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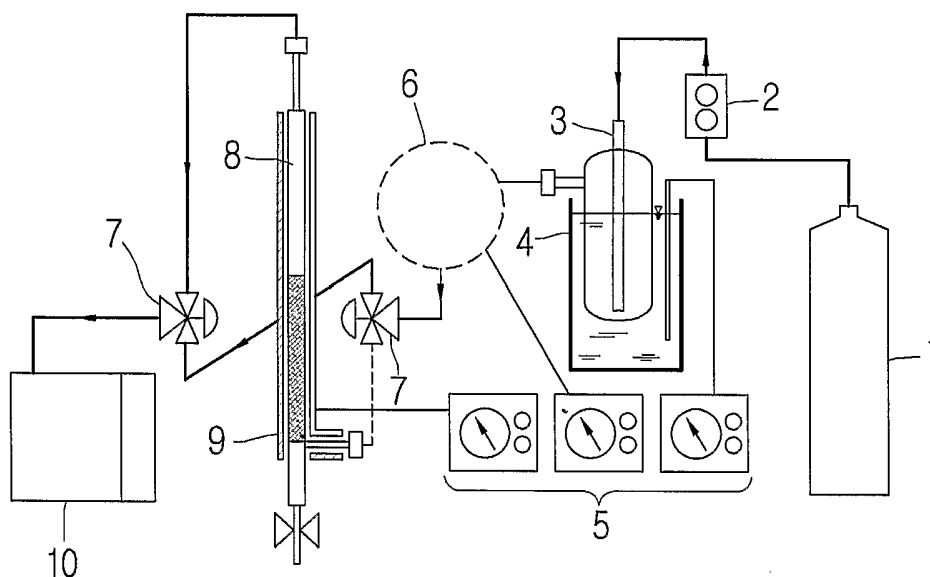
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(54) Title: A CATALYST FOR THE DISINTEGRATION OF VAPOR PHASE ORGANIC COMPOUNDS AND FOR THE ORGANIC SYNTHESIS FROM CARBON DIOXIDE AND WATER



(57) Abstract: The present invention provides catalysts that comprise a mixture of compounds that can be isolated by a Lewis acid, metal compounds that can offer an electron pair to a Lewis acid, transition metals or transition metal oxides, and electrolytes that can decompose vapor phase organic compounds, produce hydrogen by decomposing water, and synthesize organic materials by reacting water with carbon dioxide.



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DESCRIPTION

[Title of Invention]

A CATALYST FOR THE DISINTEGRATION OF VAPOR PHASE ORGANIC COMPOUNDS AND FOR THE ORGANIC SYNTHESIS FROM CARBON DIOXIDE AND WATER

[Technical Field]

The present invention relates to ceramic catalysts for decomposition of water to produce hydrogen, decomposition of vapor phase organic compounds, and organic synthesis through the reaction between carbon dioxide and water. More particularly, the present invention relates to a mixture of compounds that can be isolated by a Lewis acid, metal compounds that can offer an electron pair to a Lewis acid, transition metals or transition metal oxides, and electrolytes that can transfer electrons, decompose vapor phase organic compounds, and synthesize organic materials through the reaction between carbon dioxide and water.

[Background Art]

Conventional catalysts for the decomposition of vapor phase organic compounds including odor-causing materials are generally capable of expressing their functions at 100 °C or above and, as a result, their applications were often limited. (Japan Patent Publication No. 2001-38207, US Patent No. 6,344,987BZ). Therefore, it is not practically possible to use these catalysts to decompose odor or volatile materials at the temperature of 100°C or lower. In order to be able to use them, vapor compounds were reacted under a process condition of 100°C or higher or were artificially heated to obtain a temperature of 100°C or higher. As a result, not only the applicability of the catalysts became very limited, but decomposition of the vapor compounds also became costly.

In addition, the conventional catalysts that produce hydrogen by decomposing water or those that synthesize organic compounds such as methane by reacting carbon dioxide with water required supply of light. In

order to be able to use these photo catalysts, water and carbon dioxides that are well dispersed with the catalysts were first injected into a reactor, which allows light to penetrate, then was followed by irradiation process by which concentrated light is irradiated on convex lens, a concave mirror and the like. (*Science* 297 (2002) p2243, *Applied Catalysis. A: General* 249 (2003) p11). Accordingly, when synthesizing organic compounds from carbon dioxide and water by using photo catalysts, a specially designed light penetrating reactor which can efficiently carry out light irradiation and efficient dispersion of the photo catalysts and the like are necessary. As a result, not only the existing technical difficulties of putting these photo catalysts into practical use, but also the high cost of using a special system for light irradiation need to be overcome.

[Disclosure]

[Technical Problem]

The object of the present invention is to overcome the problems of the conventional technology and is to provide catalysts that can decompose vapor organic compounds at a temperature of 100°C or lower and those that can synthesize organic compounds through the reaction between water and carbon dioxide at 100°C or higher without using a special system for light irradiation, thereby providing economically advantageous catalysts.

[Technical Solution]

The catalysts of the present invention, which have various uses, can decompose water into hydrogen and hydroxyl radical, and can decompose vapor phase organic compounds through the reaction with the decomposed species of water on their surface at a low temperature of 100°C or lower, particularly at a room temperature (around 25°C), and can synthesize organic compounds by reacting water with carbon dioxides at a medium/high temperature of 100°C or higher.

In other words, the catalysts according to the present invention are relatively inexpensive since the catalysts comprise a mixture of raw materials

for catalysts such as Lewis acids and metal oxides. Therefore, particularly for water decomposition and organic synthesis through the reaction between carbon dioxide and water without light, since exhaust heat, carbon dioxides and steam produced from industrial sites can be used, the cost of production of hydrogen energy and energy from synthesized organic materials are expected to significantly decrease, and its economic efficiency is expected to be very high. Moreover, by achieving a remarkably more efficient property for the decomposition of vapor phase organic compounds, the industrial applicability of the catalysts, such as in the removal of odor-causing materials at room temperature, is expected to be significantly enhanced.

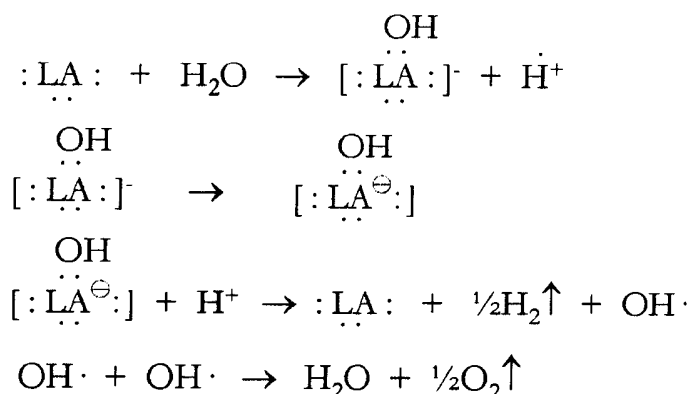
[Description of Drawings]

Figure 1 represents a schematic view of an experimental apparatus that is used for decomposition of vapor phase organic compounds and organic synthesis using the catalysts of the present invention.

[Mode of Invention]

The present invention relates to ceramic catalysts that are prepared by mixing and calcining raw materials, and they are characterized in that they can decompose water to produce active hydrogen and hydroxyl radicals, decompose vapor phase organic compounds through the reaction with active hydrogen and hydroxyl radicals at a low temperature of 100°C or below, and synthesize organic compounds by reacting water with carbon dioxide at temperature of 100°C or higher.

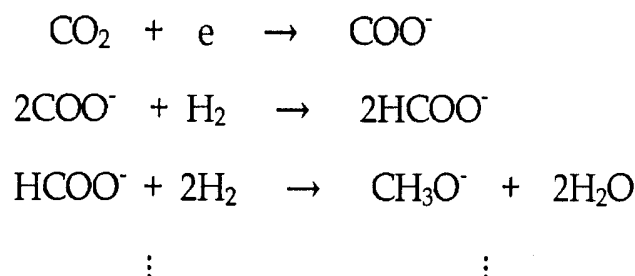
The applicants of the present invention discovered that when a suitable environment is provided (for example, enough reaction time is given or a temperature of 100°C or higher was provided), a Lewis acid uses water as a Lewis base to decompose water using the following presumptive reaction process.



(LA Lewis Acid, OH · Hydroxy radical)

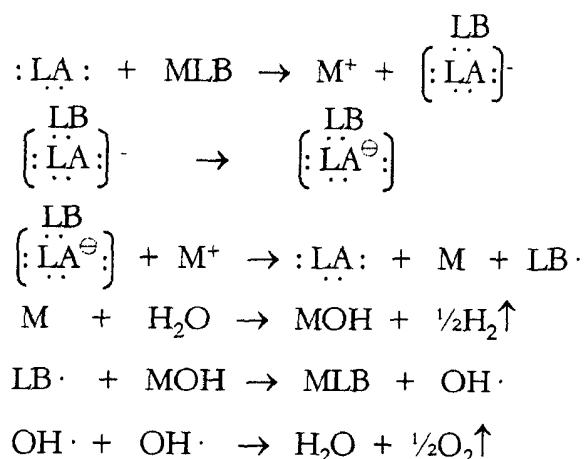
As mentioned above, it was observed that the hydroxyl radical, active hydrogen, active oxygen and the like can decompose vapor phase organic compounds at a low temperature of 100°C or below and can synthesize organic compounds at a medium/high temperature of 100°C or higher.

When water and carbon dioxide are reacted, the applicants of the present invention discovered that the electrons produced during the water decomposition migrate to the surface of metal of the Lewis acid, thereby increasing the concentration of the electrons. As a result, it is predicted that carbon dioxide and hydrogen or hydrogen ions at the metal surface of the Lewis acid undergoes, for example, the following reactions to synthesize organic compounds.



In addition, the applicants of the present invention could observe that when the compounds composed of hydrophilic functional groups, that can offer electron pairs, such as oxides, hydroxides, sulfates, etc. and of alkaline

metals or of alkaline earth metals are added to the Lewis acid, water decomposition or reaction between water and carbon dioxide can be induced by increasing the Lewis basicity, as shown in the following example.



(LB Lewis Base, M Alkaline Metal, OH · Hydroxy radical)

Moreover, the applicants of the present invention also discovered that when transition metal compounds were added to the Lewis acid to be used for catalysts for reaction between water and carbon dioxide, the electrons on the metal surface of the Lewis acid migrated, thereby making organic synthesis at the surface of transition metal possible, promoting the production of a wider range of the types of organic compounds and improving the conversion rate of the carbon dioxides.

Therefore, the ceramic catalysts according to the present invention that can decompose vapor phase organic compounds at a temperature of 100 °C or lower and synthesize organic compounds by reacting carbon dioxide with water at a temperature of 100 °C or higher could only comprise compounds that can be isolated by a Lewis acid.

For compounds that can be isolated by a Lewis acid can be any one or a mixture of two or more from the group consisting of: natural minerals such as kaolinite, bentonite, attapulgite, zeolite, montmorillonite; oxides such as zinc oxide (ZnO), aluminum oxide (Al₂O₃), titanium dioxide (TiO₂), cerium

oxide (CeO_2), vanadium pentoxide (V_2O_5), silicon dioxide (SiO_2), chromium oxide (Cr_2O_3); sulfates such as calcium sulfate (CaSO_4), manganese sulfate (MnSO_4), nickel sulfate (NiSO_4), copper sulfate (CuSO_4), cobalt sulfate (CoSO_4), cadmium sulfate (CdSO_4), magnesium sulfate (MgSO_4), iron sulfate (FeSO_4), aluminum sulfate ($\text{Al}_2(\text{SO}_4)_3$); and nitrates such as calcium nitrate ($\text{Ca}(\text{NO}_3)_2$), zinc nitrate ($\text{Zn}(\text{NO}_3)_2$), iron nitrate ($\text{Fe}(\text{NO}_3)_3$); phosphates such as aluminum phosphate (AlPO_4), iron phosphate (FePO_4), chromium phosphate (CrPO_4), copper phosphate ($\text{Cu}_3(\text{PO}_4)_2$), zinc phosphate ($\text{Zn}_3(\text{PO}_4)_4$), magnesium phosphate ($\text{Mg}_3(\text{PO}_4)_2$); and halides such as aluminum chloride (AlCl_3), titanium chloride (TiCl_4), calcium chloride (CaCl_2), calcium fluoride (CaF_2), barium fluoride (BaF_2).

Moreover, the catalysts of the present invention can include metal compounds which can provide an electron pair to the Lewis acid in addition to being able to be isolated by the Lewis acid. In this case, it is preferred that 20 to 99.9 weight % of the compounds that can be isolated by the Lewis acid and 0.1 to 80 weight % of the metal compounds are used. When the Lewis acid is less than 20 weight %, the catalyst efficiency is significantly reduced. However, when the Lewis acid is more than 99.9 weight %, the efficacy of the catalysts due to combination with the metal oxides is insignificant. It is more preferable to use 60 to 95 weight % of the Lewis acid. When less than 0.1 weight % of metal compounds is used, the catalyst efficiency is not improved and is even reduced when more than 80 weight % is used.

The metal compound that act as a Lewis base can be any one or a mixture of two or more from the group consisting of: sulfates (e.g., Li_2SO_4 , Na_2SO_4), sulfites (e.g., Li_2SO_3 , Na_2SO_3), phosphates (e.g., Li_3PO_4 , Na_3PO_4), nitrates (e.g., LiNO_3 , NaNO_3), nitrites (e.g., LiNO_2 , NaNO_2), hydroxides (e.g., LiOH , NaOH), oxides (e.g., Li_2O , Na_2O), peroxides (e.g., Na_2O_2), superoxides (e.g., KO_2 , RbO_2 , CsO_2) of an alkaline metal; and sulfates (e.g., MgSO_4 , CaSO_4), sulfites (e.g., MgSO_3 , CaSO_3), phosphates (e.g., $\text{Mg}_3(\text{PO}_4)_2$, $\text{Ca}_3(\text{PO}_4)_2$), nitrates (e.g., $\text{Mg}(\text{NO}_3)_2$, $\text{Ca}(\text{NO}_3)_2$), nitrites (e.g., $\text{Mg}(\text{NO}_2)_2$, $\text{Ca}(\text{NO}_2)_2$), hydroxides (e.g., $\text{Mg}(\text{OH})_2$, $\text{Ca}(\text{OH})_2$), oxides (e.g., MgO , CaO) and superoxides (e.g., BaO_2) of an alkaline earth metal. When the

compounds are dissolved in water, they can easily be impregnated into ceramic raw materials of the catalyst. Therefore, ceramic catalysts that are well dispersed with the metal compounds in the ceramic layers can be formed when the metal compounds are first dissolved in the water, mixed with Lewis acids and then are dried.

Additionally, the catalysts of the present invention not only can be isolated by the Lewis acid but also can contain transition metal compounds. In this case, it is preferable to use 20 to 99.9 weight % of the compounds that can be isolated by the Lewis acid and 0.1 to 80 weight % of the transition metal compounds. When the Lewis acid is less than 20 weight %, the efficiency of the catalysts are significantly reduced. However, when the Lewis acid is more than 99.9 weight %, the catalyst efficiency according to the combination of the metal oxides is insignificant. It is more preferable to include 60 to 95 weight % of the Lewis acid. In addition, when less than 0.1 weight % of metal compounds is used, the catalyst efficiency does not show improvement and is even reduced when more than 80 weight% is used.

The transition metal compounds are hydrophilic compounds which can be any one or a mixture of two or more from the group consisting of: sulfate (e.g., MnSO_4 , CoSO_4 , ZnSO_4 , CuSO_4), sulfite (e.g., MnSO_3 , CoSO_3 , ZnSO_3 , CuSO_3), phosphate (e.g., $\text{Mn}_3(\text{PO}_4)_2$, $\text{Co}_3(\text{PO}_4)_2$, $\text{Zn}_3(\text{PO}_4)_2$, $\text{Cu}_3(\text{PO}_4)_2$), nitrate (e.g., $\text{Mn}(\text{NO}_3)_2$, $\text{Co}(\text{NO}_3)_2$, $\text{Zn}(\text{NO}_3)_2$, $\text{Cu}(\text{NO}_3)_2$), nitrite (e.g., $\text{Mn}(\text{NO}_2)_2$, $\text{Co}(\text{NO}_2)_2$, $\text{Zn}(\text{NO}_2)_2$, $\text{Cu}(\text{NO}_2)_2$), hydroxide (e.g., $\text{Mn}(\text{OH})_2$, $\text{Co}(\text{OH})_2$, $\text{Zn}(\text{OH})_2$, $\text{Cu}(\text{OH})_2$) and oxides (e.g., MnO , CoO , ZnO , CuO) of a transition metal. When the compounds are calcined, they are decomposed mostly into metal oxides (e.g. MnO , Mn_2O_3 , MnO_2) or metals (e.g. Pd ., Pt). Therefore, ceramic catalysts that are well dispersed with metal oxides or metals in the ceramic layers can be formed when the metal compounds are first dissolved in the water, mixed with ceramic raw materials and then are calcined.

In addition, the ceramic catalyst of the present invention can be provided by comprising a mixture of compounds that can be isolated by a Lewis acid, the metal compounds and the transition metal compounds. In this

case, it is preferable to mix 20 to 99.9 weight % of the compounds that can be isolated by the Lewis acid with 0.1 to 80 weight % of the metal compound which can offer an electron pair to the Lewis acid, and then additionally adding 0.1 to 50 weight parts of a transition metal compound to the mixture having 100 weight parts. When the Lewis acid is less than 20 weight %, the catalyst efficiency is significantly reduced; however, when the Lewis acid is more than 99.9 weight %, the catalyst efficiency with the combination with the metal oxides is insignificant. It is more preferable to comprise 60 to 95 weight % of the Lewis acid. In addition, when less than 0.1 weight % of metal compounds included, there is no improvement of the efficiency of the catalysts and the catalyst efficiency is even reduced when more than 80 weight % is used. When less than 0.1 weight part of the transition metal compounds was added to the mixture having 100 parts, there was no improvement of the efficiency of the catalysts, and the same result was shown when more than 50 weight parts were added.

Further, the ceramic catalysts of the present invention can be provided by using a mixture of the compounds that can be isolated by the Lewis acid and electrolytes. In this case, it is preferable to add an amount of less than 0.1 to 30 weight parts of the electrolytes compared to the compounds that can be isolated by the Lewis acid having 100 parts. When less than 0.1 weight part of the electrolyte is added, there is no improvement of the efficiency of the catalyst of the present invention. Further, when more than 30 weight parts of the electrolyte are added, the catalyst efficiency was even reduced.

The electrolyte should be easily ionized such that it promotes transfer of electric charges, and for which mineral (inorganic) acids and its bases are generally used, which can be any one or a mixture of two or more from the group consisting of chloride (e.g., NaCl, KCl), nitrate (e.g., NaNO₃, KNO₃), sulfate (e.g., Na₂SO₄, K₂SO₄), carbonate (e.g., Li₂CO₃, Na₂CO₃, K₂CO₃), phosphate (e.g., NaH₂PO₄, Na₂HPO₄) of an alkaline metal and chloride (e.g., CuCl₂, NiCl₂), nitrate (e.g., Cu(NO₃)₂, Ni(NO₃)₂), sulfate (e.g., CuSO₄, NiSO₄) of a transition metal.

In addition, the ceramic catalysts of the present invention can be a mixture of compounds that can be isolated by the Lewis acid, the metal compounds and the electrolytes. In this case, it is preferable to mix 20 to 99.9 weight % of the compounds that can be isolated by the Lewis acid and 0.1 to 80 weight % of the metal compounds that can provide an electron pair to the Lewis acid, followed by adding 0.1 to 30 weight parts of the electrolytes to the mixture having 100 parts. When the Lewis acid is less than 20 weight %, the catalyst efficiency is significantly reduced; however, when more than 99.9 weight % of the Lewis acid is included, the catalyst efficiency in combination with the metal oxides is insignificant. It is more preferable to have 60 to 95 weight % of the Lewis acid. In addition, when an amount of 0.1 weight % or less of the metal compounds is included, there is no improvement of the catalyst efficiency and the characterization of the catalysts is even reduced when more than 80 weight% is used. Moreover, when less than 0.1 weight parts of the electrolytes were added to the mixture having 100 parts, there was no improvement in the characterization of the catalysts, and the same was also shown when more than 30 weight parts were added.

In addition, the ceramic catalysts of the present invention can be a mixture of the compounds that can be isolated by the Lewis acid, the transition metal compounds and the electrolytes. In this case, it is preferable to make a mixture containing 20 to 99.9 weight % of compounds that can be isolated by the Lewis acid and 0.1 to 80 weight % of the transition metal compounds, followed by adding 0.1 to 30 weight part of electrolytes to the mixture having 100 weight parts. When the Lewis acid is less than 20 weight %, the efficiency of the catalysts are significantly reduced. However, when the Lewis acid is more than 99.9 weight %, the improved efficiency of the catalysts with combination with the metal oxides is insignificant. It is more preferable to mix 60 to 95 weight % of the Lewis acid. In addition, when less than 0.1 weight % of the metal compounds is used, no improvement in the characterization of the catalysts was shown and the characterization even reduced when more than 80 weight % is used. When less than 0.1 weight parts of the transition metal compounds were added to the mixture having

100 parts, there was no improvement in the characterization of the catalysts, and the same was also shown when more than 30 weight parts were added.

In addition, the ceramic catalysts of the present invention can be a mixture of the compounds that can be isolated by the Lewis acid, the metal compounds, the transition metal compounds and the electrolytes. In this case, it is preferable to make a mixture containing 20 to 99.9 weight% of compounds that can be isolated by the Lewis acid and 0.1 to 80 weight% of the metal compounds that can provide an electron pair to the Lewis acid, followed by adding 0.1 to 50 weight parts of the transition metal compounds to the mixture having 100 weight parts and then adding 0.1 to 30 weight parts of the electrolytes to the resulting mixture having 100 weight parts. When the amount of the Lewis acid added is less than 20 weight %, the efficiency of the catalysts are significantly reduced; however, when the amount of the Lewis acid added is more than 99.9 weight %, the efficiency of the catalysts is insignificant. It is more preferable to add 60 to 95 weight % of the Lewis acid. In addition, when less than 0.1 weight % of the metal compounds is added, there is no improvement of the characterization of the catalysts and the same result is shown when more than 80 weight% is added. When an amount of less than 0.1 weight parts of the transition metal compounds was added to the mixture, there was no improvement of the properties of the catalysts, and no improvement of the catalyst properties was also shown when more than 50 weight parts were added. When less than 0.1 weight parts of the electrolytes were added, there was no improvement of the efficiency of the catalysts, and the efficiency even reduced when more than 30 weight parts were added.

The present invention is explained in detail using the following examples. The following examples of the present invention only exemplify the present invention and the scope of the present invention should not be limited by the examples.

Example 1: Reactions to Lewis acids

Reactions to Lewis acids using the experimental device of Fig. 1 were

examined.

A. Decomposition of Vapor Phase Organic Compounds: The Lewis acid catalysts were crushed into particles having an average size of 1 μ m or below, followed by adding 5g of the particles to catalyst container (8) of Fig. 1. The temperature of water bath (4), temperature control area (6) and catalyst container (8) was maintained at room temperature. Air was supplied at 5ml/min while propionaldehyde inside bubbler(3) was made to be injected into the catalyst container (8) at the concentration of 10,000 ppm. After 30 minutes of reaction, the decomposed portion of propionaldehyde was measured using Gas Chromatography (10)(HP-5890) and the results thereof are shown in Table 1.

【Table 1】

Compound name	Decomposed portion of propionaldehyde (%)
Zinc oxide(ZnO)	3.81
Aluminum oxide(Al ₂ O ₃)	4.50
Titanium oxide(TiO ₂)	3.23
Silicon oxide(SiO ₂)	2.73
Chromium oxide(Cr ₂ O ₃)	3.42
Zeolite	3.41
Montmorillonite	3.18
Calcium sulfate(CaSO ₄)	4.26
Barium sulfate(BaSO ₄)	3.96
Cobalt sulfate(CoSO ₄)	4.11
Zinc nitrate(Zn(NO ₃) ₂)	2.75
Iron nitrate(Fe(NO ₃) ₃)	3.21
Iron phosphate(FePO ₄)	2.87
Aluminum phosphate(AlPO ₄)	3.53
Calcium chloride(CaCl ₂)	2.13
Calcium fluoride(CaF ₂)	2.67

B. Water Decomposition: The Lewis acid catalysts were crushed into particles having the average size of 1 mm or below. Then, 5g of the crushed particles were put into the catalyst container (8) of Fig. 1. Then, the temperature of the water bath (4) was maintained at room temperature while that of the temperature control area (6) and the catalyst container(8) was maintained at 250 °C, followed by supplying argon gas at 5 ml/min and distilled water from bubbler(3) is allowed to migrate to the catalyst container (8) to allow reaction to occur. After 30 minutes of reaction, the decomposed portion of water was measured using a Gas Chromatography (10)(HP- 5890) and the results thereof are shown in Table 2.

【Table 2】

Compound name	Decomposed portion of water (%)
Zinc oxide(ZnO)	0.017
Aluminum oxide(Al_2O_3)	0.018
Titanium oxide(TiO_2)	0.015
Silicon oxide(SiO_2)	0.014
Chromium oxide(Cr_2O_3)	0.013
Zeolite	0.014
Montmorillonite	0.014
Calcium sulfate(CaSO_4)	0.013
Barium sulfate(BaSO_4)	0.013
Cobalt sulfate(CoSO_4)	0.014
Zinc nitrate($\text{Zn}(\text{NO}_3)_2$)	0.011
Iron nitrate($\text{Fe}(\text{NO}_3)_3$)	0.013
Iron phosphate(FePO_4)	0.014
Aluminum phosphate(AlPO_4)	0.015
Calcium chloride(CaCl_2)	0.014
Calcium fluoride(CaF_2)	0.014

C. Reactions between carbon dioxide and water: The Lewis acid catalysts are crushed into particles having the average diameter of 1 mm or below, and

then 5g of the crushed particles were placed into the catalyst container (8) as shown in Fig. 1. Then, the temperature of the water bath (4), the temperature control area (6) and the catalyst container (8) was maintained at 250°C.

Carbon dioxides were injected at 5ml/min and allowed distilled water from the bubbler (3) migrate to the catalyst container (8). After 30 minutes, the carbon dioxide conversion to organic material was measured using the Gas Chromatography (10)(HP- 5890) and the results thereof are shown in Table 3.

[Table 3]

Compound name	carbon dioxide conversion to organic material (%)
Zinc oxide(ZnO)	0.11
Aluminum oxide(Al_2O_3)	0.15
Titanium oxide(TiO_2)	0.05
Silicon oxide(SiO_2)	0.05
Chromium oxide(Cr_2O_3)	0.06
Zeolite	0.04
Montmorillonite	0.08
Calcium sulfate(CaSO_4)	0.10
Barium sulfate(BaSO_4)	0.07
Cobalt sulfate(CoSO_4)	0.05
Zinc nitrate($\text{Zn}(\text{NO}_3)_2$)	0.06
Iron nitrate($\text{Fe}(\text{NO}_3)_3$)	0.08
Iron phosphate(FePO_4)	0.04
Aluminum phosphate(AlPO_4)	0.10
Calcium chloride(CaCl_2)	0.11
Calcium fluoride(CaF_2)	0.09

Example 2: Reactions to Addition of Metal Compounds

95 parts by weight of alumina Lewis acid raw material and 5 parts by weight of metal compounds were mixed to prepare a mixture of raw material of ceramic catalysts. 1.5 times the weight of the mixture of distilled water was

mixed into the mixture and the resulting mixture was shaped into a cylinder shape having a diameter of 3cm and a length of 10cm. The shaped mixture was dried at room temperature for 72 hours and then was calcined using electric furnace at 1,100°C for 12 hours and then was cooled at room temperature, thereby obtaining ceramic catalysts.

A. Decomposition of Vapor Phase Organic Compounds: The Lewis acid catalysts were crushed into particles having an average size of the particles are 1mm or below, followed by adding 5g of the particles to catalyst container (8) of Fig. 1. The temperature of water bath (4), temperature control area (6) and catalyst container (8) was maintained at room temperature. Air was supplied at 5ml/min while propionaldehyde inside bubbler(3) was made to be injected into the catalyst container (8) at the concentration of 10,000 ppm. After 30 minutes of reaction, the decomposed portion of propionaldehyde was measured using Gas Chromatography (10)(HP-5890) and the results thereof are shown in Table 4.

[Table 4]

Metal compound name	Decomposed portion of propionaldehyde(%)
Sodium sulfate(Na_2SO_4)	9.3
Lithium phosphate(Li_3PO_4)	8.9
Magnesium nitrate($\text{Mg}(\text{NO}_3)_2$)	9.1
Calcium phosphate($\text{Ca}_3(\text{PO}_4)_2$)	8.7
Potassium hyperoxide(KO_2)	8.5
Barium peroxide(BaO_2)	8.1
Magnesium hydroxide($\text{Mg}(\text{OH})_2$)	9.1
Calcium hydroxide($\text{Ca}(\text{OH})_2$)	9.3
Sodium hydroxide(NaOH)	8.2
Magnesium oxide(MgO)	8.8

B. Water Decomposition: The cylinder shaped ceramic catalysts were

crushed into particles having the average size of 1 μm or below. Then, 5g of the crushed particles were put into the catalyst container (8) of Fig. 1 followed by sufficient purging with an inert gas (e.g. argon). The temperature of the water bath (4) was maintained at room temperature while that of the temperature control area (6) and the catalyst container (8) was maintained at 450 °C. Inert gas was supplied at 5 mL/min while letting a reaction to occur by allowing distilled water from bubbler (3) to migrate into the catalyst container (8). After 30 minutes of reaction, the decomposed portion of water was measured using Gas Chromatography (10)(HP-5890) and the results are shown in Table 5.

【Table 5】

Metal compound name	Decomposed portion of water (%)
Sodium sulfate(Na_2SO_4)	0.035
Lithium phosphate(Li_3PO_4)	0.037
Magnesium nitrate($\text{Mg}(\text{NO}_3)_2$)	0.029
Calcium phosphate($\text{Ca}_3(\text{PO}_4)_2$)	0.030
Potassium hyperoxide(KO_2)	0.028
Barium peroxide(BaO_2)	0.029
Magnesium hydroxide($\text{Mg}(\text{OH})_2$)	0.034
Calcium hydroxide($\text{Ca}(\text{OH})_2$)	0.033
Sodium hydroxide(NaOH)	0.029
Magnesium oxide(MgO)	0.032

C. Reactions between carbon dioxide and water: The Lewis acid catalysts are crushed into particles having the average diameter of 1 μm or below, and then 5g of the crushed particles were placed into the catalyst container (8) as shown in Fig. 1. Then, the temperature of the waterbath (4), the temperature control area (6) and the catalyst container (8) was maintained at 450 °C. Carbon dioxides were injected at 5 mL/min and allowed distilled water from the bubbler (3) migrate to the catalyst container(8). After 30 minutes, the carbon

dioxide conversion to organic material was measured using the Gas Chromatography (10)(HP- 5890) and the results thereof are shown in Table 6.

【Table 6】

Metal compound name	Decomposed portion of propionaldehyde(%)
Sodium sulfate(Na_2SO_4)	0.16
Lithium phosphate(Li_3PO_4)	0.11
Magnesium nitrate($\text{Mg}(\text{NO}_3)_2$)	0.14
Calcium phosphate($\text{Ca}_3(\text{PO}_4)_2$)	0.09
Potassium hyperoxide(KO_2)	0.10
Barium peroxide(BaO_2)	0.12
Magnesium hydroxide($\text{Mg}(\text{OH})_2$)	0.11
Calcium hydroxide($\text{Ca}(\text{OH})_2$)	0.11
Sodium hydroxide(NaOH)	0.10
Magnesium oxide(MgO)	0.14

Example 3: Reactions to the Addition of Transition Metal Compounds 1

95 parts by weight of alumina Lewis acid raw material and 5 parts by weight of metal compounds were mixed to prepare a mixture of raw material of ceramic catalysts. 1.5 times the weight of the mixture of distilled water was mixed into the mixture and the resulting mixture was shaped into a cylinder shape having a diameter of 3cm and a length of 10cm. The shaped mixture was dried at room temperature for 72 hours and then was calcined using electric furnace at 1,100°C for 12 hours and then was cooled at room temperature, thereby obtaining ceramic catalysts.

A. Decomposition of Vapor Phase Organic Compounds: The cylinder shape ceramic catalysts were crushed into particles having an average size of the particles are 1mm or below, followed by adding 5g of the particles to catalyst container (8) of Fig. 1. The temperature of water bath (4), temperature control area (6) and catalyst container (8) was maintained at room temperature. Air

was supplied at 5ml/min while propionaldehyde inside bubbler(3) was made to be injected into the catalyst container (8) at the concentration of 10,000 ppm. After 30 minutes of reaction, the decomposed portion of propionaldehyde was measured using Gas Chromatography(10)(HP-5890) and the results thereof are shown in Table 7.

【Table 7】

Metal compound name	Decomposed portion of propionaldehyde(%)
Copper sulfate(CuSO_4)	9.1
Cobalt sulfate(CoSO_4)	8.7
Zinc sulfate(ZnSO_4)	9.0
Manganese phosphate($\text{Mn}_3(\text{PO}_4)_2$)	8.9
Zinc hydroxide($\text{Zn}(\text{OH})_2$)	8.9
Cadmium hydroxide($\text{Cd}(\text{OH})_2$)	9.3
Chromium hydroxide($\text{Cr}(\text{OH})_2$)	9.3
Vanadium oxide(V_2O_5)	8.8
Cobalt nitrate($\text{Co}(\text{NO}_3)_2$)	8.3
Copper nitrate($\text{Cu}(\text{NO}_3)_2$)	8.1

B. Water Decomposition: The cylinder shaped ceramic catalysts were crushed into particles having the average size of 1mm or below. Then, 5g of the crushed particles were put into the catalyst container (8) of Fig. 1 followed by sufficient purging with an inert gas (e.g. argon). The temperature of the water bath (4) was maintained at room temperature while that of the temperature control area (6) and the catalyst container (8) was maintained at 450°C. Inert gas was supplied at 5ml/min while letting a reaction to occur by allowing distilled water from bubbler (3) to migrate into the catalyst container (8). After 30 minutes of reaction, the decomposed portion of water was measured using Gas Chromatography (10)(HP-5890) and the results are shown in Table 8.

【Table 8】

Metal compound name	Decomposed portion of water(%)
Copper sulfate(CuSO_4)	0.025
Cobalt sulfate(CoSO_4)	0.034
Zinc sulfate(ZnSO_4)	0.030
Manganese phosphate($\text{Mn}_3(\text{PO}_4)_2$)	0.033
Zinc hydroxide($\text{Zn}(\text{OH})_2$)	0.029
Cadmium hydroxide($\text{Cd}(\text{OH})_2$)	0.031
Chromium hydroxide($\text{Cr}(\text{OH})_2$)	0.035
Vanadium oxide(V_2O_5)	0.032
Cobalt nitrate($\text{Co}(\text{NO}_3)_2$)	0.031
Copper nitrate($\text{Cu}(\text{NO}_3)_2$)	0.029

C. Reactions between carbon dioxide and water: The Lewis acid catalysts are crushed into particles having the average diameter of 1 μm or below, and then 5g of the crushed particles were placed into the catalyst container (8) as shown in Fig. 1. Then, the temperature of the water bath (4), the temperature control area (6) and the catalyst container (8) was maintained at 450 °C. Carbon dioxides were injected at 5 mL/min and allowed distilled water from the bubbler (3) migrate to the catalyst container(8). After 30 minutes, the carbon dioxide conversion to organic material was measured using the Gas Chromatography (10)(HP- 5890) and the results thereof are shown in Table 9

【Table 9】

Metal compound name	Carbon dioxide conversion to organic material(%)
Copper sulfate(CuSO_4)	0.15
Cobalt sulfate(CoSO_4)	0.12
Zinc sulfate(ZnSO_4)	0.13
Manganese phosphate($\text{Mn}_3(\text{PO}_4)_2$)	0.10
Zinc hydroxide($\text{Zn}(\text{OH})_2$)	0.11

Cadmium hydroxide($\text{Cd}(\text{OH})_2$)	0.11
Chromium hydroxide($\text{Cr}(\text{OH})_2$)	0.12
Vanadium oxide(V_2O_5)	0.11
Cobalt nitrate($\text{Co}(\text{NO}_3)_2$)	0.12
Copper nitrate($\text{Cu}(\text{NO}_3)_2$)	0.11

Example 4: Reactions to the Addition of Transition Metal Compounds 2
 95 parts by weight of alumina Lewis acid raw material and 5 parts by weight of calcium hydroxides ($\text{Ca}(\text{OH})_2$) were mixed then 90 parts of the mixture and 10 parts of the transition metal compounds were added to prepare a mixture of raw material of ceramic catalysts. 1.5 times the weight of the mixture of distilled water was mixed into the mixture and the resulting mixture was shaped into a cylinder shape having a diameter of 3cm and a length of 10cm. The shaped mixture was dried at room temperature for 72 hours and then was calcined using electric furnace at 1,100 °C for 12 hours and then was cooled at room temperature, thereby obtaining ceramic catalysts.

A. Decomposition of Vapor Phase Organic Compounds: The ceramic catalysts were crushed into particles having an average size of the particles are 1mm or below, followed by adding 5g of the particles to catalyst container (8) of Fig. 1. The temperature of water bath (4), temperature control area (6) and catalyst container (8) was maintained at room temperature. Air was supplied at 5ml/min while propionaldehyde inside bubbler(3) was made to be injected into the catalyst container (8) at the concentration of 10,000 ppm. After 30 minutes of reaction, the decomposed portion of propionaldehyde was measured using Gas Chromatography (10)(HP-5890) and the results thereof are shown in Table 10.

【Table 10】

Metal compound name	Decomposed portion of propionaldehyde(%)
---------------------	--

Copper sulfate(CuSO_4)	9.6
Cobalt sulfate(CoSO_4)	9.1
Zinc sulfate(ZnSO_4)	9.7
Manganese phosphate($\text{Mn}_3(\text{PO}_4)_2$)	9.5
Zinc hydroxide($\text{Zn}(\text{OH})_2$)	9.9
Cadmium hydroxide($\text{Cd}(\text{OH})_2$)	10.0
Chromium hydroxide($\text{Cr}(\text{OH})_2$)	9.9
Vanadium oxide(V_2O_5)	9.2
Cobalt nitrate($\text{Co}(\text{NO}_3)_2$)	9.0
Copper nitrate($\text{Cu}(\text{NO}_3)_2$)	8.9

B. Water Decomposition: The cylinder shaped ceramic catalysts were crushed into particles having the average size of 1mm or below. Then, 5g of the crushed particles were put into the catalyst container (8) of Fig. 1 followed by sufficient purging with an inert gas (e.g. argon). The temperature of the water bath (4) was maintained at room temperature while that of the temperature control area (6) and the catalyst container (8) was maintained at 450°C. Inert gas was supplied at 5ml/min while letting a reaction to occur by allowing distilled water from bubbler (3) to migrate into the catalyst container (8). After 30 minutes of reaction, the decomposed portion of water was measured using Gas Chromatography (10)(HP-5890) and the results are shown in Table 11.

【Table 11】

Metal compound name	Decomposed portion of water(%)
Copper sulfate(CuSO_4)	0.030
Cobalt sulfate(CoSO_4)	0.038
Zinc sulfate(ZnSO_4)	0.037
Manganese phosphate($\text{Mn}_3(\text{PO}_4)_2$)	0.039
Zinc hydroxide($\text{Zn}(\text{OH})_2$)	0.037
Cadmium hydroxide($\text{Cd}(\text{OH})_2$)	0.039

Chromium hydroxide($\text{Cr}(\text{OH})_2$)	0.040
Vanadium oxide(V_2O_5)	0.039
Cobalt nitrate($\text{Co}(\text{NO}_3)_2$)	0.038
Copper nitrate($\text{Cu}(\text{NO}_3)_2$)	0.037

C. Reactions between carbon dioxide and water: The ceramic catalysts are crushed into particles having the average diameter of 1mm or below, and then 5g of the crushed particles were placed into the catalyst container (8) as shown in Fig. 1. Then, the temperature of the water bath (4), the temperature control area (6) and the catalyst container (8) was maintained at 450 °C. Carbon dioxides were injected at 5ml/min and allowed distilled water from the bubbler (3) migrate to the catalyst container(8). After 30 minutes, the carbon dioxide conversion to organic material was measured using the Gas Chromatography (10)(HP- 5890) and the results thereof are shown in Table 12.

[Table 12]

Metal compound name	Carbon dioxide conversion to organic material(%)
Copper sulfate(CuSO_4)	0.17
Cobalt sulfate(CoSO_4)	0.16
Zinc sulfate(ZnSO_4)	0.14
Manganese phosphate($\text{Mn}_3(\text{PO}_4)_2$)	0.13
Zinc hydroxide($\text{Zn}(\text{OH})_2$)	0.15
Cadmium hydroxide($\text{Cd}(\text{OH})_2$)	0.14
Chromium hydroxide($\text{Cr}(\text{OH})_2$)	0.16
Vanadium oxide(V_2O_5)	0.14
Cobalt nitrate($\text{Co}(\text{NO}_3)_2$)	0.11
Copper nitrate($\text{Cu}(\text{NO}_3)_2$)	0.10

Example 5: Reactions to the Addition of Electrolytes 1

6 weight % of the following electrolytes were added to the alumina Lewis acid

using the experimental device shown in Fig. 1 to prepare ceramic catalyst raw material compounds. 1.5 times the weight of the mixture of distilled water was mixed into the mixture and the resulting mixture was shaped into a cylinder shape having a diameter of 3cm and a length of 10cm. The shaped mixture was dried at room temperature for 72 hours and then was calcined using electric furnace at 900°C for 12 hours and then was cooled at room temperature, thereby obtaining ceramic catalysts.

A. Decomposition of Vapor Phase Organic Compounds: The ceramic catalysts were crushed into particles having an average size of the particles are 1mm or below, followed by adding 5g of the particles to catalyst container (8) of Fig. 1. The temperature of water bath (4), temperature control area (6) and catalyst container (8) was maintained at room temperature. Air was supplied at 5ml/min while propionaldehyde inside bubbler(3) was made to be injected into the catalyst container (8) at the concentration of 10,000 ppm. After 30 minutes of reaction, the decomposed portion of propionaldehyde was measured using Gas Chromatography (10)(HP-5890) and the results thereof are shown in Table 13.

[Table 13]

Electrolyte name	Decomposed portion of propionaldehyde(%)
Sodium Chloride(NaCl)	9.6
Potassium Chloride(KCl)	9.2
Sodium Nitrate(NaNO ₃)	9.7
Sodium Sulfate(Na ₂ SO ₄)	9.6
Copper Sulfate(CuSO ₄)	9.9
Lithium Carbonate(Li ₂ CO ₃)	10.0
Sodium Carbonate(Na ₂ CO ₃)	10.0
Potassium Carbonate(K ₂ CO ₃)	9.3

B. Water Decomposition: The cylinder shaped ceramic catalysts were crushed into particles having the average size of 1mm or below. Then, 5g of the crushed particles were put into the catalyst container (8) of Fig. 1 followed by sufficient purging with an inert gas (e.g. argon). The temperature of the water bath (4) was maintained at room temperature while that of the temperature control area (6) and the catalyst container (8) was maintained at 450°C. Inert gas was supplied at 5ml/min while letting a reaction to occur by allowing distilled water from bubbler (3) to migrate into the catalyst container (8). After 30 minutes of reaction, the decomposed portion of water was measured using Gas Chromatography (10)(HP-5890) and the results are shown in Table 14.

【Table 14】

Electrolyte name	Decomposed portion of water(%)
Sodium Chloride(NaCl)	0.031
Potassium Chloride(KCl)	0.038
Sodium Nitrate(NaNO ₃)	0.038
Sodium Sulfate(Na ₂ SO ₄)	0.036
Copper Sulfate(CuSO ₄)	0.033
Lithium Carbonate(Li ₂ CO ₃)	0.038
Sodium Carbonate(Na ₂ CO ₃)	0.041
Potassium Carbonate(K ₂ CO ₃)	0.039

C. Reactions between carbon dioxide and water: The ceramic catalysts are crushed into particles having the average diameter of 1mm or below, and then 5g of the crushed particles were placed into the catalyst container (8) as shown in Fig. 1. Then, the temperature of the water bath (4), the temperature control area (6) and the catalyst container (8) was maintained at 450°C. Carbon dioxides were injected at 5ml/min and allowed distilled water from the bubbler (3) migrate to the catalyst container(8). After 30 minutes, the carbon dioxide conversion to organic material was measured using the Gas

Chromatography (10)(HP- 5890) and the results thereof are shown in Table 15.

【Table 15】

Electrolyte name	Carbon dioxide conversion to organic material (%)
Sodium Chloride(NaCl)	0.17
Potassium Chloride(KCl)	0.16
Sodium Nitrate(NaNO ₃)	0.15
Sodium Sulfate(Na ₂ SO ₄)	0.14
Copper Sulfate(CuSO ₄)	0.13
Lithium Carbonate(Li ₂ CO ₃)	0.15
Sodium Carbonate(Na ₂ CO ₃)	0.14
Potassium Carbonate(K ₂ CO ₃)	0.15

Example 6: Reactions to Addition of Electrolytes 2

95 parts by weight of alumina Lewis acid raw material and 5 parts by weight of sodium hydroxide (NaOH) were mixed, then 94 parts of the resulting mixture and 6 parts of the electrolytes were added to prepare a mixture of raw materials of ceramic catalysts. 1.5 times the weight of the mixture of distilled water was mixed into the mixture and the resulting mixture was shaped into a cylinder shape having a diameter of 3cm and a length of 10cm. The shaped mixture was dried at room temperature for 72 hours and then was calcined using electric furnace at 900℃ for 12 hours and then was cooled at room temperature, thereby obtaining ceramic catalysts.

A. Decomposition of Vapor Phase Organic Compounds: The ceramic catalysts were crushed into particles having an average size of the particles are 1mm or below, followed by adding 5g of the particles to catalyst container (8) of Fig. 1. The temperature of water bath (4), temperature control area (6) and catalyst container (8) was maintained at room temperature. Air was supplied at 5ml/min while propionaldehyde inside bubbler(3) was made to be

injected into the catalyst container (8) at the concentration of 10,000 ppm. After 30 minutes of reaction, the decomposed portion of propionaldehyde was measured using Gas Chromatography (10)(HP-5890) and the results thereof are shown in Table 16.

【Table 16】

Electrolyte name	Decomposed portion of propionaldehyde (%)
Sodium Chloride(NaCl)	9.7
Potassium Chloride(KCl)	9.5
Sodium Nitrate(NaNO ₃)	9.6
Sodium Sulfate(Na ₂ SO ₄)	9.7
Copper Sulfate(CuSO ₄)	9.9
Lithium Carbonate(Li ₂ CO ₃)	9.9
Sodium Carbonate(Na ₂ CO ₃)	10.0
Potassium Carbonate(K ₂ CO ₃)	9.5

B. Water Decomposition: The cylinder shaped ceramic catalysts were crushed into particles having the average size of 1mm or below. Then, 5g of the crushed particles were put into the catalyst container (8) of Fig. 1 followed by sufficient purging with an inert gas (e.g. argon). The temperature of the water bath (4) was maintained at room temperature while that of the temperature control area (6) and the catalyst container (8) was maintained at 450°C. Inert gas was supplied at 5ml/min while letting a reaction to occur by allowing distilled water from bubbler (3) to migrate into the catalyst container (8). After 30 minutes of reaction, the decomposed portion of water was measured using Gas Chromatography (10)(HP-5890) and the results are shown in Table 17.

【Table 17】

Electrolyte name	Decomposed portion of water(%)
------------------	--------------------------------

Sodium Chloride(NaCl)	0.030
Potassium Chloride(KCl)	0.038
Sodium Nitrate(NaNO ₃)	0.039
Sodium Sulfate(Na ₂ SO ₄)	0.037
Copper Sulfate(CuSO ₄)	0.035
Lithium Carbonate(Li ₂ CO ₃)	0.038
Sodium Carbonate(Na ₂ CO ₃)	0.038
Potassium Carbonate(K ₂ CO ₃)	0.039

C. Reactions between carbon dioxide and water: The ceramic catalysts are crushed into particles having the average diameter of 1mm or below, and then 5g of the crushed particles were placed into the catalyst container (8) as shown in Fig. 1. Then, the temperature of the water bath (4), the temperature control area (6) and the catalyst container (8) was maintained at 450°C. Carbon dioxides were injected at 5ml/min and allowed distilled water from the bubbler (3) migrate to the catalyst container(8). After 30 minutes, the carbon dioxide conversion to organic material was measured using the Gas Chromatography (10)(HP- 5890) and the results thereof are shown in Table 18.

【Table 18】

Electrolyte name	Carbon dioxide conversion to organic material(%)
Sodium Chloride(NaCl)	0.16
Potassium Chloride(KCl)	0.16
Sodium Nitrate(NaNO ₃)	0.17
Sodium Sulfate(Na ₂ SO ₄)	0.18
Copper Sulfate(CuSO ₄)	0.17
Lithium Carbonate(Li ₂ CO ₃)	0.15
Sodium Carbonate(Na ₂ CO ₃)	0.14
Potassium Carbonate(K ₂ CO ₃)	0.16

Example 7: Reactions to Addition of Electrolytes 3

95 parts by weight of alumina Lewis acid raw material and 5 parts by weight of zinc sulfate (ZnSO_4) were mixed, and then 94 parts of the resulting mixture and 6 parts of the electrolytes were added to prepare ceramic catalyst raw material mixture. 1.5 times the weight of the mixture of distilled water was mixed into the mixture and the resulting mixture was shaped into a cylinder shape having a diameter of 3cm and a length of 10cm. The shaped mixture was dried at room temperature for 72 hours and then was calcined using electric furnace at 900 °C for 12 hours and then was cooled at room temperature, thereby obtaining ceramic catalysts.

A. Decomposition of Vapor Phase Organic Compounds: The ceramic catalysts were crushed into particles having an average size of the particles are 1mm or below, followed by adding 5g of the particles to catalyst container (8) of Fig. 1. The temperature of water bath (4), temperature control area (6) and catalyst container (8) was maintained at room temperature. Air was supplied at 5ml/min while propionaldehyde inside bubbler(3) was made to be injected into the catalyst container (8) at the concentration of 10,000 ppm. After 30 minutes of reaction, the decomposed portion of propionaldehyde was measured using Gas Chromatography(10)(HP-5890) and the results thereof are shown in Table 19.

【Table 19】

Electrolyte name	Decomposed portion of propionaldehyde(%)
Sodium Chloride(NaCl)	9.7
Potassium Chloride(KCl)	9.4
Sodium Nitrate(NaNO_3)	9.6
Sodium Sulfate(Na_2SO_4)	9.7
Copper Sulfate(CuSO_4)	9.9
Lithium Carbonate(Li_2CO_3)	10.0

Sodium Carbonate(Na_2CO_3)	10.1
Potassium Carbonate(K_2CO_3)	9.5

B. Water Decomposition: The cylinder shaped ceramic catalysts were crushed into particles having the average size of 1 mm or below. Then, 5g of the crushed particles were put into the catalyst container (8) of Fig. 1 followed by sufficient purging with an inert gas (e.g. argon). The temperature of the water bath (4) was maintained at room temperature while that of the temperature control area (6) and the catalyst container (8) was maintained at 450 °C. Inert gas was supplied at 5 ml/min while letting a reaction to occur by allowing distilled water from bubbler (3) to migrate into the catalyst container (8). After 30 minutes of reaction, the decomposed portion of water was measured using Gas Chromatography (10)(HP-5890) and the results are shown in Table 20.

【Table 20】

Electrolyte name	Decomposed portion of water(%)
Sodium Chloride(NaCl)	0.032
Potassium Chloride(KCl)	0.038
Sodium Nitrate(NaNO_3)	0.038
Sodium Sulfate(Na_2SO_4)	0.037
Copper Sulfate(CuSO_4)	0.035
Lithium Carbonate(Li_2CO_3)	0.038
Sodium Carbonate(Na_2CO_3)	0.040
Potassium Carbonate(K_2CO_3)	0.040

C. Reactions between carbon dioxide and water: The ceramic catalysts are crushed into particles having the average diameter of 1 mm or below, and then 5g of the crushed particles were placed into the catalyst container (8) as shown in Fig. 1. Then, the temperature of the water bath (4), the temperature control area (6) and the catalyst container (8) was maintained at 450 °C.

Carbon dioxides were injected at 5ml/min and allowed distilled water from the bubbler (3) migrate to the catalyst container(8). After 30 minutes, the carbon dioxide conversion to organic material was measured using the Gas Chromatography (10)(HP- 5890) and the results thereof are shown in Table 21.

【Table 21】

Electrolyte name	Carbon dioxide conversion to organic material(%)
Sodium Chloride(NaCl)	0.17
Potassium Chloride(KCl)	0.15
Sodium Nitrate(NaNO ₃)	0.15
Sodium Sulfate(Na ₂ SO ₄)	0.17
Copper Sulfate(CuSO ₄)	0.15
Lithium Carbonate(Li ₂ CO ₃)	0.15
Sodium Carbonate(Na ₂ CO ₃)	0.14
Potassium Carbonate(K ₂ CO ₃)	0.16

Example 8: Reactions to Addition of Electrolytes 4

90 parts by weight of alumina Lewis acid raw material and 5 parts by weight of metal compounds sodium hydroxide were mixed then 5 parts of zinc sulfates (ZnSO₄) were added followed by adding 6 parts of the following electrolytes to 94 parts of the resulting mixture there from to prepare a mixture of raw materials of ceramic catalysts. 1.5 times the weight of the mixture of distilled water was mixed into the mixture and the resulting mixture was shaped into a cylinder shape having a diameter of 3cm and a length of 10cm. The shaped mixture was dried at room temperature for 72 hours and then was calcined using electric furnace at 900°C for 12 hours and then was cooled at room temperature, thereby obtaining ceramic catalysts.

A. Decomposition of Vapor Phase Organic Compounds: The ceramic catalysts were crushed into particles having an average size of the particles

are 1 mm or below, followed by adding 5g of the particles to catalyst container (8) of Fig. 1. The temperature of water bath (4), temperature control area (6) and catalyst container (8) was maintained at room temperature. Air was supplied at 5 ml/min while propionaldehyde inside bubbler(3) was made to be injected into the catalyst container (8) at the concentration of 10,000 ppm. After 30 minutes of reaction, the decomposed portion of propionaldehyde was measured using Gas Chromatography(10)(HP-5890) and the results thereof are shown in Table 22.

【Table 22】

Electrolyte name	Decomposed portion of propionaldehyde(%)
Sodium Chloride(NaCl)	9.8
Potassium Chloride(KCl)	9.5
Sodium Nitrate(NaNO ₃)	9.8
Sodium Sulfate(Na ₂ SO ₄)	9.7
Copper Sulfate(CuSO ₄)	9.9
Lithium Carbonate(Li ₂ CO ₃)	10.1
Sodium Carbonate(Na ₂ CO ₃)	10.1
Potassium Carbonate(K ₂ CO ₃)	9.5

B. Water Decomposition: The cylinder shaped ceramic catalysts were crushed into particles having the average size of 1 mm or below. Then, 5g of the crushed particles were put into the catalyst container (8) of Fig. 1 followed by sufficient purging with an inert gas (e.g. argon). The temperature of the water bath (4) was maintained at room temperature while that of the temperature control area (6) and the catalyst container (8) was maintained at 450 °C. Inert gas was supplied at 5 ml/min while letting a reaction to occur by allowing distilled water from bubbler (3) to migrate into the catalyst container (8). After 30 minutes of reaction, the decomposed portion of water was measured using Gas Chromatography (10)(HP-5890) and the results are shown in Table 23.

【Table 23】

Electrolyte name	Decomposed portion of water(%)
Sodium Chloride(NaCl)	0.032
Potassium Chloride(KCl)	0.039
Sodium Nitrate(NaNO ₃)	0.039
Sodium Sulfate(Na ₂ SO ₄)	0.038
Copper Sulfate(CuSO ₄)	0.036
Lithium Carbonate(Li ₂ CO ₃)	0.038
Sodium Carbonate(Na ₂ CO ₃)	0.041
Potassium Carbonate(K ₂ CO ₃)	0.040

C. Reactions between carbon dioxide and water: The ceramic catalysts are crushed into particles having the average diameter of 1 mm or below, and then 5g of the crushed particles were placed into the catalyst container (8) as shown in Fig. 1. Then, the temperature of the water bath (4), the temperature control area (6) and the catalyst container (8) was maintained at 450 °C. Carbon dioxides were injected at 5 ml/min and allowed distilled water from the bubbler (3) migrate to the catalyst container(8). After 30 minutes, the carbon dioxide conversion to organic material was measured using the Gas Chromatography (10)(HP- 5890) and the results thereof are shown in Table 24.

【Table 24】

Electrolyte name	Carbon dioxide conversion to organic material(%)
Sodium Chloride(NaCl)	0.18
Potassium Chloride(KCl)	0.16
Sodium Nitrate(NaNO ₃)	0.17
Sodium Sulfate(Na ₂ SO ₄)	0.18
Copper Sulfate(CuSO ₄)	0.16

Lithium Carbonate(Li_2CO_3)	0.15
Sodium Carbonate(Na_2CO_3)	0.15
Potassium Carbonate(K_2CO_3)	0.16

As explained above, the catalysts of the present invention, which have various uses and can disperse soluble electrolyte salts in a raw material for the catalysts, can decompose water to produce hydrogen, can decompose vapor phase organic compounds at a low temperature of 100 °C or lower, particularly at a room temperature (around 25 °C) and can synthesize organic compounds by reacting water with carbon dioxide at a medium/high temperature of 100 °C or higher.

In other words, the catalysts of the present invention comprise of a mixture of catalyst raw material such as a Lewis acid which is relatively inexpensive and metal oxides, thereby having a characteristic that the cost of the catalysts are low. Therefore, particularly for water decomposition and organic synthesis through the reaction between carbon dioxide and water without light, since exhaust heat, carbon dioxides and steam produced from industrial sites can be used, the cost of production of hydrogen energy and energy from synthesized organic materials are expected to significantly decrease, and its economic efficiency is expected to be very high. Moreover, by achieving a remarkably more efficient property for the decomposition of vapor phase organic compounds, the industrial applicability of the catalysts, such as in the removal of odor-causing materials at room temperature, is expected to be significantly enhanced.

[CLAIMS]**[Claim 1]**

A catalyst for decomposing water, decomposing vapor phase organic compounds and synthesizing organic materials through the reaction between carbon dioxide and water comprising compounds that can be isolated by a Lewis acid only.

[Claim 2]

A catalyst for decomposing water, decomposing vapor phase organic compounds and synthesizing organic materials through the reaction between carbon dioxide and water comprising:

20 to 99.9 weight % of compounds that can be isolated by a Lewis acid; and
0.1 to 80 weight % of metal compounds that can offer an electron pair to the Lewis acid.

[Claim 3]

A catalyst for decomposing water, decomposing vapor phase organic compounds and synthesizing organic materials through the reaction between carbon dioxide and water comprising:

20 to 99.9 weight % of compounds that can be isolated by a Lewis acid; and
0.1 to 80 weight % of transition metal compounds.

[Claim 4]

A catalyst for decomposing water, decomposing vapor phase organic compounds and synthesizing organic materials through the reaction between carbon dioxide and water comprising 0.1 to 30 weights parts of electrolytes added to 100 weight parts of compounds that can be isolated by a Lewis acid.

[Claim 5]

The catalyst of claim 2 further comprising additional 0.1 to 50 weight parts of transition metal compounds compared to 100 parts of the catalyst composition.

[Claim 6]

The catalyst of claim 2 further comprising additional 0.1 to 30 weight parts of electrolytes compared to 100 parts of the catalyst composition.

[Claim 7]

The catalyst of claim 3 further comprising additional 0.1 to 30 weight parts of electrolytes compared to 100 parts of the catalyst composition.

[Claim 8]

The catalyst of claim 5 further comprising additional 0.1 to 30 weight parts of electrolytes compared to 100 parts of the catalyst composition.

[Claim 9]

The catalyst of any one of claims 1 to 8, wherein the compounds that can be isolated by a Lewis acid can be any one or a mixture of two or more from the group consisting of: natural minerals such as kaolinite, bentonite, attapulgite, zeolite, montmorillonite; oxides such as zinc oxide (ZnO), aluminum oxide (Al_2O_3), titanium dioxide (TiO_2), cerium oxide (CeO_2), vanadium pentoxide (V_2O_5), silicon dioxide (SiO_2), chromium oxide (Cr_2O_3); sulfates such as calcium sulfate (CaSO_4), manganese sulfate (MnSO_4), nickel sulfate (NiSO_4), copper sulfate (CuSO_4), cobalt sulfate (CoSO_4), cadmium sulfate (CdSO_4), magnesium sulfate (MgSO_4), iron sulfate (FeSO_4), aluminum sulfate ($\text{Al}_2(\text{SO}_4)_3$); and nitrates such as calcium nitrate ($\text{Ca}(\text{NO}_3)_2$), zinc nitrate ($\text{Zn}(\text{NO}_3)_2$), iron nitrate ($\text{Fe}(\text{NO}_3)_3$); phosphates such as aluminum phosphate (AlPO_4), iron phosphate (FePO_4), chromium phosphate (CrPO_4), copper phosphate ($\text{Cu}_3(\text{PO}_4)_2$), zinc phosphate ($\text{Zn}_3(\text{PO}_4)_4$), magnesium phosphate ($\text{Mg}_3(\text{PO}_4)_2$); and halides such as aluminum chloride (AlCl_3), titanium chloride (TiCl_4), calcium chloride (CaCl_2), calcium fluoride (CaF_2), barium fluoride (BaF_2).

[Claim 10]

The catalyst of any one of claims 2, 5, 6 and 8, wherein the metal compounds that can provide an electron pair to the Lewis acid can be any one or a mixture of two or more from the group consisting of: sulfates (Li_2SO_4 , Na_2SO_4), sulfites (Li_2SO_3 , Na_2SO_3), phosphates (Li_3PO_4 , Na_3PO_4), nitrates (LiNO_3 , NaNO_3), nitrites (LiNO_2 , NaNO_2), hydroxides (LiOH , NaOH), oxides (Li_2O , Na_2O), peroxides (Na_2O_2), superoxides (KO_2 , RbO_2 , CsO_2) of an alkaline metal; and sulfates (MgSO_4 , CaSO_4), sulfites (MgSO_3 , CaSO_3), phosphates ($\text{Mg}_3(\text{PO}_4)_2$, $\text{Ca}_3(\text{PO}_4)_2$), nitrates ($\text{Mg}(\text{NO}_3)_2$, $\text{Ca}(\text{NO}_3)_2$), nitrites ($\text{Mg}(\text{NO}_2)_2$, $\text{Ca}(\text{NO}_2)_2$), hydroxides ($\text{Mg}(\text{OH})_2$, $\text{Ca}(\text{OH})_2$), oxides (MgO , CaO) and superoxides (BaO_2) of an alkaline earth metal.

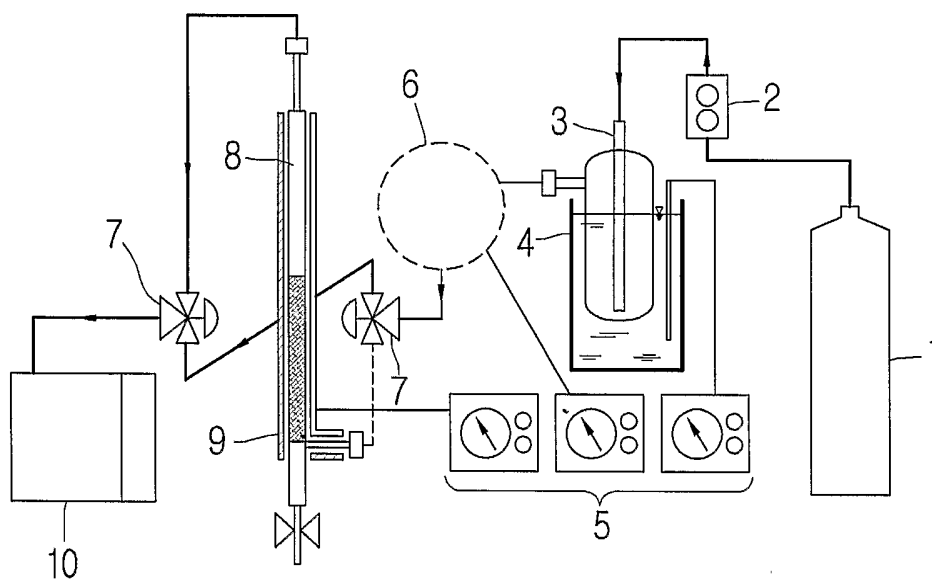
[Claim 11]

The catalyst of any one of claims 3, 7 and 8, wherein the transition metal compounds can be any one or a mixture of two or more from the group consisting of: sulfate (e.g., MnSO_4 , CoSO_4 , ZnSO_4 , CuSO_4), sulfite (e.g., MnSO_3 , CoSO_3 , ZnSO_3 , CuSO_3), phosphate (e.g., $\text{Mn}_3(\text{PO}_4)_2$, $\text{Co}_3(\text{PO}_4)_2$, $\text{Zn}_3(\text{PO}_4)_2$, $\text{Cu}_3(\text{PO}_4)_2$), nitrate (e.g., $\text{Mn}(\text{NO}_3)_2$, $\text{Co}(\text{NO}_3)_2$, $\text{Zn}(\text{NO}_3)_2$, $\text{Cu}(\text{NO}_3)_2$), nitrite (e.g., $\text{Mn}(\text{NO}_2)_2$, $\text{Co}(\text{NO}_2)_2$, $\text{Zn}(\text{NO}_2)_2$, $\text{Cu}(\text{NO}_2)_2$), hydroxide (e.g., $\text{Mn}(\text{OH})_2$, $\text{Co}(\text{OH})_2$, $\text{Zn}(\text{OH})_2$, $\text{Cu}(\text{OH})_2$) and oxides (e.g., MnO , CoO , ZnO , CuO) of a transition metal.

[Claim 12]

The catalyst of any one of claims 4, 6, 7 and 8, wherein the electrolytes can be any one or a mixture of two or more from the group consisting of chloride (NaCl , KCl), nitrate (NaNO_3 , KNO_3), sulfate (Na_2SO_4 , K_2SO_4), carbonate (Li_2CO_3 , Na_2CO_3 , K_2CO_3), phosphate (NaH_2PO_4 , Na_2HPO_4) of an alkaline metal and chloride (CuCl_2 , NiCl_2), nitrate ($\text{Cu}(\text{NO}_3)_2$, $\text{Ni}(\text{NO}_3)_2$), sulfate (CuSO_4 , NiSO_4) of a transition metal.

[Fig. 1]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2006/000426**A. CLASSIFICATION OF SUBJECT MATTER*****B01J 23/00(2006.01)i, B01J 23/02(2006.01)i, B01J 31/02(2006.01)i***

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 8 B01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean Utility models and applications for Utility models since 1975

Japanese Utility models and applications for Utility models since 1975

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKIPASS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2000-42404 A (JAPAN SCIENCE & TECHNOLOGY CORP.) 15 February 2000 see abstract, claims 1-7, [0001], [0010], [0015]-[0018], [0029]	1-4
A	JP 11-244705 A (JAPAN SCIENCE & TECHNOLOGY CORP.) 14 September 1999 see abstract, claims 1, 7-10, [0001], [0010], [0013]-[0014], [0027]	1-4
A	JP 2003-190795 A (INST GEORGETOWN UNIV.) 8 July 2003 see abstract, claims 1-7, [0001], [0008]-[0013], [0019], [0021], [0034]	1-4
A	US 5,773,383 A (Suciu) 30 June 1998 see abstract	1-4



Further documents are listed in the continuation of Box C.



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Date of the actual completion of the international search

12 MAY 2006 (12.05.2006)

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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