Claims

1. A modified Y-type molecular sieve, having a rare earth content of 4% to 11% by weight on the basis of the oxide, a phosphorus content of 0.05% to 10% by weight on the basis of P_2O_5, a sodium content of no more than 0.5% by weight on the basis of sodium oxide, a gallium content of 0.1% to 2.5% by weight on the basis of gallium oxide, and a zirconium content of 0.1% to 2.5% by weight on the basis of zirconia, based on the weight of the modified Y-type molecular sieve on a dry basis; wherein the modified Y-type molecular sieve has a total pore volume of 0.36 mL/g to 0.48 mL/g, a percentage of the pore volume of secondary pores having a pore size of 2-100 nm to the total pore volume of 20% to 40%; a lattice constant of 2.440 nm to 2.455 nm, a lattice collapse temperature of not lower than 1060 °C, a percentage of non-framework aluminum content to the total aluminum content of no more than 10%, and a ratio of B acid to L acid in the strong acid content of the modified Y-type molecular sieve of no less than 3.5.

2. The modified Y-type molecular sieve according to claim 1, wherein the modified Y-type molecular sieve has one or more of the following characteristics:

a percentage of the pore volume of secondary pores having a pore size of 2-100 nm to the total pore volume of the modified Y-type molecular sieve of 28% to 38%;

a percentage of non-framework aluminum content to the total aluminum content of the modified Y-type molecular sieve of 5% to 9.8%;

a framework silica-alumina ratio of the modified Y-type molecular sieve of 7 to 14, calculated on the basis of $nSiO_2/n(Al_2O_3)$;

a lattice collapse temperature of the modified Y-type molecular sieve of 1065 °C to 1085 °C;

a ratio of B acid to L acid in the strong acid content of the modified Y-type molecular sieve of 3.5 to 6.5, as determined by the pyridine adsorption infrared spectroscopy at 350 °C;

a relative crystallinity of the modified Y-type molecular sieve of 70% to 80%; and/or

a relative crystallinity retention of the modified Y-type molecular sieve of 38% or more, as determined by XRD after aging at 800 °C in 100% steam atmosphere for 17 hours.

3. The modified Y-type molecular sieve according to any one of the preceding claims, wherein the modified Y-type molecular sieve has a rare earth content of 4.5% to 10% by weight on the basis of the oxide, a phosphorus content of 0.5% to 5% by weight on the

basis of P_2O_5, a sodium content of 0.05% to 0.3% by weight on the basis of sodium oxide, a gallium content of 0.2% to 2% by weight on the basis of gallium oxide, and a zirconium content of 0.5% to 2% by weight on the basis of zirconia, based on the weight of the modified Y-type molecular sieve on a dry basis; and the modified Y-type molecular sieve has a lattice constant of 2.442 nm to 2.451 nm; and a framework silica-alumina ratio of 8.5 to 12.6 calculated on the basis of $nSiO_2/n(Al_2O_3)$;

preferably, the rare earth comprises a rare earth element selected from the group consisting of La, Ce, Pr, Nd, and any combination thereof.

4. A method for the preparation of the modified Y-type molecular sieve according to any one of claims 1-3, comprising the steps of:

(1) contacting a NaY molecular sieve with a rare earth salt solution for ion-exchange reaction, to obtain an ion-exchanged molecular sieve;

(2) subjecting the ion-exchanged molecular sieve to roasting at a temperature of 350 °C to 480 °C in an atmosphere comprising 30 vol% to 90 vol% of steam for 4.5 hours to 7 hours, to obtain a molecular sieve undergone a mild hydrothermal ultra-stabilization treatment;

(3) subjecting the molecular sieve undergone a mild hydrothermal ultra-stabilization treatment to gas phase ultra-stabilization by contacting and reacting with gaseous $SiCl_4$, to obtain a gas phase ultra-stabilized molecular sieve;

(4) subjecting the gas phase ultra-stabilized molecular sieve to an acid treatment by contacting with an acid solution, to obtain an acid-treated molecular sieve;

(5) subjecting the acid-treated molecular sieve to phosphorus modification by contacting with a phosphorus compound, to obtain a phosphorus-modified molecular sieve; and

(6) subjecting the phosphorus-modified molecular sieve to a modification treatment by contacting with gallium and zirconium in a solution, and then to calcination, to obtain the modified Y-type molecular sieve.

5. The method according to claim 4, wherein the step (1) further comprises contacting a NaY molecular sieve with a rare earth salt in an aqueous solution for ion-exchange reaction, wherein the ion-exchange reaction is conducted under the following conditions:

a temperature of 15 °C to 95 °C, a reaction time of 30 min to 120 min, and a weight ratio of the NaY molecular sieve, the rare earth salt and water of 1 : (0.01-0.18) : (5-20),

preferably, the ion-exchanged molecular sieve obtained has a sodium content of no more

than 9.5% by weight, based on the weight of the ion-exchanged molecular sieve on a dry basis.

6. The method according to claim 4 or 5, wherein the ion-exchanged molecular sieve has a lattice constant of 2.465 nm to 2.472 nm, a rare earth content of 4.5% to 13% by weight on the basis of the oxide, and a sodium content of 4.5% to 9.5% by weight on the basis of sodium oxide.

7. The method according to any one of claims 4 to 6, wherein the rare earth salt is rare earth chloride or rare earth nitrate.

8. The method according to any one of claims 4 to 7, wherein in the step (2), the ion-exchanged molecular sieve is subjected to roasting at a temperature of 380 °C to 460 °C in an atmosphere comprising 40 vol% to 80 vol% of steam for 5 hours to 6 hours;

preferably, the resulting molecular sieve undergone a mild hydrothermal ultra-stabilization treatment has a lattice constant of 2.450 nm to 2.462 nm and a water content of no more than 1% by weight.

9. The method according to any one of claims 4 to 8, wherein, in the step (3), the weight ratio of the $SiCl_4$ to the molecular sieve undergone a mild hydrothermal ultra-stabilization treatment on a dry basis is (0.1-0.7) : 1, the reaction temperature is 200 °C to 650 °C, and the reaction time is 10 min to 5 hours;

preferably, the step (3) further comprises washing the gas phase ultra-stabilized molecular sieve obtained with water to an extent that no free ions like Na^+, Cl^- and Al^{3+} can be detected in the spent washing liquid, and the washing conditions may include: a temperature of 30 °C to 60 °C, a weight ratio of water to the gas phase ultra-stabilized molecular sieve before washing of (6-15) : 1, and a pH of the spent washing liquid of 2.5 to 5.0.

10. The method according to any one of claims 4 to 9, wherein in the step (4), the acid treatment is conducted under the following conditions: an acid treatment temperature of 80 °C to 99 °C, an acid treatment time of 1 hour to 4 hours, an acid solution comprising an organic acid and/or an inorganic acid, and a weight ratio of the acid in the acid solution, water in the acid solution, and the gas phase ultra-stabilized molecular sieve on a dry basis of (0.001-0.15) : (5-20) : 1;

preferably, the organic acid is selected from the group consisting of oxalic acid, malonic acid, succinic acid, methyl succinic acid, malic acid, tartaric acid, citric acid, salicylic acid, and any combination thereof; and/or

preferably, the inorganic acid is selected from the group consisting of phosphoric acid,

hydrochloric acid, nitric acid, sulfuric acid, and any combination thereof.

11. The method according to claim 10, wherein the acid treatment of the step (4) further comprises: contacting the gas phase ultra-stabilized molecular sieve first with an inorganic acid solution, and then with an organic acid solution;

wherein the contacting with the inorganic acid solution is conducted under the following conditions: a contact time of 60 min to 120 min, a contact temperature of 90 °C to 98 °C, and a weight ratio of the inorganic acid in the inorganic acid solution, water in the inorganic acid solution, and the gas phase ultra-stabilized molecular sieve on a dry basis of (0.01-0.05) : (5-20) : 1; and

the contacting with the organic acid solution is conducted under the following conditions: a contact time of 60 min to 120 min, a contact temperature of 90 °C to 98 °C, and a weight ratio of the organic acid in the organic acid solution, water in the organic acid solution, and the gas phase ultra-stabilized molecular sieve on a dry basis of (0.02-0.1) : (5-20) : 1.

12. The method according to any one of claims 4 to 11, wherein the phosphorus compound is selected from the group consisting of phosphoric acid, ammonium phosphate, ammonium dihydrogen phosphate, diammonium hydrogen phosphate, and any combination thereof;

preferably, the step (5) further comprises: contacting and reacting the acid-treated molecular sieve with a solution containing a phosphorus compound at a temperature of 15 °C to 100 °C for 10 min to 100 min, wherein the weight ratio of the phosphorus in the phosphorus compound-containing solution calculated on the basis of P_2O_5, water in the phosphorus compound-containing solution, and the acid-treated molecular sieve is (0.0005-0.10) : (2-5) : 1.

13. The method according to any one of claims 4 to 12, wherein the step (6) further comprises: mixing the phosphorus-modified molecular sieve homogeneously with an aqueous solution containing a gallium salt and a zirconium salt, and then standing at 15 °C to 40 °C for 24 hours to 36 hours, wherein the weight ratio of the gallium in the aqueous solution containing a gallium salt and a zirconium salt calculated on the basis of gallium oxide, the zirconium in the aqueous solution containing a gallium salt and a zirconium salt calculated on the basis of zirconia, and the phosphorus-modified molecular sieve on a dry basis is (0.001-0.025) : (0.001-0.025) : 1, and the weight ratio of water in the aqueous solution to the phosphorus-modified molecular sieve on a dry basis is (2-3) : 1.

14. The method according to any one of claims 4 to 13, wherein the calcination of the step

(6) is carried out under the following conditions: a calcination temperature of 450 °C to 600 °C and a calcination time of 2 hours to 5 hours.

15. A catalytic cracking catalyst, comprising 10% to 50% by weight of a modified Y-type molecular sieve, 10% to 40% by weight of an alumina binder calculated on the basis of alumina, and 10% to 80% by weight on a dry basis of clay, based on the weight of the catalyst on a dry basis, wherein the modified Y-type molecular sieve is a modified Y-type molecular sieve according to any one of claims 1 to 3;

preferably, the clay is selected from the group consisting of kaolin, hydrated halloysite, montmorillonite, diatomaceous earth, halloysite, saponite, rectorite, sepiolite, attapulgite, hydrotalcite, bentonite, and any combination thereof; and/or

preferably, the alumina binder is selected from the group consisting of alumina, hydrated alumina, aluminum sol, and any combination thereof.

16. Use of a modified Y-type molecular sieve according to any one of claims 1 to 3 in the catalytic cracking of a hydrocarbon feedstock, comprising contacting the hydrocarbon feedstock with a catalytic cracking catalyst comprising the modified Y-type molecular sieve under catalytic cracking conditions,

preferably, the hydrocarbon feedstock is a hydrogenated light cycle oil (LCO); and/or

preferably, the catalytic cracking conditions include: a reaction temperature of 500 °C to 610 °C, a weight hourly space velocity of 2 h^{-1} to 16 h^{-1}, and a catalyst-to-oil weight ratio of 3 to 10.