CLAIMS

[Claim 1]

A catalyst for producing at least one of an unsaturated aldehyde compound, an unsaturated carboxylic acid compound, and a conjugated diene comprising, as an essential component,

molybdenum;

bismuth; and

cobalt, wherein

a sum (S) of ratios of peak intensities expressed by the following formula in an X-ray diffraction pattern obtained by using CuKα rays as an X-ray source is 42 or more and 113 or less.

$S = \{(\text{peak intensity at } 2\theta = 14.1° \pm 0.1°) + (\text{peak intensity at } 2\theta = 25.4° \pm 0.1°) + (\text{peak intensity at } 2\theta = 28.5° \pm 0.1°)\}/(\text{peak intensity at } 2\theta = 26.5° \pm 0.1°) \times 100$

[Claim 2]

The catalyst for producing at least one of an unsaturated aldehyde compound, an unsaturated carboxylic acid compound, and a conjugated diene according to claim 1, wherein a ratio (S4) of a peak intensity expressed by the following formula is 2 or more and 16 or less.

$S4 = (\text{peak intensity at } 2\theta = 27.4° \pm 0.1°) / (\text{peak intensity at } 2\theta = 26.5° \pm 0.1°) \times 100$

[Claim 3]

The catalyst for producing at least one of an unsaturated aldehyde compound, an unsaturated carboxylic acid compound, and a conjugated diene according to claim 1 or 2, wherein a composition of a catalytically active component is represented by the following formula (I-1):

$Mo_{a1}Bi_{b1}Ni_{c1}Co_{d1}Fe_{e1}X_{f1}Y_{g1}Z_{h1}O_{i1}$...(I-1)

(in the formula, Mo, Bi, Ni, Co and Fe represent molybdenum, bismuth, nickel, cobalt and iron, respectively; X is at least one element selected from tungsten, antimony, tin, zinc, chromium, manganese, magnesium, silica, aluminum, cerium and titanium; Y is at least one element selected from sodium, potassium, cesium, rubidium, and thallium; Z belongs to the 1st to 16th groups in the periodic table and means at least one element selected from elements other than the above Mo, Bi, Ni, Co, Fe, X, and Y; a1, b1, c1, d1, e1, f1, g1, h1, and i1 represent the number of atoms of molybdenum, bismuth, nickel, cobalt, iron, X, Y, Z, and oxygen,

respectively; when $a1 = 12$, $0 < b1 \leq 7$, $0 \leq c1 \leq 10$, $0 < d1 \leq 10$, $0 < c1 + d1 \leq 20$, $0 \leq e1 \leq 5$, $0 \leq f1 \leq 2$, $0 \leq g1 \leq 3$, $0 \leq h1 \leq 5$, and i1 is a value determined by an oxidation state of each element).

[Claim 4]

The catalyst for producing at least one of an unsaturated aldehyde compound, an unsaturated carboxylic acid compound, and a conjugated diene according to any one of claims 1 to 3, which is a catalyst in which a catalytically active component is carried on an inert carrier.

[Claim 5]

The catalyst for producing at least one of an unsaturated aldehyde compound, an unsaturated carboxylic acid compound, and a conjugated diene according to claim 4, wherein the inert carrier is silica, alumina, or a combination thereof.

[Claim 6]

A method for producing at least one of an unsaturated aldehyde compound, an unsaturated carboxylic acid compound, and a conjugated diene comprising, using the catalyst for producing at least one of an unsaturated aldehyde compound, an unsaturated carboxylic acid compound, and a conjugated diene according to any one of claims 1 to 5.

[Claim 7]

The method according to claim 6, wherein the unsaturated aldehyde compound is acrolein, the unsaturated carboxylic acid compound is acrylic acid, and the conjugated diene is 1,3-butadiene.

[Claim 8]

A method for filling a catalyst for producing at least one of an unsaturated aldehyde compound, an unsaturated carboxylic acid compound, and a conjugated diene, the method comprising:

filling a composite metal oxide catalyst containing molybdenum, bismuth, and cobalt as an essential component such that two or more layers are stacked in a tube axis direction for multi-layer filling,

wherein a composition of the composite metal oxide catalyst contained in one catalyst

layer is different from a composition of the composite metal oxide catalyst contained in at least one of the other catalyst layers,

a ratio of a component amount of bismuth to a component amount of molybdenum in a catalyst layer closest to a gas inlet side of a tube axis is smaller than a ratio of a component amount of bismuth to a component amount of molybdenum in a catalyst layer closest to a gas outlet side of the tube axis, and

in any of two catalyst layers adjacent to each other, the catalysts are filled such that a ratio of the component amount of bismuth to the component amount of molybdenum in a catalyst layer on the gas inlet side of the tube axis is equal to or smaller than a ratio of the component amount of bismuth to the component amount of molybdenum in a catalyst layer on the gas outlet side of the tube axis.

[Claim 9]

A method for filling a catalyst for producing at least one of an unsaturated aldehyde compound, an unsaturated carboxylic acid compound, and a conjugated diene, the method comprising:

filling a composite metal oxide catalyst containing molybdenum, bismuth, and cobalt as an essential component such that two or more layers are stacked in a tube axis direction for multi-layer filling,

wherein the catalysts are filled such that, with respect to a sum (S) of ratios of peak intensities of a catalyst contained in one catalyst layer, which is expressed by the following formula in an X-ray diffraction pattern obtained by using CuKα rays as an X-ray source, the sum (S) of ratios of peak intensities of a catalyst contained in a catalyst layer closest to a gas outlet side of a tube axis is smaller than the sum (S) of ratios of peak intensities of a catalyst contained in a catalyst layer closest to a gas inlet side of the tube axis.

$S = \{(\text{peak intensity at } 2\theta = 14.1° \pm 0.1°) + (\text{peak intensity at } 2\theta = 25.4° \pm 0.1°) + (\text{peak intensity at } 2\theta = 28.5° \pm 0.1°)\}/(\text{peak intensity at } 2\theta = 26.5° \pm 0.1°) \times 100$

[Claim 10]

The method for filling a catalyst for producing at least one of an unsaturated aldehyde compound, an unsaturated carboxylic acid compound, and a conjugated diene according to claim 8 or 9, wherein the catalysts are filled such that, with respect to a ratio (S1) of a peak intensity of the catalyst contained in one catalyst layer, which is expressed by the following

formula in the X-ray diffraction pattern obtained by using CuKα rays as an X-ray source, the ratio (S1) of a peak intensity of a catalyst contained in the catalyst layer closest to the gas outlet side of the tube axis is smaller than the ratio (S1) of a peak intensity of a catalyst contained in the catalyst layer closest to the gas inlet side of the tube axis.

S1 = (peak intensity at $2\theta = 14.1° \pm 0.1°$)/(peak intensity at $2\theta = 26.5° \pm 0.1°$) × 100

[Claim 11]

The method for filling a catalyst for producing at least one of an unsaturated aldehyde compound, an unsaturated carboxylic acid compound, and a conjugated diene according to any one of claims 8 to 10, wherein the catalysts are filled such that, with respect to a ratio (S2) of a peak intensity of the catalyst contained in one catalyst layer, which is expressed by the following formula in the X-ray diffraction pattern obtained by using CuKα rays as an X-ray source, the ratio (S2) of a peak intensity of a catalyst contained in the catalyst layer closest to the gas outlet side of the tube axis is smaller than the ratio (S2) of a peak intensity of a catalyst contained in the catalyst layer closest to the gas inlet side of the tube axis.

S2 = (peak intensity at $2\theta = 25.4° \pm 0.1°$)/(peak intensity at $2\theta = 26.5° \pm 0.1°$) × 100

[Claim 12]

The method for filling a catalyst for producing at least one of an unsaturated aldehyde compound, an unsaturated carboxylic acid compound, and a conjugated diene according to any one of claims 8 to 11, wherein the catalysts are filled such that, with respect to a ratio (S3) of a peak intensity of the catalyst contained in one catalyst layer, which is expressed by the following formula in the X-ray diffraction pattern obtained by using CuKα rays as an X-ray source, the ratio (S3) of a peak intensity of a catalyst contained in the catalyst layer closest to the gas outlet side of the tube axis is smaller than the ratio (S3) of a peak intensity of a catalyst contained in the catalyst layer closest to the gas inlet side of the tube axis.

S3 = (peak intensity at $2\theta = 28.5° \pm 0.1°$)/(peak intensity at $2\theta = 26.5° \pm 0.1°$) × 100

[Claim 13]

A method for producing at least one of an unsaturated aldehyde compound, an unsaturated carboxylic acid compound, and a conjugated diene, using a reaction tube filled with a catalyst by the method for filling a catalyst according to any one of claims 8 to 12.

[Claim 14]

The method according to claim 13, wherein the unsaturated aldehyde compound is acrolein, the unsaturated carboxylic acid compound is acrylic acid, and the conjugated diene is 1,3-butadiene.