layers is regulated to Sn ≤ 6.

B) The method for producing an unsaturated aldehyde and/or an unsaturated carboxylic acid as set forth in A),

wherein at least one of the plurality of catalyst layers is regulated to Sn ≤ 3.

C) The method for producing an unsaturated aldehyde and/or an unsaturated carboxylic acid as set forth in A) or B),

wherein N is 2 or 3.

D) The method for producing an unsaturated aldehyde and/or an unsaturated carboxylic acid as set forth in any one of A) to C),

wherein a concentration of the alkene in a raw material is 7 to 12% by volume.

E) The method for producing an unsaturated aldehyde and/or an unsaturated carboxylic acid as set forth in any one of A) to D),

wherein all of the catalyst layers contain a complex metal oxide having a formulation represented by the following formula (1):

Formula (1)

$$Mo_{12}Bi_aFe_bCo_cNi_dX_eY_fZ_gO_h$$

(X is at least one element selected from the group consisting of magnesium (Mg), calcium (Ca), manganese (Mn), copper (Cu), zinc (Zn), cerium (Ce) and samarium (Sm); Y is at least one element selected from the group consisting of boron (B), phosphorus (P), asthenic (As), antimony (Sb) and tungsten (W); Z is at least one element selected from the group consisting of sodium (Na), potassium (K), rubidium (Rb) and cesium (Cs); a to g~~(a) to (g)~~ represent atomic ratios of the respective components; h is a numerical value determined by degrees of oxidations of the catalyst components; a = 0.80 to 2.0, b = 1 to 3; c = 3 to 7; d = 2 to 4; e = 0 to 10; f = 0 to 10; g = 0.01 to 0.10; h is expressed by the numerical value satisfying the oxidation states of other elements; d/a is 1.9 or more and 3.2 or less; d/g is 29 or more and 69 or less; and a/g is 18 or more and 39 or less.)

Effects of Invention

[0007]

According to the present invention, in using, as a raw material, an alkene or an alcohol capable of producing an alkene through its intramolecular dehydration reaction to produce a corresponding unsaturated aldehyde or unsaturated carboxylic acid, it becomes possible to keep

oxide-containing gas, an ammonia-containing gas, a hydrogen gas, or a mixture thereof for the purpose of rendering the system into a reducing atmosphere. There is thus obtained a catalyst (E).

[0016]

Although the catalyst contained in all of the catalyst layers of the fixed bed multitubular reactor which is used for the method of the present invention is not particularly limited, a catalyst containing a complex metal oxide having a formulation represented by the following formula (1) is preferred.

[0017]

$$Mo_{12}Bi_aFe_bCo_cNi_dX_eY_fZ_gO_h \qquad (1)$$

[0018]

(X is at least one element selected from the group consisting of magnesium (Mg), calcium (Ca), manganese (Mn), copper (Cu), zinc (Zn), cerium (Ce) and samarium (Sm); Y is at least one element selected from the group consisting of boron (B), phosphorus (P), asthenic (As), antimony (Sb) and tungsten (W); Z is at least one element selected from the group consisting of sodium (Na), potassium (K), rubidium (Rb) and cesium (Cs); a to g~~(a) to (g)~~ represent atomic ratios of the respective components; h is a numerical value determined by degrees of oxidations of the catalyst components; a = 0.80 to 2.0, b = 1 to 3; c = 3 to 7; d = 2 to 4; e = 0 to 10; f = 0 to 10; g = 0.01 to 0.10; h is expressed by the numerical value satisfying the oxidation states of other elements; d/a is 1.9 or more and 3.2 or less; d/g is 29 or more and 69 or less; and a/g is 18 or more and 39 or less.)

[0019]

In the complex metal oxide having the formulation represented by the foregoing formula (1), more preferably, b = 1 to 2.5, d = 2 to 3.5, and a/g is 18 or more and 35 or less.

[0020]

The catalytic gas-phase oxidation reaction of an alkene in the present invention is carried out by introducing a mixed gas composed of 7 to 12% by volume of an alkene, 5 to 18% by volume of molecular oxygen, 0 to 60% by volume of steam, and 20 to 70% by volume of an inert gas, for example, nitrogen, carbon dioxide, etc., in terms of a raw material gas formulation onto the catalyst prepared above at a temperature ranging from 250 to 450°C under a pressure of atmospheric pressure to 10 atms, preferably atmospheric pressure to 5 atms, and more preferably atmospheric pressure to 3 atms for a contact time of 0.5 to 10 seconds. It is to be

Table 1

	Space velocity of propylene (h^{-1})	Reaction bath temperature (°C)	Temperature of hot spot (°C)	Sn	Maximum effective yield (mol%)
Example 1	100	328	401	2.05	91.8
		318	380		
Example 2	100	328	397	2.21	91.3
		316	370		
Example 3	100	324	407	1.20	91.5
		314	395		
Example 4	110	321	394	1.86	91.1
		310	376		
Example 5	150	326	406	2.02	90.1
		314	383		
Comparative Example 1	100	330	419	7.73	91.1
		322	353		

[0040]

While the invention has been described in detail and with reference to specific embodiments thereof, it will be apparent to one skilled in the art that various changes and modifications can be made therein without departing from the spirit and scope thereof.

It is to be noted that the present application is based on a Japanese patent application filed on July 18, 2013 (Japanese Patent Application No. 2013-149333), the entireties of which are incorporated by reference. In addition, all references cited herein are incorporated as a whole.

Industrial Applicability

[0041]

The present invention is useful for the industrial plant of producing an unsaturated aldehyde or an unsaturated carboxylic acid.

manganese (Mn), copper (Cu), zinc (Zn), cerium (Ce) and samarium (Sm); Y is at least one element selected from the group consisting of boron (B), phosphorus (P), asthenic (As), antimony (Sb) and tungsten (W); Z is at least one element selected from the group consisting of sodium (Na), potassium (K), rubidium (Rb) and cesium (Cs); a to g~~(a) to (g)~~ represent atomic ratios of the respective components; h is a numerical value determined by degrees of oxidations of the catalyst components; a = 0.80 to 2.0, b = 1 to 3; c = 3 to 7; d = 2 to 4; e = 0 to 10; f = 0 to 10; g = 0.01 to 0.10; h is expressed by the numerical value satisfying the oxidation states of other elements; d/a is 1.9 or more and 3.2 or less; d/g is 29 or more and 69 or less; and a/g is 18 or more and 39 or less.)

[Claim 6]

The method for producing an unsaturated aldehyde and/or an unsaturated carboxylic acid according to claim 5,

wherein b = 1 to 2.5, d = 2 to 3.5, and a/g is 18 or more and 35 or less.