were well distributed on the shell of the carrier.

This catalyst was evaluated by the same methods as in Example 1, and the results are listed in Table 1.

Example 4

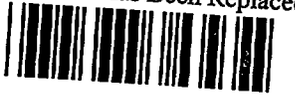
This is a repetition of Example 1 except that, an aqueous Na_2PdCl_4 solution with weight of 2.2 kg containing 30 weight % of palladium and an aqueous $HAuCl_4$ solution with weight of 0.5 kg containing 60 weight % of gold were prepared. As well, a catalyst was obtained that contained 6.6 g/l of palladium, 3.0 g/l of gold and 30 g/l of potassium acetate, wherein all palladium and gold were well distributed on the shell of the carrier.

This catalyst was evaluated by the same methods as in Example 1, and the results are listed in Table 1.

Comparative Example 1

This is a repetition of Example 1, wherein the catalyst was prepared with an aqueous Na_2PdCl_4 solution with weight of 2.2 kg containing 15 weight % of palladium and an aqueous $HAuCl_4$ solution with weight of 0.5 kg containing 30 weight % of gold except that step 4) was altered as follows: the impregnated 5 mm porous carrier after step 3) was poured into 50 l of an aqueous solution containing 5 % N_2H_4 for 4 hours, so that the hydroxide state palladium and gold deposited on the carrier were reduced into metallic state palladium and gold. The same procedures thereafter as in Example 1 were followed, and the carrier was washed, potassium

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acetate was added and the catalyst carrier was dried.

This catalyst was evaluated by the same methods as in Example 1, and the results are listed in Table 1.

Comparative Example 2

This is a repetition of catalyst preparation as in Comparative Example 1 except that an aqueous Na_2PdCl_4 solution with weight of 2.2 kg containing 18 weight % of palladium and an aqueous $HAuCl_4$ solution with weight of 0.5 kg containing 36 weight % of gold were prepared.

This catalyst was evaluated by the same methods as in Example 1, and the results are listed in Table 1.

Comparative Example 3

This is a repetition of catalyst preparation as in Comparative Example 1 except that an aqueous Na_2PdCl_4 solution with weight of 2.2 kg containing 22.5 weight % of palladium and an aqueous $HAuCl_4$ solution with weight of 0.5 kg containing 45 weight % of gold were prepared.

This catalyst was evaluated by the same methods as in Example 1, and the results are listed in Table 1.

Comparative Example 4

This is a repetition of catalyst preparation as in Comparative Example 1 except that an aqueous Na_2PdCl_4 solution with weight of 2.2 kg containing 30 weight % of palladium and an aqueous $HAuCl_4$ solution with weight of 0.5 kg containing 60 weight % of gold were prepared.

This catalyst was evaluated by the same methods as in Example 1, and the results are listed in Table 1.

Example 5

This is a repetition of catalyst preparation as in Comparative Example 1 except that Na_2PdCl_4 solution with weight of 2.2 kg containing 15 weight % of palladium and an aqueous $CuCl_2$ solution with weight of 0.5 kg containing 14.6 weight % of copper were prepared.

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After the above steps, a catalyst was obtained that contained 3.3 g/l of palladium,0.34 g/l of copper and 30 g/l of potassium acetate, wherein all palladium and copper were well distributed on the shell of the carrier.

Six hundred milliliters of thus obtained catalyst was charged into a reacting tube with an inner diameter of 20 mm and a length of 2.0 m. Under a pressure of 7.0 kg/cm^2 (gauge pressure) at the entrance of the reactor, the reacting gaseous mixture was introduced into the reactor at a temperature of 148 ℃. The gaseous mixture was comprised of 29 volume % of propylene, 44 volume % of nitrogen gas, 6.7 volume % of acetic acid 13.5 volume % of steam and 6.5 volume % of oxygen. According to the same methods as in Example 1, while the composition at the exit was analyzed in a definite time, the activity and the selectivity of the catalyst were calculated, and the surface area of metals was determined. The results are listed in Table 1.

Example 6

This is a repetition of catalyst preparation as in Example 1 except that an aqueous Na_2PdCl_4 solution with weight of 2.2 kg containing 15 weight % of palladium and an aqueous $CuCl_2$ solution with weight of 0.5 kg containing 6.0 weight % of copper were prepared.

This catalyst was evaluated by the same methods as in Example 5, and the results are listed in Table 1.

Example 7

This is a repetition of catalyst preparation as in Example 1 except that an aqueous Na_2PdCl_4 solution with weight of 2.2 kg containing 22.5 weight % of palladium and an aqueous $CuCl_2$ solution with weight of 0.5 kg containing 14.6 weight % of copper were prepared.

This catalyst was evaluated by the same methods as in Example 5, and the results are listed in Table 1.

Comparative Example 5

This is a repetition of catalyst preparation as in Comparative Example 1 except that an

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aqueous Na_2PdCl_4 solution with weight of 2.2 kg containing 15 weight % of palladium and an aqueous $CuCl_2$ solution with weight of 0.5 kg containing 14.6 weight % of copper were prepared.

This catalyst was evaluated by the same methods as in Example 5, and the results are listed in Table 1.

Comparative Example 6

This is a repetition of catalyst preparation as in Comparative Example 1 except that an aqueous Na_2PdCl_4 solution with weight of 2.2 kg containing 15 weight % of palladium and an aqueous $CuCl_2$ solution with weight of 0.5 kg containing 6.0 weight % of copper were prepared.

This catalyst was evaluated by the same methods as in Example 5, and the results are listed in Table 1.

Comparative Example 7

This is a repetition of catalyst preparation as in Comparative Example 1 except that an aqueous Na_2PdCl_4 solution with weight of 2.2 kg containing 22.5 weight % of palladium and an aqueous $CuCl_2$ solution with weight of 0.5 kg containing 14.6 weight % of copper were prepared.

This catalyst was evaluated by the same methods as in Example 5, and the results are listed in Table 1.

Comparative Example 8

This is a repetition of Example 1 except that instead of hydrogen, ethylene was used as the gaseous reducing agent in the reducing process.

This catalyst was evaluated by the same methods as in Example 1, and the results are listed in Table 1.

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Table 1

	Activity (g/l/hr)	Selectivity (%)	Surface Area of Metals (m^2/g.metal)
Example 1	401	95.4	138
Example 2	456	95.7	143
Example 3	632	94.8	123
Example 4	785	95.4	117
Comparative Example 1	327	95.5	123
Comparative Example 2	380	95.6	122
Comparative Example 3	440	94.1	102
Comparative Example 4	537	92.6	101
Example 5	609	97.5	120
Example 6	554	97.0	127
Example 7	689	97.3	125
Comparative Example 5	547	96.4	105
Comparative Example 6	497	96.0	109
Comparative Example 7	612	96.7	109
Comparative Example 8	306	96.2	101

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What is claimed is:

1. A preparing process of a catalyst, which comprises (a) impregnating on the surface of a catalyst supporting material with a solution containing an oxidative state noble metal as the main catalyst and an oxidative state metal for assisting catalysis, reducing the metals from oxidative state into metallic state in vapor phase with gaseous reducing agent at a temperature in the range of 100 to 300 ℃, and a pressure in the range of 0 to 5 kg/cm^2 (gauge pressure); (b) impregnating the reduced catalyst with a solution of alkali or alkali earth metal compound, then drying the catalyst.
2. The process according to claim 1, wherein said noble metal is palladium.
3. The process according to claim 1, wherein said metals for assisting catalysis are gold, copper, molybdenum, cadmium and magnesium.
4. The process according to claim 1, wherein said alkali or alkali earth metal compound are the hydroxides, acetates, nitrates and bicarbonates of potassium, sodium, cesium, magnesium and barium.
5. The process according to claim 1, wherein said catalyst supporting material are alumina, silica gel, silica, active carbon, silicon carbide, diatomaceous earth and pumice.
6. The process according to claim 1, wherein said gaseous reducing agent is hydrogen.
7. A catalyst prepared by the process according to claim 1, which is suitable for producing alkenyl acetates through reaction of olefins, acetic acid and oxygen in vapor phase.
8. The catalyst according to claim 7, wherein said olefins are ethylene, propylene and isobutylene.
9. The catalyst according to claim 7, wherein said alkenyl acetate is vinyl acetate.
10. The catalyst according to claim 7, wherein said alkenyl acetate is propenyl acetate.

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