

Supported Catalyst, Preparation Method Therefor and Use Thereof, and Method for Preparation of Isobutylene from Halomethane

Field of the Invention

The present invention relates to a supported catalyst, method for its preparation and use thereof, and a method for preparation of isobutylene from halomethane by using this supported catalyst.

Background of the Invention

Isobutylene is an important basic organic chemical raw material. It has numerous derivatives. Its upstream and downstream industrial chains are complex. Its consumption structure is in diversified trends. From isobutylene, many products with high added value may be prepared, such as: butyl rubber, polyisobutylene, methyl tertiary-butyl ether, isoprene, polymethyl methacrylate and many other organic chemical raw materials and fine chemical products. As the market size of isobutylene downstream products keeps expanding, the imbalance between supply and demand will get more prominent. Particularly, under the background of increasing depletion of petroleum resources, the output of isobutylene has become a critical bottleneck holding back the development of downstream industry. Therefore, it is urgent to develop an isobutylene preparation route rather than a petroleum route.

Methane is a main component of natural gas, so methane conversion and utilization becomes an important research content of natural gas chemical technology. Particularly, in the recent years, under the general background of shale gas development and utilization, if isobutylene can be made from methane, it will be a new way to obtain isobutylene. However, methane has stable properties and is not easily activated, so it turns to be a bottleneck of chemical utilization of methane. Many domestic and foreign researchers have carried out the research of methane activation and conversion. The technology of halogen functionalization and then conversion of methane hopefully will become an important breakthrough to the technical problem of methane conversion.

From halomethane, many chemical products may be prepared. CN101041609A and CN101284232A disclose a method of converting methane into bromomethane under the action of oxygen and HBr/H₂O and then taking further reaction of bromomethane to generate C₃~C₁₃ mixed high-carbon hydrocarbons. The selectivity of hydrocarbons of C₅ or higher is 70%. HBr is used to bromize methane in the first reactor and released in the second reactor. After recovery, it is used in the first reaction again to realize cyclic use of HBr. Wang Ye et al (Jieli He, Ting Xu, Zhihui Wang, et.al. Angew. Chem. Int. Ed. 2012, 51, 2438-2442) discloses a modified molecular sieve catalyst of propylene from halomethane and preparation method thereof. By using a molecular sieve modified and treated with fluorinated compound to obtain an acidic catalyst containing an appropriate micropore structure, this catalyst may effectively catalyze halomethane and convert it into propylene. In the preparation and conversion of propylene from bromomethane, the single-pass bromomethane conversion rate of the prepared catalyst is 35~99% and the selectivity of propylene is 27~70%; in the preparation and conversion of propylene from chloromethane, the single-pass chloromethane conversion rate is 30~99% and the selectivity of propylene is 15~70%. Ivan M. Lorkovic et al (Ivan M. Lorkovic, Aysen Yilmaz, Gurkan A. Yilmaz, et al. Catalysis Today, 2004, 98, 317-322) also put forth a bromine circulation of using bromine to react with hydrocarbons in natural gas to generate bromo-hydrocarbons, then converting bromo-hydrocarbons into dimethyl ether, methanol and metal bromide on a metal oxide catalyst, and regenerating metal bromide by oxygen to obtain metal oxide and release simple substance bromine.

At present, the target products of halomethane conversion in the existing literature are methanol,

dimethyl ether, acetic acid, high-carbon hydrocarbon, ethylene and propylene. In the technologies in which low-carbon olefins with high added value are target products, the selectivity of a single product is not high. So far there is no report on highly selective synthesis of isobutylene from bromomethane.

Summary of the Invention

To address the shortcomings of prior art, the present invention provides a supported catalyst for highly selective generation of isobutylene from halomethane and its preparation method and use.

According to one aspect of the present invention, the present invention provides a supported catalyst, wherein the catalyst contains a support and a metallic active component supported on the support; the metallic active component contains zinc oxide and zinc halide, and the content of zinc oxide is 0.5 wt.%-20 wt.%, the content of zinc halide is 10 wt.%-50 wt.%, and the content of the support is 40 wt.%-88 wt.% based on the total weight of the catalyst.

According to the second aspect of the present invention, the present invention provides a method for preparing a supported catalyst, wherein the method includes the following steps: introducing zinc oxide to a support and then halogenating the resulted support after introducing zinc oxide.

According to the third aspect of the present invention, the present invention provides a use of the supported catalyst of the present invention in preparation of isobutylene.

According to the fourth aspect of the present invention, the present invention provides a method for preparation of isobutylene from halomethane, wherein the method includes carrying out hydrogen reduction activation of the supported catalyst of the present invention to make the content of halogen in the activated catalyst be 20 wt.%-90 wt.% of the total content of halogen in the supported catalyst without reduction, then contacting halomethane with the activated catalyst to prepare isobutylene.

Compared with prior art, the catalyst of the present invention may convert halomethane into isobutylene with high selectivity. The reaction for conversion and preparation of isobutylene from bromomethane is conducted by the method of the present invention. The bromomethane conversion rate is 90% or more and the selectivity of isobutylene is 80% or more. The preparation method of this catalyst is simple and can be easily industrialized. The method for preparation and conversion of isobutylene from bromomethane in the present invention has such advantages as moderate reaction conditions and high product selectivity, can be easily industrialized and has a broad application prospect.

Detailed Description of the Embodiments

According to one aspect of the present invention, the present invention provides a supported catalyst, wherein the catalyst contains a support and a metallic active component supported on the support, the metallic active component contains zinc oxide and zinc halide, and the content of zinc oxide is 0.5 wt.%-20 wt.%, the content of zinc halide is 10 wt.%-50 wt.%, and the content of the support is 40 wt.%-88 wt.% based on the total weight of the catalyst.

Preferably, based on the total weight of the catalyst, the content of zinc oxide is 1 wt.%-15 wt.%, the content of zinc halide is 15 wt.%-45 wt.%, and the content of the support is 50 wt.%-84 wt.%, more preferably, the content of zinc oxide is 1 wt.%-9 wt.%, the content of zinc halide is 18 wt.%-39 wt.%, and the content of the support is 55 wt.%-80 wt.% based on the total weight of the catalyst.

According to the present invention, the zinc halide may be selected from one or more of zinc fluoride, zinc chloride, zinc bromide and zinc iodide. The support may be one or more of aluminum oxide,

silicon oxide and ZSM-5 molecular sieve.

Preferably, the zinc halide is zinc bromide, and the support is aluminum oxide. The aluminum oxide may be γ -aluminum oxide and/or θ -aluminum oxide.

According to the supported catalyst of the present invention, preferably, this catalyst further contains an appropriate amount of promoter, which is selected from one or more of Ti, Zr, Ce and La. More preferably, the promoter is Zr.

The weight content of the promoter calculated on element is 0.1 wt.%-10 wt.%, more preferably 0.5 wt.%-5 wt.%, still more preferably 0.5 wt.%-3 wt.% based on the total weight of the catalyst.

According to the supported catalyst of the present invention, it is determined by NH_3 -TPD method that the total acidity of 450°C or less in the catalyst is 0.5 mmol/g-1.3 mmol/g, and the acidity of 250°C-350°C is 20%-90% of the total acidity of 450°C or less; preferably, the total acidity of 450°C or less in the catalyst is 0.6 mmol/g-1.2 mmol/g, and the acidity of 250°C-350°C is 30%-80% of the total acidity of 450°C or less; more preferably, the total acidity of 450°C or less in the catalyst is 0.7 mmol-1.1 mmol/g, and the acidity of 250°C-350°C is 40%-80% of the total acidity of 450°C or less.

In the present invention, the acids determined by NH_3 -TPD method in correspondence to 150°C-250°C are weak acids, the acids in correspondence to 250°C-400°C are moderate strong acids, and the acids in correspondence to 400°C-500°C are strong acids; the sum of the acid content of weak acids, moderately strong acids and strong acids are total acid content.

According to the method for preparing a supported catalyst in the present invention, wherein the method includes the following steps: introducing zinc oxide to the support and then halogenating the resulted support after introducing zinc oxide.

The amount of introduced zinc oxide and the conditions of halogenation make the content of zinc oxide be 0.5 wt.%-20 wt.%, the content of zinc halide be 10 wt.%-50 wt.%, and the content of the support be 40 wt.%-88 wt.% based on the total weight of the obtained supported catalyst. Preferably, the content of zinc oxide is 1 wt.%-15 wt.%, the content of zinc halide is 15 wt.%-40 wt.%, and the content of the support is 50 wt.%-84 wt.%, more preferably, the content of zinc oxide is 1 wt.%-9 wt.%, the content of zinc halide is 18 wt.%-39 wt.%, and the content of the support is 55 wt.%-80 wt.%.

According to the present invention, various means may be adopted to halogenate the support containing the introduced zinc oxide as long as an appropriate amount of zinc oxide in it is converted into zinc halide. Preferably, the mean of the halogenation includes contacting gaseous-phase halogen-containing compound with the support containing the introduced zinc oxide under the contact conditions that make the zinc oxide on the support partially converted into zinc halide.

Gaseous-phase halogen-containing compound may directly contact the support containing the introduced zinc oxide. Alternatively, gaseous-phase halogen-containing compound may contact the support containing the introduced zinc oxide in a form of a mixed gas of gaseous-phase halogen-containing compound and inert gas. In the mixed gas, the concentration of the gaseous-phase halogen-containing compound is not less than 20 v/v%, preferably not less than 30 v/v%, more preferably 30-90 v/v%, still more preferably 50-80 v/v%.

The gaseous-phase halogen-containing compound may be various kinds of halogen-containing compounds that are gaseous under the contact conditions, preferably halomethane, more preferably one or more of monohalomethane, bihalomethane and trihalomethane, still more preferably monohalomethane.

The halogen may be one or more of F, Cl, Br and I, preferably Cl and/or Br.

More preferably, the gaseous-phase halogen-containing compound is monobromomethane.

According to the present invention, the preferred mean of the contact includes putting the support containing the introduced zinc oxide in a continuous flow fixed bed reactor, raising temperature to 150°C-400°C in an inert atmosphere, and inputting gaseous-phase halogen-containing compound or a mixed gas containing gaseous-phase halogen-containing compound. The space velocity is 50h⁻¹-1000 h⁻¹, the contact pressure is 0.1MPa-0.5MPa and the time is 0.5h-8h. Preferably, temperature is raised to 180°C-350°C in an inert atmosphere, more preferably, the temperature is raised to 200°C-300°C, the space velocity is 100h⁻¹-500h⁻¹, the contact pressure is 0.1MPa-0.3MPa and the time is 1h-4h. The pressure is absolute pressure. The space velocity is space velocity by volume.

According to the present invention, zinc oxide may be introduced to the support in various existing means. For example, it may be introduced by impregnation, or by kneading during forming, or by gelling and co-precipitation during preparation of the support. Impregnation is preferred, i.e.: making a dissolvable compound of zinc into an impregnation liquid, then impregnating the support in the impregnation liquid and then drying and calcinating them. The dissolvable compound of zinc may be dissolvable inorganic salt and/or organic salt of zinc, such as: one or more of chloride, nitrate, sulfate, hydrochloride, acetate and citrate. As to element zinc, the concentration of the impregnation liquid is 5 g/L-300 g/L, preferably 20 g/L-200 g/L, more preferably 40 g/L-160 g/L. Impregnation in an equal volume or oversaturated impregnation may be adopted.

When the catalyst of the present invention further contains a promoter, the promoter may be introduced before, after or simultaneously with zinc oxide. It may be introduced by impregnation, or by kneading during forming, or by gelling and co-precipitation during preparation of the support. Impregnation is preferred, specifically: adopting a zinc salt and promoter metal salt solution to impregnate the formed support, drying and calcinating and then carrying out halogenation, or adopting a zinc salt solution to impregnate the formed support at first, drying and calcinating and then carrying out halogenation, lastly impregnating in a promoter metal salt solution and then drying and calcinating to obtain halomethane, which is used to make isobutylene catalyst.

The drying temperature may be 50°C-200°C, preferably 60°C-150°C, more preferably 80°C-120°C; the drying time is 1h-24h, preferably 4h-8h; the drying may be vacuum drying, or drying under protection of inert gas, or drying in an air atmosphere; the calcination temperature is 200°C-800°C, preferably 400°C-600°C; the calcination time is 1h-24h, preferably 4h-8h; the calcination may be under protection of inert gas, or in an air atmosphere.

The support may be an existing commercial product, or prepared by a method well known to those skilled in the art. The support may be prepared according to need or made into an appropriate granular shape, such as: bar, slice, cylinder or sphere. The forming may be based on general knowledge of the art.

The present invention also provides application of the supported catalyst of the present invention in the preparation of isobutylene.

The present invention further provides a method for preparation of isobutylene from halomethane, including carrying out hydrogen reduction activation of the supported catalyst of the present invention to make the content of halogen in the activated catalyst be 20 wt.%-90 wt.% of the total content of halogen in the supported catalyst without reduction, then contacting halomethane with the activated catalyst to prepare isobutylene.

According to the present invention, the conditions of the hydrogen reduction activation make the content of halogen in the activated catalyst be preferably 30 wt.%-80 wt.% of the total content of halogen in the supported catalyst without reduction, more preferably 40 wt.%-80 wt.%.

According to an embodiment of the present invention, the way of hydrogen reduction activation includes raising temperature of the catalyst to 300°C-600°C in an inert atmosphere; then inputting hydrogen or a mixed gas of hydrogen and inert gas at a space velocity of 200h⁻¹-2000h⁻¹ and holding pressure at 0.1MPa-0.5MPa for 2h-16h. The volume percentage of hydrogen in the mixed gas is 10%-95%. Preferably, raising temperature to 350°C-550°C; then inputting hydrogen or a mixed gas of hydrogen and inert gas at a space velocity of 500h⁻¹-1000h⁻¹ and holding pressure at 0.1MPa-0.3MPa for 4h-8h. The volume percentage of hydrogen in the mixed gas is 30%-90%.

According to the present invention, the halomethane may be one or more of monohalomethane, bihalomethane and trihalomethane, preferably, one or more of monobromomethane, bibromomethane and tribromomethane.

Preferably, the contact conditions include reaction temperature 150°C-350°C, reaction pressure 0.1MPa-5MPa and space velocity 50h⁻¹-1000h⁻¹; more preferably, reaction temperature 180°C-300°C, still more preferably 200-270°C; reaction pressure 0.1MPa-3MPa; space velocity 200h⁻¹-500h⁻¹.

According to an embodiment of the present invention, the method for preparing isobutylene from halomethane includes raising temperature of the catalyst to 300°C-600°C in an inert atmosphere, preferably 350°C-550°C; then inputting hydrogen or a mixed gas of hydrogen and inert gas at a space velocity of 200h⁻¹-2000h⁻¹, preferably 500h⁻¹-1000h⁻¹; and after treating at 0.1MPa-0.5MPa (absolute pressure), preferably 0.1MPa-0.3MPa (absolute pressure) for 2h-16h, preferably 4h-8h, lowering temperature to reaction temperature and inputting halomethane to take reaction. The volume percentage of hydrogen in the mixed gas is 10%-95%, preferably 30%-90%, more preferably 50%-90%.

In the use of the present invention, the raw material may alternatively be a mixed gas of halomethane and inert gas, of which the volume concentration of halomethane is 10%-90%, preferably 30%-80%.

The inert gas involved in the use of the present invention is nitrogen, argon, helium and other gases that don't take reaction under the conditions involved in the present invention, preferably nitrogen.

According to the use of the present invention, the reaction for preparing isobutylene from halomethane may be conducted in any form of existing reactors, such as: reactors in form of fixed bed, fluidized bed, fixed fluidized bed, moving bed, slurry bed or bubbling bed, preferably fixed bed and fluidized bed reactors.

Thereafter, the present invention is further described by referring to examples, but they are not intended to limit the present invention.

In the following examples and comparative examples, acid content is determined by NH₃-TPD method. The adopted instrument is AutoChem 2920 chemical adsorption instrument of American MICROMERITICS. The concrete determination process is as follows: purging the sample with helium at 450°C for 1h, reducing temperature to 150°C, introducing a mixed gas of ammonia and helium, with ammonia volume content of 10%, and carrying out pulse adsorption for five times to achieve a balance; purging with helium for 2h, and then raising temperature according to a temperature increase speed program of 10°C/min and conducting desorption of ammonia till 450°C; detecting ammonia by TCD detector after desorption and quantitatively calculating the acidity on catalyst surface.

In the following examples and comparative examples, the content of element Br and that of element Zn are determined by XRF (X-ray fluorescent spectroscopy) method. The adopted instrument is ZSX X-ray fluorescence spectrophotometer of Japanese Rigaku. The content of ZnBr₂ is calculated based on the content of element Br. The content of ZnO is calculated based on total Zn content minus the content of Zn in ZnBr₂.

Example 1

Weigh an appropriate amount of zinc nitrate, dissolve it in deionized water, support it to aluminum oxide (pore volume 0.71 ml/g, specific surface area 236 m²/g, bar type, equivalent diameter 1.5 mm) support by the method of incipient wetness impregnation, dry at 80°C for 8h and calcinate at 600°C for 4h to obtain catalyst precursor ZnO/Al₂O₃. Put 5g of the catalyst precursor in a continuous flow fixed bed reactor and treat the catalyst precursor with monobromomethane under the conditions of 250°C, 0.2 MPa (absolute pressure), 100h⁻¹ and 2h to obtain a catalyst for preparation of isobutylene from halomethane, marked as C-1. The weight composition of the catalyst is that the weight content of ZnBr₂ is 27%, the weight content of ZnO is 6%, the total acidity of 450°C or less in the catalyst is 0.92 mmol/g, and the acidity of 250°C-350°C is 55.1% of the total acidity of 450°C or less.

The reaction for preparation of isobutylene from bromomethane takes place in a continuous fluidized fixed bed micro-reactor. The loading amount of catalyst is 5g. The feed gas is a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 50%. The reaction temperature is 230°C, reaction pressure is 1MPa (absolute pressure) and space velocity is 500h⁻¹. Before input of feed gas, the catalyst is activated in a hydrogen atmosphere. The conditions of reduction are 400°C, 0.2MPa (absolute pressure) and 1000h⁻¹. The time of reduction is 4h. The content of halogen in the catalyst after reduction is 67.51% of the total content of halogen in the catalyst before reduction. After the reaction has become stable for one hour, samples are taken and analyzed. The reaction result is shown in Table 1.

Example 2

Weigh an appropriate amount of zinc nitrate, dissolve it in deionized water, support it to aluminum oxide (pore volume 0.71 ml/g, specific surface area 236 m²/g, bar type, equivalent diameter 1.5 mm) support by the method of incipient wetness impregnation, dry at 120°C for 4h and calcinate at 500°C for 8h to obtain catalyst precursor ZnO/Al₂O₃. Put 5g of the catalyst precursor in a continuous flow fixed bed reactor and treat the catalyst precursor with a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 80% under the conditions of 250°C, 0.3MPa (absolute pressure), 300h⁻¹ and 2h to obtain a catalyst for preparation of isobutylene from halomethane, marked as C-2. The weight composition of the obtained catalyst is that the weight content of ZnBr₂ as to bromide is 30%, the weight content of ZnO is 4%, the total acidity of 450°C or less in the catalyst is 0.93 mmol/g, and the acidity of 250°C-350°C is 63.2% of the total acidity of 450°C or less.

The reaction for preparation of isobutylene from bromomethane takes place in a continuous fluidized fixed bed micro-reactor. The loading amount of catalyst is 5g. The feed gas is a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 70%. The reaction temperature is 230°C, reaction pressure is 2MPa (absolute pressure) and space velocity is 200h⁻¹. Before input of feed gas, the catalyst is activated in a mixed atmosphere containing hydrogen. The volume content of hydrogen in the mixed gas is 80%. The conditions of reduction are 450°C, 0.3MPa (absolute pressure) and 800h⁻¹. The time of reduction is 4h. The content of halogen in the catalyst after reduction is 53.47% of the total content of halogen in the catalyst before reduction. After the reaction has become stable for one hour, samples are taken and analyzed. The reaction result is shown in Table 1.

Example 3

Weigh an appropriate amount of zinc nitrate, dissolve it in deionized water, support it to aluminum

oxide (pore volume 0.71 ml/g, specific surface area 236 m²/g, bar type, equivalent diameter 1.5 mm) support by the method of incipient wetness impregnation, dry under vacuum at 100°C for 8h and calcinate at 400°C for 8h to obtain catalyst precursor ZnO/Al₂O₃. Put 5g of the catalyst precursor in a continuous flow fixed bed reactor and treat the catalyst precursor with a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 30% under the conditions of 300°C, 0.1MPa (absolute pressure), 500h⁻¹ and 4h to obtain a catalyst for preparation of isobutylene from halomethane, marked as C-3. The weight composition of the obtained catalyst is that the weight content of ZnBr₂ as to bromide is 33%, the weight content of ZnO as to oxide is 2%, the total acidity of 450°C or less in the catalyst is 0.95 mmol/g, and the acidity of 250°C-350°C is 75.5% of the total acidity of 450°C or less.

The reaction for preparation of isobutylene from bromomethane takes place in a continuous fluidized fixed bed micro-reactor. The loading amount of catalyst is 5g. The feed gas is a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 80%. The reaction temperature is 200°C, reaction pressure is 3MPa (absolute pressure) and space velocity is 350h⁻¹. Before input of feed gas, the catalyst is activated in a mixed atmosphere containing hydrogen. The volume content of hydrogen in the mixed gas is 50%. The conditions of reduction are 500°C, 0.1MPa (absolute pressure) and 500h⁻¹. The time of reduction is 4h. The content of halogen in the catalyst after reduction is 47.22% of the total content of halogen in the catalyst before reduction. After the reaction has become stable for one hour, samples are taken and analyzed. The reaction result is shown in Table 1.

Example 4

Weigh an appropriate amount of zinc nitrate, dissolve it in deionized water, support it to aluminum oxide (pore volume 0.71 ml/g, specific surface area 236 m²/g, bar type, equivalent diameter 1.5 mm) support by the method of incipient wetness impregnation, dry at 120°C for 4h and calcinate at 500°C for 8h to obtain catalyst precursor ZnO/Al₂O₃. Put 5g of the catalyst precursor in a continuous flow fixed bed reactor and treat the catalyst precursor with monobromomethane under the conditions of 200°C, 0.3MPa (absolute pressure), 300h⁻¹ and 1h to obtain a catalyst for preparation of isobutylene from halomethane, marked as C-4. The weight composition of the obtained catalyst is that the weight content of ZnBr₂ as to bromide is 18%, the weight content of ZnO as to oxide is 2%, the total acidity of 450°C or less in the catalyst is 0.72 mmol/g, and the acidity of 250°C-350°C is 66.8% of the total acidity of 450°C or less.

The reaction for preparation of isobutylene from bromomethane takes place in a continuous fluidized fixed bed micro-reactor. The loading amount of catalyst is 5g. The feed gas is a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 30%. The reaction temperature is 270°C, reaction pressure is 2MPa (absolute pressure) and space velocity is 350h⁻¹. Before input of feed gas, the catalyst is activated in a mixed atmosphere containing hydrogen. The volume content of hydrogen in the mixed gas is 70%. The conditions of reduction are 350°C, 0.3MPa (absolute pressure) and 800h⁻¹. The time of reduction is 6h. The content of halogen in the catalyst after reduction is 57.81% of the total content of halogen in the catalyst before reduction. After the reaction has become stable for one hour, samples are taken and analyzed. The reaction result is shown in Table 1.

Example 5

Weigh an appropriate amount of zinc nitrate, dissolve it in deionized water, support it to aluminum

oxide (pore volume 0.71 ml/g, specific surface area 236 m²/g, bar type, equivalent diameter 1.5 mm) support by the method of incipient wetness impregnation, dry at 100°C for 6h and calcinate at 500°C for 6h under protection of nitrogen to obtain catalyst precursor ZnO/Al₂O₃. Put 5g of the catalyst precursor in a continuous flow fixed bed reactor and treat the catalyst precursor with a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 70% under the conditions of 200°C, 0.3MPa (absolute pressure), 300h⁻¹ and 2h to obtain a catalyst for preparation of isobutylene from halomethane, marked as C-5. The weight composition of the obtained catalyst is that the weight content of ZnBr₂ as to bromide is 39%, the weight content of ZnO as to oxide is 6%, the total acidity of 450°C or less in the catalyst is 0.98mmol/g, and the acidity of 250°C-350°C is 64.1% of the total acidity of 450°C or less.

The reaction for preparation of isobutylene from bromomethane takes place in a continuous fluidized fixed bed micro-reactor. The loading amount of catalyst is 5g. The feed gas is monobromomethane. The reaction temperature is 270°C, reaction pressure is 2MPa (absolute pressure) and space velocity is 350h⁻¹. Before input of feed gas, the catalyst is activated in a mixed atmosphere containing hydrogen. The volume content of hydrogen in the mixed gas is 60%. The conditions of reduction are 550°C, 0.3MPa (absolute pressure) and 800h⁻¹. The time of reduction is 8h. The content of halogen in the catalyst after reduction is 41.37% of the total content of halogen in the catalyst before reduction. After the reaction has become stable for one hour, samples are taken and analyzed. The reaction result is shown in Table 1.

Example 6

Weigh an appropriate amount of zinc nitrate, dissolve it in deionized water, support it to aluminum oxide (pore volume 0.71 ml/g, specific surface area 236 m²/g, bar type, equivalent diameter 1.5 mm) support by the method of incipient wetness impregnation, dry at 120°C in a nitrogen atmosphere for 4h and calcinate at 500°C in a nitrogen atmosphere for 4h to obtain catalyst precursor ZnO/Al₂O₃. Put 5g of the catalyst precursor in a continuous flow fixed bed reactor and treat the catalyst precursor with monobromomethane under the conditions of 250°C, 0.2MPa (absolute pressure), 100h⁻¹ and 1h to obtain a catalyst for preparation of isobutylene from halomethane, marked as C-6. The weight composition of the obtained catalyst is that the weight content of ZnBr₂ as to bromide is 35%, the weight content of ZnO as to oxide is 9%, the total acidity of 450°C or less in the catalyst is 0.94 mmol/g, and the acidity of 250°C-350°C is 57.3% of the total acidity of 450°C or less.

The reaction for preparation of isobutylene from bromomethane takes place in a continuous fluidized fixed bed micro-reactor. The loading amount of catalyst is 5g. The feed gas is a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 50%. The reaction temperature is 230°C, reaction pressure is 0.1MPa (absolute pressure) and space velocity is 500h⁻¹. Before input of feed gas, the catalyst is activated in a mixed atmosphere containing hydrogen. The volume content of hydrogen in the mixed gas is 80%. The conditions of reduction are 450°C, 0.2MPa (absolute pressure) and 1000h⁻¹. The time of reduction is 4h. The content of halogen in the catalyst after reduction is 58.39% of the total content of halogen in the catalyst before reduction. After the reaction has become stable for one hour, samples are taken and analyzed. The reaction result is shown in Table 1.

Example 7

Weigh an appropriate amount of zinc nitrate, dissolve it in deionized water, support it to aluminum oxide (pore volume 0.71 ml/g, specific surface area 236 m²/g, bar type, equivalent diameter 1.5 mm)

support by the method of incipient wetness impregnation, dry at 120°C for 4h and calcinate at 500°C for 4h to obtain catalyst precursor ZnO/Al₂O₃. Put 5g of the catalyst precursor in a continuous flow fixed bed reactor and treat the catalyst precursor with mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 90% under the conditions of 300°C, 0.1MPa (absolute pressure), 500h⁻¹ and 4h to obtain a catalyst for preparation of isobutylene from halomethane, marked as C-7. The weight composition of the obtained catalyst is that the weight content of ZnBr₂ as to bromide is 20%, the weight content of ZnO as to oxide is 1%, the total acidity of 450°C or less in the catalyst is 0.79 mmol/g, and the acidity of 250°C-350°C is 74.9% of the total acidity of 450°C or less.

The reaction for preparation of isobutylene from bromomethane takes place in a continuous fluidized fixed bed micro-reactor. The loading amount of catalyst is 5g. The feed gas is a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 80%. The reaction temperature is 200°C, reaction pressure is 3MPa (absolute pressure) and space velocity is 350h⁻¹. Before input of feed gas, the catalyst is activated in a mixed atmosphere containing hydrogen. The volume content of hydrogen in the mixed gas is 90%. The conditions of reduction are 500°C, 0.1MPa (absolute pressure) and 500h⁻¹. The time of reduction is 6h. The content of halogen in the catalyst after reduction is 51.94% of the total content of halogen in the catalyst before reduction. After the reaction has become stable for one hour, samples are taken and analyzed. The reaction result is shown in Table 1.

Example 8

Weigh an appropriate amount of zinc nitrate and zirconium nitrate, dissolve it in deionized water, support it to aluminum oxide (pore volume 0.71 ml/g, specific surface area 236 m²/g, bar type, equivalent diameter 1.5 mm) support by the method of incipient wetness impregnation, dry at 120°C for 4h and calcinate at 500°C for 4h to obtain catalyst precursor ZnO-Zr/Al₂O₃. Put 5g of the catalyst precursor in a continuous flow fixed bed reactor and treat the catalyst precursor with a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 80% under the conditions of 250°C, 0.3MPa (absolute pressure), 300h⁻¹ and 2h to obtain a catalyst for preparation of isobutylene from halomethane, marked as C-8. The weight composition of the obtained catalyst is that the weight content of ZnBr₂ as to bromide is 30%, the weight content of ZnO as to oxide is 4%, the weight content of Zr as to element is 2%, the total acidity of 450°C or less in the catalyst is 0.97mmol/g, and the acidity of 250°C-350°C is 69.7% of the total acidity of 450°C or less.

The reaction for preparation of isobutylene from bromomethane takes place in a continuous fluidized fixed bed micro-reactor. The loading amount of catalyst is 5g. The feed gas is a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 70%. The reaction temperature is 230°C, reaction pressure is 2MPa (absolute pressure) and space velocity is 200h⁻¹. Before input of feed gas, the catalyst is activated in a mixed atmosphere containing hydrogen. The volume content of hydrogen in the mixed gas is 80%. The conditions of reduction are 450°C, 0.3MPa (absolute pressure) and 800h⁻¹. The time of reduction is 4h. The content of halogen in the catalyst after reduction is 39.14% of the total content of halogen in the catalyst before reduction. After the reaction has become stable for one hour, samples are taken and analyzed. The reaction result is shown in Table 1.

Example 9

Weigh an appropriate amount of zinc nitrate and cerium nitrate, dissolve it in deionized water, support it to aluminum oxide (pore volume 0.71 ml/g, specific surface area 236 m²/g, bar type,

equivalent diameter 1.5 mm) support by the method of incipient wetness impregnation, dry at 120°C for 4h and calcinate at 500°C for 4h to obtain catalyst precursor ZnO-Ce/Al₂O₃. Put 5g of the catalyst precursor in a continuous flow fixed bed reactor and treat the catalyst precursor with a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 80% under the conditions of 250°C, 0.3MPa (absolute pressure), 300h⁻¹ and 2h to obtain a catalyst for preparation of isobutylene from halomethane, marked as C-9. The weight composition of the obtained catalyst is that the weight content of ZnBr₂ as to bromide is 30%, the weight content of ZnO as to oxide is 4%, the weight content of Ce as to element is 1%, the total acidity of 450°C or less in the catalyst is 0.91mmol/g, and the acidity of 250°C-350°C is 68.9% of the total acidity of 450°C or less.

The reaction for preparation of isobutylene from bromomethane takes place in a continuous fluidized fixed bed micro-reactor. The loading amount of catalyst is 5g. The feed gas is a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 70%. The reaction temperature is 230°C, reaction pressure is 2MPa (absolute pressure) and space velocity is 200h⁻¹. Before input of feed gas, the catalyst is activated in a mixed atmosphere containing hydrogen. The volume content of hydrogen in the mixed gas is 80%. The conditions of reduction are 450°C, 0.3MPa (absolute pressure) and 800h⁻¹. The time of reduction is 4h. The content of halogen in the catalyst after reduction is 63.73% of the total content of halogen in the catalyst before reduction. After the reaction has become stable for one hour, samples are taken and analyzed. The reaction result is shown in Table 1.

Example 10

Weigh an appropriate amount of zinc nitrate and lanthanum nitrate, dissolve it in deionized water, support it to aluminum oxide (pore volume 0.71 ml/g, specific surface area 236 m²/g, bar type, equivalent diameter 1.5 mm) support by the method of incipient wetness impregnation, dry at 120°C for 4h and calcinate at 500°C for 4h to obtain catalyst precursor ZnO-La/Al₂O₃. Put 5g of the catalyst precursor in a continuous flow fixed bed reactor and treat the catalyst precursor with a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 80% under the conditions of 250°C, 0.3MPa (absolute pressure), 300h⁻¹ and 2h to obtain a catalyst for preparation of isobutylene from halomethane, marked as C-10. The weight composition of the obtained catalyst is that the weight content of ZnBr₂ as to bromide is 30%, the weight content of ZnO as to oxide is 4%, the weight content of La as to element is 0.5%, the total acidity of 450°C or less in the catalyst is 0.87 mmol/g, and the acidity of 250°C-350°C is 65.3% of the total acidity of 450°C or less.

The reaction for preparation of isobutylene from bromomethane takes place in a continuous fluidized fixed bed micro-reactor. The loading amount of catalyst is 5g. The feed gas is a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 70%. The reaction temperature is 230°C, reaction pressure is 2MPa (absolute pressure) and space velocity is 200h⁻¹. Before input of feed gas, the catalyst is activated in a mixed atmosphere containing hydrogen. The volume content of hydrogen in the mixed gas is 80%. The conditions of reduction are 450°C, 0.3MPa (absolute pressure) and 800h⁻¹. The time of reduction is 4h. The content of halogen in the catalyst after reduction is 62.72% of the total content of halogen in the catalyst before reduction. After the reaction has become stable for one hour, samples are taken and analyzed. The reaction result is shown in Table 1.

Example 11

Weigh an appropriate amount of zinc nitrate and titanium nitrate, dissolve it in deionized water, support it to aluminum oxide (pore volume 0.71 ml/g, specific surface area 236 m²/g, bar type, equivalent diameter 1.5 mm) support by the method of incipient wetness impregnation, dry at 120°C for 4h and calcinate at 500°C for 4h to obtain catalyst precursor ZnO-Ti/Al₂O₃. Put 5g of the catalyst precursor in a continuous flow fixed bed reactor and treat the catalyst precursor with a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 80% under the conditions of 250°C, 0.3MPa (absolute pressure), 300h⁻¹ and 2h to obtain a catalyst for preparation of isobutylene from halomethane, marked as C-11. The weight composition of the obtained catalyst is that the weight content of ZnBr₂ as to bromide is 30%, the weight content of ZnO as to oxide is 4%, the weight content of Ti as to element is 3%, the total acidity of 450°C or less in the catalyst is 0.96 mmol/g, and the acidity of 250°C-350°C is 63.4% of the total acidity of 450°C or less.

The reaction for preparation of isobutylene from bromomethane takes place in a continuous fluidized fixed bed micro-reactor. The loading amount of catalyst is 5g. The feed gas is a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 70%. The reaction temperature is 230°C, reaction pressure is 2MPa (absolute pressure) and space velocity is 200h⁻¹. Before input of feed gas, the catalyst is activated in a mixed atmosphere containing hydrogen. The volume content of hydrogen in the mixed gas is 80%. The conditions of reduction are 450°C, 0.3MPa (absolute pressure) and 800h⁻¹. The time of reduction is 4h. The content of halogen in the catalyst after reduction is 53.62% of the total content of halogen in the catalyst before reduction. After the reaction has become stable for one hour, samples are taken and analyzed. The reaction result is shown in Table 1.

Example 12

Weigh an appropriate amount of zinc chloride, dissolve it in deionized water, support it to aluminum oxide (pore volume 0.71 ml/g, specific surface area 236 m²/g, bar type, equivalent diameter 1.5 mm) support by the method of incipient wetness impregnation, dry at 120°C for 4h and calcinate at 500°C for 4h to obtain catalyst precursor ZnO/Al₂O₃. Put 5g of the catalyst precursor in a continuous flow fixed bed reactor and treat the catalyst precursor with a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 80% under the conditions of 250°C, 0.3MPa (absolute pressure), 300h⁻¹ and 2h to obtain a catalyst for preparation of isobutylene from halomethane, marked as C-12. The weight composition of the obtained catalyst is that the weight content of ZnBr₂ as to bromide is 30%, the weight content of ZnO as to oxide is 4%, the total acidity of 450°C or less in the catalyst is 0.87 mmol/g, and the acidity of 250°C-350°C is 65.7% of the total acidity of 450°C or less.

The reaction for preparation of isobutylene from bromomethane takes place in a continuous fluidized fixed bed micro-reactor. The loading amount of catalyst is 5g. The feed gas is a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 70%. The reaction temperature is 230°C, reaction pressure is 2MPa (absolute pressure) and space velocity is 200h⁻¹. Before input of feed gas, the catalyst is activated in a mixed atmosphere containing hydrogen. The volume content of hydrogen in the mixed gas is 80%. The conditions of reduction are 450°C, 0.3MPa (absolute pressure) and 800h⁻¹. The time of reduction is 4h. The content of halogen in the catalyst after reduction is 47.89% of the total content of halogen in the catalyst before reduction. After the reaction has become stable for one hour, samples are taken and analyzed. The reaction result is shown in Table 1.

Example 13

Weigh an appropriate amount of zinc nitrate, dissolve it in deionized water, support it to silicon dioxide (pore volume 1.06 ml/g, specific surface area 387 m²/g, spherical shape, equivalent diameter 0.5 mm) support by the method of incipient wetness impregnation, dry at 120°C for 4h and calcinate at 500°C for 4h to obtain catalyst precursor ZnO/SiO₂. Put 5g of the catalyst precursor in a continuous flow fixed bed reactor and treat the catalyst precursor with a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 80% under the conditions of 250°C, 0.3MPa (absolute pressure), 300h⁻¹ and 2h to obtain a catalyst for preparation of isobutylene from halomethane, marked as C-13. The weight composition of the obtained catalyst is that the weight content of ZnBr₂ as to bromide is 30%, the weight content of ZnO as to oxide is 4%, the total acidity of 450°C or less in the catalyst is 1.08 mmol/g, and the acidity of 250°C-350°C is 49.7% of the total acidity of 450°C or less.

The reaction for preparation of isobutylene from bromomethane takes place in a continuous fluidized fixed bed micro-reactor. The loading amount of catalyst is 5g. The feed gas is a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 70%. The reaction temperature is 230°C, reaction pressure is 2MPa (absolute pressure) and space velocity is 200h⁻¹. Before input of feed gas, the catalyst is activated in a mixed atmosphere containing hydrogen. The volume content of hydrogen in the mixed gas is 80%. The conditions of reduction are 400°C, 0.3MPa (absolute pressure) and 800h⁻¹. The time of reduction is 4h. The content of halogen in the catalyst after reduction is 31.28% of the total content of halogen in the catalyst before reduction. After the reaction has become stable for one hour, samples are taken and analyzed. The reaction result is shown in Table 1.

Example 14

Weigh an appropriate amount of zinc nitrate, dissolve it in deionized water, support it to hydrogen-type ZSM-5 (silica-alumina mole ratio 50, pore volume 0.23 ml/g, specific surface area 426 m²/g, bar type, equivalent diameter 1.5 mm) support by the method of incipient wetness impregnation, dry at 120°C for 4h and calcinate at 500°C for 4h to obtain catalyst precursor ZnO/H-ZSM-5. Put 5g of the catalyst precursor in a continuous flow fixed bed reactor and treat the catalyst precursor with mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 80% under the conditions of 250°C, 0.3MPa (absolute pressure), 300h⁻¹ and 2h to obtain a catalyst for preparation of isobutylene from halomethane, marked as C-14. The weight composition of the obtained catalyst is that the weight content of ZnBr₂ as to bromide is 30%, the weight content of ZnO as to oxide is 4%, the total acidity of 450°C or less in the catalyst is 0.74 mmol/g, and the acidity of 250°C-350°C is 48.7% of the total acidity of 450°C or less.

The reaction for preparation of isobutylene from bromomethane takes place in a continuous fluidized fixed bed micro-reactor. The loading amount of catalyst is 5g. The feed gas is a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 70%. The reaction temperature is 230°C, reaction pressure is 2MPa (absolute pressure) and space velocity is 200h⁻¹. Before input of feed gas, the catalyst is activated in a mixed atmosphere containing hydrogen. The volume content of hydrogen in the mixed gas is 80%. The conditions of reduction are 400°C, 0.3MPa (absolute pressure) and 800h⁻¹. The time of reduction is 4h. The content of halogen in the catalyst after reduction is 79.73% of the total content of halogen in the catalyst before reduction. After the reaction has become stable for one hour, samples are taken and analyzed. The reaction result is shown in Table 1.

Example 15

Weigh an appropriate amount of zinc nitrate, dissolve it in deionized water, support it to aluminum oxide (pore volume 0.71 ml/g, specific surface area 236 m²/g, bar type, equivalent diameter 1.5 mm) support by the method of incipient wetness impregnation, dry at 120°C for 4h and calcinate at 500°C for 4h to obtain catalyst precursor ZnO/Al₂O₃. Put 5g of the catalyst precursor in a continuous flow fixed bed reactor and treat the catalyst precursor with a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 80% under the conditions of 250°C, 0.3MPa (absolute pressure), 300h⁻¹ and 2h. Weigh an appropriate amount of zirconium nitrate, dissolve it in deionized water, impregnate bromized sample by the method of incipient wetness impregnation, dry at 120°C in a nitrogen atmosphere for 4h and calcinate at 500°C in a nitrogen atmosphere for 4h to obtain a catalyst for preparation of isobutylene from halomethane, marked as C-15. The weight composition of the obtained catalyst is that the weight content of ZnBr₂ as to bromide is 30%, the weight content of ZnO as to oxide is 4%, the weight content of Zr as to element is 1%, the total acidity of 450°C or less in the catalyst is 0.72 mmol/g, and the acidity of 250°C-350°C is 71.4% of the total acidity of 450°C or less.

The reaction for preparation of isobutylene from bromomethane takes place in a continuous fluidized fixed bed micro-reactor. The loading amount of catalyst is 5g. The feed gas is a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 70%. The reaction temperature is 230°C, reaction pressure is 2MPa (absolute pressure) and space velocity is 200h⁻¹. Before input of feed gas, the catalyst is activated in a mixed atmosphere containing hydrogen. The volume content of hydrogen in the mixed gas is 80%. The conditions of reduction are 450°C, 0.3MPa (absolute pressure) and 800h⁻¹. The time of reduction is 4h. The content of halogen in the catalyst after reduction is 42.57% of the total content of halogen in the catalyst before reduction. After the reaction has become stable for one hour, samples are taken and analyzed. The reaction result is shown in Table 1.

Example 16

Weigh an appropriate amount of zinc nitrate, dissolve it in deionized water, support it to aluminum oxide (pore volume 0.71 ml/g, specific surface area 236 m²/g, bar type, equivalent diameter 1.5 mm) support by the method of incipient wetness impregnation, dry at 120°C for 4h and calcinate at 500°C for 4h to obtain catalyst precursor ZnO/Al₂O₃. Put 5g of the catalyst precursor in a continuous flow fixed bed reactor and treat the catalyst precursor with a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 80% under the conditions of 250°C, 0.3MPa (absolute pressure), 300h⁻¹ and 2h. Weigh an appropriate amount of cerium nitrate, dissolve it in deionized water, impregnate bromized sample by the method of incipient wetness impregnation, dry at 80°C in a nitrogen atmosphere for 8h and calcinate at 500°C in a nitrogen atmosphere for 4h to obtain a catalyst for preparation of isobutylene from halomethane, marked as C-16. The weight composition of the obtained catalyst is that the weight content of ZnBr₂ as to bromide is 30%, the weight content of ZnO as to oxide is 4%, the weight content of Ce as to element is 0.5%, the total acidity of 450°C or less in the catalyst is 0.81 mmol/g, and the acidity of 250°C-350°C is 69.3% of the total acidity of 450°C or less.

The reaction for preparation of isobutylene from bromomethane takes place in a continuous fluidized fixed bed micro-reactor. The loading amount of catalyst is 5g. The feed gas is a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 70%. The reaction temperature is 230°C, reaction pressure is 2MPa (absolute pressure) and space velocity is 200h⁻¹. Before input of feed gas, the catalyst is activated in a mixed atmosphere containing hydrogen. The volume content of hydrogen in the mixed gas is 80%. The conditions of reduction are 450°C, 0.3MPa (absolute pressure) and 500h⁻¹. The time of reduction is 6h. The content of

halogen in the catalyst after reduction is 65.49% of the total content of halogen in the catalyst before reduction. After the reaction has become stable for one hour, samples are taken and analyzed. The reaction result is shown in Table 1.

Example 17

A supported catalyst is prepared and the reaction for preparing isobutylene from bromomethane takes place according to the methods described in Example 16 except that aluminum oxide with pore volume of 0.51 ml/g, specific surface area of 162.4 m²/g, bar type and equivalent diameter of 1 mm is used as a support to obtain a catalyst for preparation of isobutylene from halomethane, marked as C-17. The total acidity of 450°C or less in the obtained catalyst is 0.72 mmol/g, and the acidity of 250°C-350°C is 70.5% of the total acidity of 450°C or less. The content of halogen in the catalyst after reduction activation is 72.57% of the total content of halogen in the catalyst before reduction. The catalyst properties and reaction result are shown in Table 1.

Example 18

A supported catalyst is prepared and the reaction for preparing isobutylene from bromomethane takes place according to the methods described in Example 16 except that bromomethane is substituted with dichloromethane in equal molar weight. The result indicates the conversion rate of dichloromethane is 97.4%, and the selectivity of isobutylene is 67.9%.

Comparative Example 1

Weigh an appropriate amount of zinc nitrate, dissolve it in deionized water, support it to aluminum oxide (pore volume 0.71 ml/g, specific surface area 236 m²/g, bar type, equivalent diameter 1.5 mm) support by the method of incipient wetness impregnation, dry at 120°C for 4h and calcinate at 500°C for 8h to obtain catalyst ZnO/Al₂O₃, marked as D-1. The weight composition of the obtained catalyst is that the weight content of ZnO as to oxide is 20%, the total acidity of 450°C or less in the catalyst is 0.49 mmol/g, and the acidity of 250°C-350°C is 44.5% of the total acidity of 450°C or less.

The reaction for preparation of isobutylene from bromomethane takes place in a continuous fluidized fixed bed micro-reactor. The loading amount of catalyst is 5g. The feed gas is a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 30%. The reaction temperature is 270°C, reaction pressure is 2MPa (absolute pressure) and space velocity is 350h⁻¹. Before input of feed gas, the catalyst is activated in a hydrogen atmosphere. The volume content of hydrogen in the mixed gas is 70%. The conditions of reduction are 350°C, 0.3MPa (absolute pressure) and 800h⁻¹. The time of reduction is 6h. After the reaction has become stable for one hour, samples are taken and analyzed. The reaction result is shown in Table 1.

Comparative Example 2

Weigh an appropriate amount of zinc nitrate, dissolve it in deionized water, support it to aluminum oxide (pore volume 0.71 ml/g, specific surface area 236 m²/g, bar type, equivalent diameter 1.5 mm) support by the method of incipient wetness impregnation, dry at 120°C for 4h and calcinate at 500°C for 8h to obtain catalyst precursor ZnO/Al₂O₃. Put 5g of the catalyst precursor in a continuous flow fixed bed reactor and treat the catalyst precursor with a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 80% under the conditions of

250°C, 0.3MPa (absolute pressure), 300h⁻¹ and 2h to obtain a catalyst for preparation of isobutylene from halomethane, marked as D-2. The weight composition of the obtained catalyst is that the weight content of ZnBr₂ as to bromide is 30%, the weight content of ZnO as to oxide is 4%, the total acidity of 450°C or less in the catalyst is 0.93 mmol/g, and the acidity of 250°C-350°C is 63.2% of the total acidity of 450°C or less.

The reaction for preparation of isobutylene from bromomethane takes place in a continuous fluidized fixed bed micro-reactor. The loading amount of catalyst is 5g. The feed gas is a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 70%. The reaction temperature is 230°C, reaction pressure is 2MPa (absolute pressure) and space velocity is 200h⁻¹. After the reaction has become stable for one hour, samples are taken and analyzed. The reaction result is shown in Table 1.

Comparative Example 3

Weigh an appropriate amount of zinc bromide, dissolve it in deionized water, support it to aluminum oxide (pore volume 0.71 ml/g, specific surface area 236 m²/g, bar type, equivalent diameter 1.5 mm) support by the method of incipient wetness impregnation, dry at 80°C in a nitrogen atmosphere for 4h and calcinate at 500°C in a nitrogen atmosphere for 4h to obtain catalyst ZnBr₂/Al₂O₃, marked as D-3. The weight composition of the obtained catalyst is that the weight content of ZnBr₂ as to bromide is 30%, the total acidity of 450°C or less in the catalyst is 1.01 mmol/g, and the acidity of 250°C-350°C is 74.3% of the total acidity of 450°C or less.

The reaction for preparation of isobutylene from bromomethane takes place in a continuous fluidized fixed bed micro-reactor. The loading amount of catalyst is 5g. The feed gas is a mixed gas of monobromomethane and nitrogen of which volume concentration of monobromomethane is 70%. The reaction temperature is 230°C, reaction pressure is 2MPa (absolute pressure) and space velocity is 200h⁻¹. Before input of feed gas, the catalyst is activated in a mixed atmosphere containing hydrogen. The volume content of hydrogen in the mixed gas is 80%. The conditions of reduction are 450°C, 0.3MPa (absolute pressure) and 800h⁻¹. The time of reduction is 4h. The content of halogen in the catalyst after reduction is 91.27% of the total content of halogen in the catalyst before reduction. After the reaction has become stable for one hour, samples are taken and analyzed. The reaction result is shown in Table 1.

Table 1 Catalyst reactivity

Catalyst	zinc oxide wt. %	zinc halide wt. %	promoter wt. %	Support	Total acidity mmol/g	Acid ratio %	Bromomethane conversion rate, %	Isobutylene selectivity, %
C-1	6	27 (ZnBr ₂)	0	Al ₂ O ₃	0.92	55.1	94.5	73.4
C-2	4	30 (ZnBr ₂)	0	Al ₂ O ₃	0.93	63.2	99.4	82.5
C-3	2	33 (ZnBr ₂)	0	Al ₂ O ₃	0.95	75.5	92.1	81.6
C-4	2	18 (ZnBr ₂)	0	Al ₂ O ₃	0.72	66.8	96.2	86.3
C-5	6	39 (ZnBr ₂)	0	Al ₂ O ₃	0.98	64.1	97.8	91.2
C-6	9	35 (ZnBr ₂)	0	Al ₂ O ₃	0.94	57.3	91.5	78.7
C-7	1	20 (ZnBr ₂)	0	Al ₂ O ₃	0.79	74.9	91.4	82.7
C-8	4	30 (ZnBr ₂)	2(Zr)	Al ₂ O ₃	0.97	69.7	99.3	84.2
C-9	4	30 (ZnBr ₂)	1(Ce)	Al ₂ O ₃	0.91	68.9	98.5	88.2
C-10	4	30 (ZnBr ₂)	0.5(La)	Al ₂ O ₃	0.87	65.3	97.8	86.6
C-11	4	30 (ZnBr ₂)	3(Ti)	Al ₂ O ₃	0.96	63.4	95.9	88.5
C-12	4	30 (ZnBr ₂)	0	Al ₂ O ₃	0.87	65.7	95.4	84.3
C-13	4	30 (ZnBr ₂)	0	SiO ₂	1.08	49.7	57.8	71.1
C-14	4	30 (ZnBr ₂)	0	ZSM-5	0.74	48.7	92.6	52.2
C-15	4	30 (ZnBr ₂)	1(Zr)	Al ₂ O ₃	0.72	71.4	94.2	91.3
C-16	4	30 (ZnBr ₂)	0.5(Ce)	Al ₂ O ₃	0.81	69.3	92.5	86.7
C-17	4	30 (ZnBr ₂)	0.5(Ce)	Al ₂ O ₃	0.72	70.5	93.6	76.4
D-1	20	0	0	Al ₂ O ₃	0.49	44.5	99.7	0
D-2	4	30 (ZnBr ₂)	0	Al ₂ O ₃	0.93	63.2	0	0
D-3	0	30 (ZnBr ₂)	0	Al ₂ O ₃	1.01	74.3	8.31	0

The results in Table 1 indicate the catalyst of the present invention has obviously higher bromomethane conversion rate and isobutene selectivity.

Claims

What is claimed is:

1. A supported catalyst comprising a support and a metallic active component supported on the support; the metallic active component contains zinc oxide and zinc halide, and the content of zinc oxide is 0.5 wt.%-20 wt.%, the content of zinc halide is 10 wt.%-50 wt.%, and the content of the support is 40 wt.%-88 wt.% based on the total weight of the catalyst.
2. The supported catalyst according to claim 1, wherein the content of zinc oxide is 1 wt.%-15 wt.%, the content of zinc halide is 15 wt.%-40 wt.%, and the content of the support is 50 wt.%-84 wt.%, preferably, the content of zinc oxide is 1 wt.%-9 wt.%, the content of zinc halide is 18 wt.%-39 wt.%, and the content of the support is 55 wt.%-80 wt.% based on the total weight of the catalyst.
3. The supported catalyst according to claim 1 or 2, wherein the zinc halide is selected from one or more of zinc fluoride, zinc chloride, zinc bromide and zinc iodide, and the support is selected from one or more of aluminum oxide, silicon oxide and ZSM-5 molecular sieve; preferably, the zinc halide is zinc bromide, and the support is aluminum oxide.
4. The supported catalyst according to any one of claims 1-3, further comprising a promoter selected from one or more of Ti, Zr, Ce and La, and the content of the promoter calculated on element is 0.1 wt.%-10 wt.% based on the total weight of the catalyst.
5. The supported catalyst according to claim 4, wherein the promoter is Zr, and the weight content of the promoter calculated on element is 0.5 wt.%-5 wt.% based on the total weight of the catalyst.
6. The supported catalyst according to any one of claims 1-5, wherein it is determined by NH_3 -TPD method that the total acidity of 450°C or less in the catalyst is 0.5 mmol/g-1.3 mmol/g, and the acidity of 250°C-350°C is 20%-90% of the total acidity of 450°C or less; preferably, the total acidity of 450°C or less in the catalyst is 0.6 mmol/g-1.2 mmol/g, and the acidity of 250°C-350°C is 30%-80% of the total acidity of 450°C or less; more preferably, the total acidity of 450°C or less in the catalyst is 0.7 mmol-1.1 mmol/g, and the acidity of 250°C-350°C is 40%-80% of the total acidity of 450°C or less.
7. A method for preparing a supported catalyst including the following steps: introducing zinc oxide to a support and then halogenating the resulted support after introducing zinc oxide.
8. The method according to claim 7, wherein the mean of halogenation includes contacting gaseous-phase halogen-containing compound with the support containing the introduced zinc oxide, and the contact conditions make the zinc oxide on the support partially converted into zinc halide.
9. The method according to claim 7 or 8, wherein the dose of zinc oxide makes the content of the support be 40%-88% based on the total weight of the obtained supported catalyst, and the contact conditions make the content of zinc oxide on the support be 0.5%-20%, and the content of zinc halide be 10%-50%.
10. The method according to claim 9, wherein gaseous-phase halogen-containing compound contacts the support containing the introduced zinc oxide in a form of a mixed gas of gaseous-phase halogen-containing compound and inert gas, and the concentration of gaseous-phase halogen-containing compound in the mixed gas is not less than 20 v/v%.
11. The method according to claim 10, wherein the gaseous-phase halogen-containing compound is one or more of monohalomethane, bihalomethane and trihalomethane.

12. The method according to claim 10 or 11, wherein the mean of contact includes putting the support containing the introduced zinc oxide in a continuous flow fixed bed reactor, raising temperature to 150°C-400°C in an inert atmosphere, and inputting gaseous-phase halogen-containing compound or a mixed gas containing gaseous-phase halogen-containing compound with the space velocity 50h⁻¹-1000 h⁻¹, the contact pressure 0.1MPa-0.5MPa and the time 0.5h-8h; preferably, the temperature is raised to 180°C-350°C in an inert atmosphere, the space velocity is 100h⁻¹-500h⁻¹, the contact pressure is 0.1MPa-0.3MPa and the time is 1h-4h.
13. Use of the supported catalyst according to any one of claims 1-6 in the preparation of isobutylene.
14. A method for preparation of isobutylene from halomethane including carrying out hydrogen reduction activation of the supported catalyst according to any one of claims 1-6 to make the content of halogen in the activated catalyst be 20 wt. %-90 wt. % of the total content of halogen in the supported catalyst without reduction, then contacting halomethane with the activated catalyst to prepare isobutylene.
15. The method according to claim 14, wherein the contact conditions include reaction temperature 150°C-350°C, reaction pressure 0.1MPa-5MPa and space velocity 50h⁻¹-1000h⁻¹; preferably, reaction temperature 180°C-300°C, reaction pressure 0.1MPa-3MPa and space velocity 200h⁻¹-500h⁻¹.
16. The method according to claim 14, wherein the conditions of hydrogen reduction activation make the content of halogen in the catalyst be 30 wt. %-80 wt. % of the total content of halogen in the catalyst before reduction.
17. The method according to any one of claims 14-16, wherein the means of hydrogen reduction activation includes raising temperature of the catalyst to 300°C-600°C in an inert atmosphere; then inputting hydrogen or a mixed gas of hydrogen and inert gas in which the volume percentage of hydrogen in the mixed gas is 10%-95% at a space velocity of 200h⁻¹-2000h⁻¹ and holding pressure at 0.1MPa-0.5MPa for 2h-16h; preferably, raising temperature to 350°C-550°C; then inputting hydrogen or a mixed gas of hydrogen and inert gas in which the volume percentage of hydrogen in the mixed gas is 30%-90% at a space velocity of 500h⁻¹-1000h⁻¹ and holding pressure at 0.1MPa-0.3MPa for 4h-8h.
18. The method according to any one of claims 14-17, wherein halomethane is one or more of monohalomethane, bihalomethane and trihalomethane, preferably, one or more of monobromomethane, dibromomethane and tribromomethane.
19. The method according to any one of claims 14-18, wherein the contact takes place in a fixed bed, fluidized bed, fixed fluidized bed, moving bed, slurry bed or bubbling bed reactor.