

Y-TYPE MOLECULAR SIEVE AND SYNTHESIS METHOD THEREFOR

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The application claims benefit of the Chinese patent application No. 202110019016.7 filed on January 07, 2021, the content of which is incorporated herein by reference.

TECHNICAL FIELD

[0002] The invention belongs to the technical field of molecular sieve synthesis, and relates to a Y-type molecular sieve and a synthesis method therefor, particularly to a Y-type molecular sieve having a small grain size and a high silica-alumina ratio and a synthesis method therefor.

BACKGROUND ART

[0003] Y-type molecular sieves are molecular sieves having a FAU-type framework structure, the three-dimensional channel structure of Y-type molecular sieves is composed of interconnected pores of faujasite cage. Y-type molecular sieves have been widely used in catalysis, gas separation, adsorption, and ion exchange and other fields in recent years due to their unique structure and properties. Y-type molecular sieves have been put into use in the Fields of Catalytic Cracking (FCC) and

hydrocracking for over 50 years, and have an industrially irreplaceable position due to the inherent properties such as a large specific surface area, a large pore volume, abundant acid-center active sites, desirable thermal and chemical stability.

[0004] The Y-type molecular sieves used in the industrial production at the earliest stage had a size of micron level, however, because of the longer channels in micron-sized Y-type molecular sieves, the product molecules are prone to diffuse through the channels and cause secondary cracking thereby lowering the liquid yield during the process of catalytic cracking, hydrocracking and hydroisomerization. In addition, the traditional Y-type molecular sieves without subjecting to the post-treatment have very small external surface areas and fairly limited conversion of the macromolecule polycyclic aromatic hydrocarbons. The Y-type molecular sieves having a small grain size are provided with a larger specific surface area while retaining the skeleton structure of Y-type molecular sieves, thus have attracted more and more attention.

[0005] Currently, there are several methods for synthesizing NaY molecular sieves with a small grain size:

[0006] 1. A directing agent is added during the synthesis process, in order to improve the product properties by modifying the properties of the directing agent. For example, the Chinese patent application CN1033503C discloses a process for preparation of small crystal grain

NaY molecular sieve, the method is performed by firstly adding the sodium silicate solution in the conventional directing agent whose light transmittance is less than 30%, to produce an improved directing agent whose light transmittance is more than 70%, the improved directing agent is subsequently added into the silica-alumina gel before crystallization to produce the small crystal grain NaY molecular sieve, the molecular sieve has a silica-alumina ratio being 5 or more, and a grain size about several hundred nanometers. CN1032803C discloses a synthetic method of small crystal grain NaY molecular sieve, such that the NaY molecular sieve with a grain size of 100-500nm can be prepared, the method relates to firstly subjecting the silica-alumina gel to crystallization under the high temperature, and feeding the directing agent following the crystallization process, and continuously carrying out crystallization to prepare the final product.

[0007] 2. The size of NaY molecular sieve is reduced by adding a surfactant or an organic dispersant. For example, CN103449470B discloses a synthesis method of highly-stable small-grain NaY molecular sieve by adding a highly alkali sodium metaaluminate solution into a water glass solution, stirring the solutions uniformly and then pouring into an aqueous solution of surfactant, producing an improved directing agent after aging, adding the directing agent to a material which is prepared according to a certain molar ratio, and carrying out

crystallization for 8-72 hours to produce small-grain NaY molecular sieve. The grain size is within a range of 100-400nm. US 3516786 uses organic solvents to synthesize small-grain NaY molecular sieve. Water-soluble solvents such as methanol, ethanol, dimethylsulfoxide and dimethylformamide can be added to a silicon source or an aluminum source before gelling, or can be added after gel formation according to an addition amount of 0.1-20% of the gel amount. The small grain Y-type molecular sieve can be produced after crystallization.

[0008] 3. A method for increasing alkalinity of the synthesis system. EP0435625A2 proposes a direct synthesis method of small grain Y-type molecular sieve by using a highly alkali silica-alumina gel, a particle size of the synthesized Y-type molecular sieve may be tens of nanometers. The method involves with firstly pouring an aqueous sodium aluminate solution into a highly alkali water glass solution, subjecting the gel to high speed agitation at a rotational speed of 3,000 rpm to convert the gel to a homogeneous mixture, a product can be prepared after aging and crystallization. However, the NaY molecular sieve prepared with the method has a relatively low $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio, a poor hydrothermal stability, thus the product can hardly be industrially applied.

[0009] The Y-type molecular sieves prepared with the aforementioned methods have too low silica-alumina ratio, or large grain size, or non-uniform particle size distribution, resulting in the defects such as

easy collapse of the structure, low catalytic activity, unstable performance, and short catalyst life when the Y-type molecular sieves are used as the catalyst carrier.

SUMMARY OF THE INVENTION

[0010] The invention intends to solve the defects in the prior art, and provides a Y-type molecular sieve and synthesis method therefor, the Y-type molecular sieve simultaneously has the advantages of high silica-alumina ratio, small grain size, uniform particle size distribution, and good hydrothermal stability.

[0011] According to a first aspect, the invention provides a Y-type molecular sieve, wherein the grain size of the molecular sieve is 20-100nm, preferably 40-70nm, and more preferably 50-60nm; the silica/alumina molar ratio of the molecular sieve is 4.5-7, preferably 5.0-6.5, and more preferably 6.0-6.5; the proportion of 40-70nm grains in the molecular sieve that is measured by means of a dynamic light scattering method is 80% to 95%, preferably 85% to 93%.

[0012] Preferably, the Y-type molecular sieve of the invention has a specific surface area of 800-950 m²/g, preferably 850-920 m²/g, such as 810, 820, 830, 840, 850, 860, 870, 880, 890, 900, 905, 910, 914, 920, 930, 940, 948 m²/g.

[0013] Preferably, the Y-type molecular sieve of the invention has an

external specific surface area of 100-200 m²/g, preferably 150-180 m²/g.

[0014] Preferably, the molecular sieve has a R value of 4-9, such as 4, 5, 6, 6.2, 6.5, 7, 7.3, 7.8, 8, 8.5, 9, wherein $R = \text{specific surface area} / \text{external specific surface area}$.

[0015] Preferably, the Y-type molecular sieve of the invention has a pore volume not less than 0.36mL/g, more preferably not less than 0.38mL/g and not more than 0.56mL/g, further preferably not more than 0.53mL/g, further more preferably 0.43-0.53mL/g, such as 0.44, 0.45, 0.46, 0.47, 0.48, 0.49, 0.50, 0.51, 0.52mL/g.

[0016] The Y-type molecular sieve provided by the invention may be NaY, or HY after an ammonium exchange. When the Y-type molecular sieve is HY, the molecular sieve has a degree of crystallinity within a range of 75-90%, preferably 83-88%, after treatment under a high temperature water vapor atmosphere of 700°C and 0.1 MPa for 2h.

[0017] When the Y-type molecular sieve is NaY, the Y-type molecular sieve has a hydrothermal stability such that, after ammonium exchange, the molecular sieve has a degree of crystallinity within a range of 75-90%, preferably 83-88%, after treatment under a high temperature water vapor atmosphere of 700°C and 0.1 MPa for 2h.

[0018] The Y-type molecular sieve of the invention has a small particle size, thus it has a large external specific surface area, and the combined properties of Y-type molecular sieve and nanomaterial; due to a high

silica-alumina ratio, Y-type molecular sieve has a good hydrothermal stability, and does not collapse easily; in addition, because of its uniform particle size distribution, the performance of the catalyst is stable.

[0019] According to a second aspect, the invention provides a synthetic method of a Y-type molecular sieve, the method comprises the following steps:

[0020] (1) mixing a silicon source, an aluminum source, an alkali source and water and subjecting the mixture to a first crystallization to obtain a directing agent A, the characteristic diffraction peaks belonging to Y-type molecular sieve are not observed from XRD spectrogram of the directing agent A;

[0021] (2) adding one or more of a silicon source, an aluminum source, an alkali source and water into the directing agent A and carrying out a second crystallization to obtain a directing agent B, which has a degree of crystallinity within a range of 5%-20%, preferably 8%-16%;

[0022] (3) adding one or more of a silicon source, an aluminum source, an alkali source and water into the directing agent B and carrying out a third crystallization;

[0023] wherein the molar ratio of $\text{Na}_2\text{O} : \text{H}_2\text{O}$ in step (1) is lower than the molar ratio of $\text{Na}_2\text{O} : \text{H}_2\text{O}$ in step (2) by 0.01-0.045, preferably 0.01-0.035, more preferably 0.015-0.030, further preferably 0.02-0.026.

[0024] In the process of the invention, the molar ratio of $\text{Na}_2\text{O} : \text{H}_2\text{O}$ in a

system of step (2) (i.e., a crystallization system for preparing the directing agent B) is higher than the molar ratio of $\text{Na}_2\text{O}:\text{H}_2\text{O}$ in a system of step (3) (i.e., a crystallization system formed by further adding one or more of a silicon source, an aluminum source, an alkali source and water into the directing agent B) by 0.01-0.04, preferably 0.015-0.035, further preferably 0.023-0.033.

[0025] In the above method, the silicon source is preferably one or more selected from the group consisting of water glass, silica sol, silica and sodium silicate; the aluminum source is preferably one or more selected from the group consisting of sodium metaaluminate, aluminum powder, aluminum hydroxide and aluminum isopropoxide; and the alkali source is preferably one or more selected from the group consisting of hydroxide, tetraethylammonium hydroxide and tetrapropylammonium hydroxide.

[0026] The water is preferably distilled water.

[0027] In accordance with a specific embodiment of the invention, the method for synthesizing the Y-type molecular sieve specifically comprises the following steps:

[0028] (1) Dissolving an aluminum source, preferably sodium aluminate, in distilled water under the stirring conditions, then adding a silicon source, preferably water glass, and stirring uniformly, followed by the addition of sodium hydroxide, and continuously stirring, subjecting the gel to a constant temperature crystallization at a certain temperature for a

period of time, and taking out the gel to obtain a solution of the incompletely crystallized Y-molecular sieve, which is denoted as a directing agent A. The directing agent A obtained in the meanwhile has some essential structural units, it as a whole exhibits an amorphous phase, the characteristic diffraction peak belonging to Y-type molecular sieve is not observed from XRD spectrogram of the directing agent A, that is, a degree of crystallinity is 0.

[0029] (2) Adding a certain amount of silicon source (e.g., a highly alkali water glass solution) and an aluminum source (e.g., a sodium aluminate solution) successively into the directing agent A obtained in step (1) under the stirring conditions, stirring uniformly, subjecting the materials to a constant temperature crystallization at a certain temperature, taking out the crystallization product and cooling to room temperature so as to obtain a directing agent B. In the meanwhile, the directing agent B has a degree of crystallinity of 5%-20%, preferably 8%-16%.

[0030] (3) Adding a low alkaline water glass, sodium aluminate solution into the directing agent B under the stirring conditions, subjecting the materials to a constant temperature crystallization at a certain temperature, subjecting the obtained solid product to a suction filtration, and washing it to neutral, and drying the washed product to prepare the product.

[0031] In the invention, the highly alkali water glass and the low alkaline water glass refer to a high level or low level of sodium hydroxide content

in the water glass solution, the specific content of sodium hydroxide shall satisfy the required molar ratio of feedstock in the step.

[0032] In the method of the invention, the molar ratio of feedstock in step (1) is $(7-14)\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:(20-33)\text{SiO}_2:(300-650)\text{H}_2\text{O}$, further preferably $(9-12)\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:(23-28)\text{SiO}_2:(350-550)\text{H}_2\text{O}$.

[0033] In the method of the invention, the crystallization temperature of step (1) is $70-100^\circ\text{C}$, preferably $80-90^\circ\text{C}$; the crystallization time is 4-12 hours, preferably 6-10 hours.

[0034] In the method of the invention, it is preferable that the directing agent A added in step (2) accounts for 25-38wt%, more preferably 28-35wt%, of the total mass of the directing agent B, based on the mass of Al_2O_3 . By controlling the directing agent A within the above-mentioned specific proportion range, the grain size of the directing agent B can be controlled, thereby desirably ensuring that the grain size of the prepared Y-type molecular sieve falls within a desired range and the particle size distribution is uniform.

[0035] In the method of the invention, the feedstock molar ratio of directing agent B in step (2) is $(17-26)\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:(13-19)\text{SiO}_2:(400-618)\text{H}_2\text{O}$, preferably $(21-24)\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:(15-17)\text{SiO}_2:(400-550)\text{H}_2\text{O}$.

[0036] In the method of the invention, the crystallization temperature of step (2) is $40-70^\circ\text{C}$, preferably $50-65^\circ\text{C}$; the crystallization time is 15-41

hours, preferably 18-28 hours.

[0037] In the above method, the first crystallization temperature (i.e., the crystallization temperature at which the directing agent A is prepared) is higher than the second crystallization temperature (i.e., the crystallization temperature at which the directing agent B is prepared) by 5-60°C, preferably 15-40°C. By controlling that the second crystallization is performed at a lower temperature, the grain size of the molecular sieve is smaller, and the formation of miscellaneous crystals is avoided.

[0038] Preferably, the first crystallization time is less than the second crystallization time by 8-37h, more preferably 8-22h.

[0039] In the method of the invention, the directing agent B added in step (3) accounts for 45-65wt%, preferably 50-60wt%, of the mass of the composition of the final sol (i.e., the feedstock subjected to the third crystallization) based on the mass of Al_2O_3 .

[0040] In the method of the invention, after adding the water glass and sodium aluminate solution in step (3), the composition of the formed final sol is $(12-20)\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:(14-20)\text{SiO}_2:(550-1,050)\text{H}_2\text{O}$, preferably $(14-17)\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:(16-18)\text{SiO}_2:(650-950)\text{H}_2\text{O}$.

[0041] In the method of the invention, the crystallization temperature of step (3) is 80-105°C, preferably 90-100°C; the crystallization time is 6-13 hours, preferably 8-12 hours.

[0042] Preferably, the third crystallization temperature is higher than the

second crystallization temperature by 20-60°C, preferably 35-50°C

[0043] Preferably, the third crystallization time is less than the second crystallization time by 5-35 hours, preferably 6-20 hours.

[0044] According to a preferred embodiment of the invention, the method of the invention further comprises subjecting the product obtained from the third crystallization to one or more ammonium exchanges to obtain the desired HY molecular sieve.

[0045] The ammonium exchange may be carried out in a known manner and conditions, for example, the ammonium exchanges are performed with 1.5mol/L ammonium chloride solution at 70°C for three times, a solid-solution ratio of each ammonium exchange is 1:10. The content will not be repeatedly described herein.

[0046] The synthesis method provided by the invention comprises firstly carrying out crystallization under the conditions of high silica-alumina ratio in the feedstock and a low alkalinity, forming a large amount of nanometer Y-type molecular sieve precursors which are not fully crystallized in the solution; then carrying out a second crystallization by increasing alkalinity of sol at a slightly lower temperature, so as to obtain nanometer seed crystals having a small grain size and a high silica-alumina ratio; on this basis, carrying out a third crystallization under the conditions of a low alkalinity and a high silica-alumina ratio, such that the silica-alumina ratio can be further increased, the degree of

crystallinity is enhanced, and the skeleton structure is more complete, thereby preparing the Y-type molecular sieve having a small grain size, concentrated grain distribution, high silica-alumina ratio and good hydrothermal stability, and can meet the needs of industrial production. As a result, the synthesis method of the invention is suitable for industrial application.

BRIEF DESCRIPTION OF THE DRAWINGS

[0047] FIG. 1 illustrates XRD diffractograms of the directing agent A, directing agent B and Y-type molecular sieve prepared in Example 1 sequentially from left to right.

[0048] FIG. 2 shows a Scanning Electron Microscopy (SEM) image at 10k magnification and a SEM image at 50k magnification of the Y-type molecular sieve prepared in Example 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0049] In the method of the invention, the degree of crystallinity of the directing agent A and director B was measured by using X-ray diffraction according to the method stipulated in the Chinese Petrochemical Industry Standard SH/T0340-92.

[0050] The measurement of hydrothermal stability of the Y-type molecular sieve referred to the degree of crystallinity of a sample after

treatment under a high temperature water vapor atmosphere of 700°C and 0.1 MPa for 2h. The higher was the degree of crystallinity, it denoted that the better was the hydrothermal stability. The specific measurement method comprised the following steps: a sample was initially subjected to ammonium exchanges for three times with 1.5mol/L of ammonium chloride solution at 70°C, the solid-to-liquid ratio by weight for each ammonium exchange was 1:10. The sample was then subjected to treatment under a high temperature water vapor atmosphere of 700°C and 0.1 MPa for 2h, the degree of crystallinity of said sample after the hydrothermal treatment was subsequently measured by using X-ray diffraction according to the method stipulated in the Chinese Petrochemical Industry Standard SH/T0340-92.

[0051] The specific surface area and pore volume of the molecular sieve were measured by using the N₂-adsorption desorption method. Before the measurement, the samples were first subjected to heat treatment at 300°C for 3h, and then tested by adsorbing nitrogen gas at 77K. The specific surface area of molecular sieve was calculated with the BET method, the total pore volume was measured at a place where $p/p^0=0.98$, and the external specific surface area was obtained through the t-Plot method.

[0052] The silicon-aluminum molar ratio of molecular sieve framework was measured by using X-ray diffraction method. The lattice cell parameter a_0 was measured using the Chinese Petrochemical Industry

Standard SH/T0339-92, the lattice cell parameter was then introduced into the Breck equation $\text{Si/Al} = ((192 \times 0.00868) / (a_0 - 24.191)) - 1$ to implement calculation. The resulting silicon-aluminum molar ratio was represented by $\text{SiO}_2/\text{Al}_2\text{O}_3$.

[0053] The grain size of molecular sieves was measured by using a Scanning Electron Microscopy (SEM).

[0054] The particle size distribution of molecular sieve was measured by using a dynamic light scattering (DLS) method stipulated in the method of the Chinese National Standard GB/T29022-2012.

[0055] The gel composition in each step was calculated based on the feeding amount.

[0056] The catalytic cracking performance of molecular sieves was tested by using 1,3,5-triisopropylbenzene (TIPB) as a model compound. The reaction was carried out in a fixed bed reactor, 2g of a sieved 20-40 mesh HY molecular sieve was weighted and filled into a reactor. The catalyst was first subjected to an N_2 purge at normal temperature for 30min, and the N_2 flow rate was controlled at 50mL/min. The temperature was subsequently raised to 500°C to carry out activation, and the temperature was reduced to 450°C after the activation process, the feedstock was introduced at a flow rate of 12mL/h. The reaction products were analyzed by using the Agilent 7890B gas phase chromatograph (FID detector), and the results of Table 2 below illustrated the compositions of

the products collected after the reaction was performed for 48 hours and entered a stationary phase.

[0057] The preparation processes and product properties of the method of the invention were further demonstrated below with reference to the Examples and Comparative Examples, but the following Examples did not impose limitation to the method of the invention.

[0058] Example 1

[0059] (1) Sodium aluminate was dissolved in distilled water under stirring conditions, a water glass solution was then added and stirred to homogenize the gel, a sodium hydroxide solution was subsequently added and continuously stirred, the composition of finally formed gel was $9\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:23.0\text{SiO}_2:550\text{H}_2\text{O}$. The gel was crystallized for 10h under a constant temperature of 80°C , the gel was taken out and cooled to room temperature to obtain the directing agent A. The characteristic diffraction peak belonging to Y-type molecular sieve was not observed from XRD spectrogram of the directing agent A.

[0060] (2) A water glass solution and a sodium aluminate solution were added successively to the directing agent A under stirring conditions, the composition of the formed gel was $23\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:16\text{SiO}_2:550\text{H}_2\text{O}$, the directing agent A accounted for 28wt% of the total gel mass (based on the percentage content of Al_2O_3 in the gel). The gel was crystallized for 18h under a constant temperature of 65°C , the gel was taken out and cooled to

room temperature, the cooled gel was denoted as the directing agent B, the degree of crystallinity was 13%.

[0061] (3) A water glass solution and a sodium aluminate solution were added to the directing agent B under stirring conditions, the composition of the finally formed gel was $15\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:18\text{SiO}_2:820\text{H}_2\text{O}$, the directing agent B accounted for 50wt% of the total gel mass (based on the percentage content of Al_2O_3 in the gel). The gel was crystallized for 12h under a constant temperature of 90°C , the gel was cooled to room temperature, then filtered and dried to obtain the final product. The XRD spectrograms of the products obtained by crystallization of step (1), step (2) and step (3) were shown in FIG. 1. The SEM image at 10k magnification and the SEM image at 50k magnification of the Y-type molecular sieve prepared in Example 1 were illustrated in FIG. 2.

[0062] Example 2

[0063] (1) Sodium aluminate was dissolved in distilled water under stirring conditions, a water glass solution was then added and stirred to homogenize the gel, a sodium hydroxide solution was subsequently added and continuously stirred, the composition of finally formed gel was $12.0\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:25\text{SiO}_2:450\text{H}_2\text{O}$. The gel was crystallized for 6h under a constant temperature of 90°C , the gel was taken out and cooled to room temperature to obtain the directing agent A. The characteristic diffraction peak belonging to Y-type molecular sieve was not observed from XRD

spectrogram of the directing agent A.

[0064] (2) A water glass solution and a sodium aluminate solution were added successively to the directing agent A under stirring conditions, the composition of the formed gel was $21\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:17\text{SiO}_2:440\text{H}_2\text{O}$, the directing agent A accounted for 35wt% of the total gel mass (based on the percentage content of Al_2O_3 in the gel). The gel was crystallized for 28h under a constant temperature of 50°C , the gel was taken out and cooled to room temperature, the cooled gel was denoted as the directing agent B, the degree of crystallinity was 18%.

[0065] (3) A water glass solution and a sodium aluminate solution were added to the directing agent B under stirring conditions, the composition of the finally formed gel was $14\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:17\text{SiO}_2:950\text{H}_2\text{O}$, the directing agent B accounted for 60wt% of the total gel mass (based on the percentage content of Al_2O_3 in the gel). The gel was crystallized for 8h under a constant temperature of 100°C , the gel was cooled to room temperature, then filtered and dried to obtain the final product.

[0066] Example 3

[0067] (1) Sodium aluminate was dissolved in distilled water under stirring conditions, a water glass solution was then added and stirred to homogenize the gel, a sodium hydroxide solution was subsequently added and continuously stirred, the composition of finally formed gel was $10.5\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:28\text{SiO}_2:350\text{H}_2\text{O}$. The gel was crystallized for 8h under a

constant temperature of 85°C, the gel was taken out and cooled to room temperature to obtain the directing agent A. The characteristic diffraction peak belonging to Y-type molecular sieve was not observed from XRD spectrogram of the directing agent A.

[0068] (2) A water glass solution and a sodium aluminate solution were added successively to the directing agent A under stirring conditions, the composition of the formed gel was $21.5\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:15\text{SiO}_2:400\text{H}_2\text{O}$, the directing agent A accounted for 33wt% of the total gel mass (based on the percentage content of Al_2O_3 in the gel). The gel was crystallized for 25h under a constant temperature of 60°C, the gel was taken out and cooled to room temperature, the cooled gel was denoted as the directing agent B, the degree of crystallinity was 14%.

[0069] (3) A water glass solution and a sodium aluminate solution were added to the directing agent B under stirring conditions, the composition of the finally formed gel was $17\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:16\text{SiO}_2:660\text{H}_2\text{O}$, the directing agent B accounted for 55wt% of the total gel mass (based on the percentage content of Al_2O_3 in the gel). The gel was crystallized for 10h under a constant temperature of 100°C, the gel was cooled to room temperature, then filtered and dried to obtain the final product.

[0070] Example 4

[0071] (1) Sodium aluminate was dissolved in distilled water under stirring conditions, a water glass solution was then added and stirred to

homogenize the gel, a sodium hydroxide solution was subsequently added and continuously stirred, the composition of finally formed gel was $10\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:20\text{SiO}_2:640\text{H}_2\text{O}$. The gel was crystallized for 12h under a constant temperature of 70°C , the gel was taken out and cooled to room temperature to obtain the directing agent A. The characteristic diffraction peak belonging to Y-type molecular sieve was not observed from XRD spectrogram of the directing agent A.

[0072] (2) A water glass solution and a sodium aluminate solution were added successively to the directing agent A under stirring conditions, the composition of the formed gel was $25.6\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:19\text{SiO}_2:420\text{H}_2\text{O}$, the directing agent A accounted for 30wt% of the total gel mass (based on the percentage content of Al_2O_3 in the gel). The gel was crystallized for 25h under a constant temperature of 55°C , the gel was taken out and cooled to room temperature, the cooled gel was denoted as the directing agent B, the degree of crystallinity was 10%.

[0073] (3) A water glass solution and a sodium aluminate solution were added to the directing agent B under stirring conditions, the composition of the finally formed gel was $20\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:18\text{SiO}_2:950\text{H}_2\text{O}$, the directing agent B accounted for 65wt% of the total gel mass (based on the percentage content of Al_2O_3 in the gel). The gel was crystallized for 6h under a constant temperature of 105°C , the gel was cooled to room temperature, then filtered and dried to obtain the final product.

[0074] Example 5

[0075] (1) Sodium aluminate was dissolved in distilled water under stirring conditions, a water glass solution was then added and stirred to homogenize the gel, a sodium hydroxide solution was subsequently added and continuously stirred, the composition of finally formed gel was $14.0\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:33\text{SiO}_2:520\text{H}_2\text{O}$. The gel was crystallized for 4h under a constant temperature of 75°C , the gel was taken out and cooled to room temperature to obtain the directing agent A. The characteristic diffraction peak belonging to Y-type molecular sieve was not observed from XRD spectrogram of the directing agent A.

[0076] (2) A water glass solution and a sodium aluminate solution were added successively to the directing agent A under stirring conditions, the composition of the formed gel was $17.0\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:16\text{SiO}_2:400\text{H}_2\text{O}$, the directing agent A accounted for 25wt% of the total gel mass (based on the percentage content of Al_2O_3 in the gel). The gel was crystallized for 15h under a constant temperature of 70°C , the gel was taken out and cooled to room temperature, the cooled gel was denoted as the directing agent B, the degree of crystallinity was 20%.

[0077] (3) A water glass solution and a sodium aluminate solution were added to the directing agent B under stirring conditions, the composition of the finally formed gel was $12\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:14\text{SiO}_2:1,050\text{H}_2\text{O}$, the directing agent B accounted for 45wt% of the total gel mass (based on the

percentage content of Al_2O_3 in the gel). The gel was crystallized for 10h under a constant temperature of 90°C , the gel was cooled to room temperature, then filtered and dried to obtain the final product.

[0078] Example 6

[0079] (1) Sodium aluminate was dissolved in distilled water under stirring conditions, a water glass solution was then added and stirred to homogenize the gel, a sodium hydroxide solution was subsequently added and continuously stirred, the composition of finally formed gel was $7.0\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:26\text{SiO}_2:300\text{H}_2\text{O}$. The gel was crystallized for 8h under a constant temperature of 100°C , the gel was taken out and cooled to room temperature to obtain the directing agent A. The characteristic diffraction peak belonging to Y-type molecular sieve was not observed from XRD spectrogram of the directing agent A.

[0080] (2) A water glass solution and a sodium aluminate solution were added successively to the directing agent A under stirring conditions, the composition of the formed gel was $23.0\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:13\text{SiO}_2:615\text{H}_2\text{O}$, the directing agent A accounted for 38wt% of the total gel mass (based on the percentage content of Al_2O_3 in the gel). The gel was crystallized for 16h under a constant temperature of 40°C , the gel was taken out and cooled to room temperature, the cooled gel was denoted as the directing agent B, the degree of crystallinity was 10%.

[0081] (3) A water glass solution and a sodium aluminate solution were

added to the directing agent B under stirring conditions, the composition of the finally formed gel was $15\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:20\text{SiO}_2:550\text{H}_2\text{O}$, the directing agent B accounted for 55wt% of the total gel mass (based on the percentage content of Al_2O_3 in the gel). The gel was crystallized for 10h under a constant temperature of 85°C , the gel was cooled to room temperature, then filtered and dried to obtain the final product.

[0082] Example 7

[0083] (1) Sodium aluminate was dissolved in distilled water under stirring conditions, a water glass solution was then added and stirred to homogenize the gel, a sodium hydroxide solution was subsequently added and continuously stirred, the composition of finally formed gel was $12\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:20\text{SiO}_2:530\text{H}_2\text{O}$. The gel was crystallized for 6h under a constant temperature of 90°C , the gel was taken out and cooled to room temperature to obtain the directing agent A. The characteristic diffraction peak belonging to Y-type molecular sieve was not observed from XRD spectrogram of the directing agent A.

[0084] (2) A water glass solution and a sodium aluminate solution were added successively to the directing agent A under stirring conditions, the composition of the formed gel was $17\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:14\text{SiO}_2:420\text{H}_2\text{O}$, the directing agent A accounted for 35wt% of the total gel mass (based on the percentage content of Al_2O_3 in the gel). The gel was crystallized for 31h under a constant temperature of 60°C , the gel was taken out and cooled to

room temperature, the cooled gel was denoted as the directing agent B, the degree of crystallinity was 6%.

[0085] (3) A water glass solution and a sodium aluminate solution were added to the directing agent B under stirring conditions, the composition of the finally formed gel was $20\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:16\text{SiO}_2:800\text{H}_2\text{O}$, the directing agent B accounted for 55wt% of the total gel mass (based on the percentage content of Al_2O_3 in the gel). The gel was crystallized for 10h under a constant temperature of 95°C , the gel was cooled to room temperature, then filtered and dried to obtain the final product.

[0086] Example 8

[0087] (1) Sodium aluminate was dissolved in distilled water under stirring conditions, a water glass solution was then added and stirred to homogenize the gel, a sodium hydroxide solution was subsequently added and continuously stirred, the composition of finally formed gel was $12\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:25\text{SiO}_2:500\text{H}_2\text{O}$. The gel was crystallized for 4h under a constant temperature of 70°C , the gel was taken out and cooled to room temperature to obtain the directing agent A. The characteristic diffraction peak belonging to Y-type molecular sieve was not observed from XRD spectrogram of the directing agent A.

[0088] (2) A water glass solution and a sodium aluminate solution were added successively to the directing agent A under stirring conditions, the composition of the formed gel was $17\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:15\text{SiO}_2:500\text{H}_2\text{O}$, the

directing agent A accounted for 30wt% of the total gel mass (based on the percentage content of Al_2O_3 in the gel). The gel was crystallized for 24h under a constant temperature of 40°C , the gel was taken out and cooled to room temperature, the cooled gel was denoted as the directing agent B, the degree of crystallinity was 10%.

[0089] (3) A water glass solution and a sodium aluminate solution were added to the directing agent B under stirring conditions, the composition of the finally formed gel was $14.4\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:16\text{SiO}_2:800\text{H}_2\text{O}$, the directing agent B accounted for 62wt% of the total gel mass (based on the percentage content of Al_2O_3 in the gel). The gel was crystallized for 6h under a constant temperature of 100°C , the gel was cooled to room temperature, then filtered and dried to obtain the final product.

[0090] Example 9

[0091] (1) Sodium aluminate was dissolved in distilled water under stirring conditions, a water glass solution was then added and stirred to homogenize the gel, a sodium hydroxide solution was subsequently added and continuously stirred, the composition of finally formed gel was $12\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:22\text{SiO}_2:500\text{H}_2\text{O}$. The gel was crystallized for 5h under a constant temperature of 80°C , the gel was taken out and cooled to room temperature to obtain the directing agent A. The characteristic diffraction peak belonging to Y-type molecular sieve was not observed from XRD spectrogram of the directing agent A.

[0092] (2) A water glass solution and a sodium aluminate solution were added successively to the directing agent A under stirring conditions, the composition of the formed gel was $25\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:17\text{SiO}_2:500\text{H}_2\text{O}$, the directing agent A accounted for 35wt% of the total gel mass (based on the percentage content of Al_2O_3 in the gel). The gel was crystallized for 9h under a constant temperature of 60°C , the gel was taken out and cooled to room temperature, the cooled gel was denoted as the directing agent B, the degree of crystallinity was 8%.

[0093] (3) A water glass solution and a sodium aluminate solution were added to the directing agent B under stirring conditions, the composition of the finally formed gel was $20\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:18\text{SiO}_2:800\text{H}_2\text{O}$, the directing agent B accounted for 60wt% of the total gel mass (based on the percentage content of Al_2O_3 in the gel). The gel was crystallized for 13h under a constant temperature of 90°C , the gel was cooled to room temperature, then filtered and dried to obtain the final product.

[0094] Comparative Example 1

[0095] The Y-type molecular sieve was prepared according to the method in Example 9, except that the directing agent B was not prepared, the final crystallization was carried out by adding a water glass solution and a sodium aluminate solution into the directing agent A directly under stirring conditions. The directing agent A accounted for 60wt% of the total gel mass (based on the percentage content of Al_2O_3 in the gel), the

composition of the finally formed gel was $20\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:18\text{SiO}_2:800\text{H}_2\text{O}$.

[0096] Comparative Example 2

[0097] The Y-type molecular sieve was prepared according to the method in Example 9, except that the directing agent A was not prepared, the directing agent B was prepared directly according to the gel composition of $25\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:17\text{SiO}_2:500\text{H}_2\text{O}$, the directing agent B was then added to carry out a final crystallization. The directing agent B accounted for 60wt% of the total gel mass (based on the percentage content of Al_2O_3 in the gel), the composition of the finally formed gel was $20\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:18\text{SiO}_2:800\text{H}_2\text{O}$.

[0098] Comparative Example 3

[0099] The Y-type molecular sieve was prepared according to the method in Example 9, except that the composition of gel in step (2) was $37\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:17\text{SiO}_2:500\text{H}_2\text{O}$.

[0100] Comparative Example 4

[0101] The Y-type molecular sieve was prepared according to the method in Example 9, except that the constant temperature crystallization of step (1) was carried out at 70°C for 24h, the degree of crystallinity of the directing agent A in the XRD test was 25%.

[0102] Comparative Example 5

[0103] The Y-type molecular sieve was prepared according to the method

in Example 9, except that the constant temperature crystallization of step (2) was carried out at 65°C for 50h, the degree of crystallinity of the directing agent B in the XRD test was 45%.

[0104] The product properties of the aforesaid Examples and Comparative Examples were shown in Table 1.

[0105] Table 1 Structural properties of the products in Examples and Comparative Examples

	Specific surface area, m ² /g	External specific surface area, m ² /g	Pore volume, mL/g	Silica-alumina ratio	Grain distribution, nm	Proportion of 40-70nm grains in the molecular sieve, %	Degree of crystallinity after hydro-thermal process, %
Example 1	918	152	0.43	6.3	35-80	88	89
Example 2	870	180	0.53	6.5	20-90	93	86
Example 3	851	177	0.49	6.0	30-95	85	84
Example 4	805	143	0.45	5.5	22-80	81	80
Example 5	947	102	0.39	5.2	30-92	80	78
Example 6	860	192	0.55	4.6	26-86	85	75
Example 7	821	132	0.42	5.3	23-85	83	77
Example 8	846	150	0.41	5.0	30-80	82	83
Example 9	842	124	0.43	5.7	25-88	82	82
Comparative Example 1	843	63	0.36	5.2	180-350	0	76
Comparative Example 2	816	120	0.40	3.3	60-180	25	50
Comparative Example 3	720	130	0.45	3.2	20-85	77	43
Comparative Example 4	821	102	0.38	4.2	20-100	60	60
Comparative Example 5	855	101	0.41	4.5	50-100	52	62

[0106] Table 2 Catalytic properties of the products in Examples and Comparative Examples

	Conversion	Product distribution (%)
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	rate (%)	C ₅ +liquid	Diisopropyl benzene (DIPB)	Isopropylbe nzene	Benzene	Carbon deposition
Example 1	93.4	72.5	19.3	36.2	17.0	5.0
Example 2	95.3	70.4	21.5	32.8	16.1	4.3
Example 3	91.8	71.6	18.1	34.3	19.2	5.4
Example 4	84.0	65.3	25.6	30.2	9.5	6.2
Example 5	83.3	64.6	27.1	25.2	12.3	7.0
Example 6	78.4	68.2	26.2	30.8	11.2	5.1
Example 7	83.5	64.8	23.2	28.9	12.7	6.0
Example 8	75.3	66.7	26.7	29.5	10.5	6.4
Example 9	82.0	65.4	20.6	31.7	13.1	7.3
Comparative Example 1	43.8	54.6	30.3	19.1	5.2	28.7
Comparative Example 2	45.5	65.9	26.4	26.1	13.4	11.9
Comparative Example 3	42.8	69.0	26.2	30.2	12.6	6.7
Comparative Example 4	57.6	60.6	25.4	25.1	10.1	10.6
Comparative Example 5	62.3	58.5	28.1	21.9	8.5	10.7

[0107] As can be seen from the results of the above Table 1, the Y-type molecular sieve provided by the invention has small grain size, concentrated grain distribution, high silica-alumina ratio and good hydrothermal stability, and can meet the needs of industrial production. When the Y-type molecular sieve is used for preparing a catalyst, the performance of the catalyst is stable.

[0108] As illustrated by the results of the aforesaid Table 2, the Y-type molecular sieve provided by the invention exhibits desired cracking activity for the macromolecular reactants 1,3,5-triisopropylbenzene. The molecular sieve has a small grain size, a concentrated particle size distribution, and abundant acidic sites on an external surface, which are

conducive to cracking of macromolecular reactants into micro-molecular products (isopropylbenzene and benzene). The molecular sieve has desirable diffusion properties for macromolecular reactants, and is not prone to form carbon deposit, thus the molecular sieve facilitates the long-term operation.

Claims

1. A Y-type molecular sieve, it is characterized in that the grain size of the molecular sieve is 20-100nm, the silica/alumina molar ratio of the molecular sieve is 4.5-7, the proportion of 40-70nm grains in the molecular sieve that is measured by means of a dynamic light scattering method is 80% to 95%.

2. The molecular sieve of claim 1, wherein the grain size of the molecular sieve is 40-70nm, the silica/alumina molar ratio of the molecular sieve is 5-6.5, preferably 6-6.5; the proportion of 40-70nm grains in the molecular sieve that is measured by means of a dynamic light scattering method is 85% to 93%.

3. The molecular sieve of claim 1 or 2, wherein the molecular sieve has a R value of 4.5-9.5, preferably 4.5-6, $R = \text{specific surface area} / \text{external specific surface area}$;
preferably, the molecular sieve has a specific surface area of 800-950 m^2/g , an external specific surface area of 100-200 m^2/g , and a pore volume of 0.38-0.56 mL/g .

4. The molecular sieve of any of claims 1-3, wherein the molecular sieve has a specific surface area of 850-920 m^2/g , an external specific surface

area of 150-180 m²/g, and a pore volume of 0.43-0.53 mL/g.

5. The molecular sieve of any of claims 1-4, wherein the molecular sieve has a degree of crystallinity within a range of 75-90%, preferably 83-89%, after treatment under a high temperature water vapor atmosphere of 700°C and 0.1MPa for 2h.

6. A synthetic method of a Y-type molecular sieve, it is characterized in that the method comprises the following steps:

(1) mixing a silicon source, an aluminum source, an alkali source and water and subjecting the mixture to a first crystallization to obtain a directing agent A, the characteristic diffraction peak belonging to Y-type molecular sieve is not observed from XRD spectrogram of the directing agent A;

(2) adding one or more of a silicon source, an aluminum source, an alkali source and water into the directing agent A and carrying out a second crystallization to obtain a directing agent B, which has a degree of crystallinity within a range of 5%-20%;

(3) adding one or more of a silicon source, an aluminum source, an alkali source and water into the directing agent B and carrying out a third crystallization;

wherein the molar ratio of Na₂O: H₂O in step (1) is lower than the molar

ratio of $\text{Na}_2\text{O}:\text{H}_2\text{O}$ in step (2) by 0.01-0.045, preferably 0.015-0.03, further preferably 0.02-0.026;

the molar ratio of feedstock in step (1) is $(7-14)\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:(20-33)\text{SiO}_2:(300-650)\text{H}_2\text{O}$;

the crystallization temperature of step (1) is $70-100^\circ\text{C}$, the crystallization time is 4-12 hours;

the feedstock molar ratio of directing agent B in step (2) is $(17-26)\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:(13-19)\text{SiO}_2:(400-618)\text{H}_2\text{O}$;

the crystallization temperature of step (2) is $40-70^\circ\text{C}$, the crystallization time is 15-41 hours;

the composition of the feedstock subjected to the third crystallization in step (3) is $(12-20)\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:(14-20)\text{SiO}_2:(550-1,050)\text{H}_2\text{O}$;

the crystallization temperature of step (3) is $80-105^\circ\text{C}$, the crystallization time is 6-13 hours.

7. The method of claim 6, wherein the molar ratio of $\text{Na}_2\text{O}:\text{H}_2\text{O}$ in step (2) is higher than the molar ratio of $\text{Na}_2\text{O}:\text{H}_2\text{O}$ in step (3) by 0.01-0.04, preferably 0.015-0.035, further preferably 0.023-0.033.

8. The method of claim 6 or 7, wherein the molar ratio of feedstock in step (1) is $(9-12)\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:(23-28)\text{SiO}_2:(350-550)\text{H}_2\text{O}$.

9. The method of any one of claims 6-8, wherein the first crystallization temperature is higher than the second crystallization temperature by 5-60°C, preferably 15-40°C, and the first crystallization time is less than the second crystallization time by 8-37h, preferably 8-22h.

10. The method of any one of claims 6-9, wherein the crystallization temperature of step (1) is 80-90°C, the crystallization time is 6-10 hours.

11. The method of any one of claims 6-10, wherein the directing agent A added in step (2) accounts for 25-38wt%, preferably 28-35wt%, of the total mass of the directing agent B, based on the mass of Al_2O_3 .

12. The method of any one of claims 6-11, wherein the feedstock molar ratio of directing agent B in step (2) is $(21-24)\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:(15-17)\text{SiO}_2:(400-550)\text{H}_2\text{O}$.

13. The method of any one of claims 6-12, wherein the crystallization temperature of step (2) is 50-65°C, the crystallization time is 18-28 hours.

14. The method of any one of claims 6-13, wherein the directing agent B added in step (3) accounts for 45-65wt%, preferably 50-60wt%, of the mass of feedstock composition of the third crystallization, based on the

mass of Al_2O_3 .

15. The method of any one of claims 6-14, wherein the composition of the feedstock subjected to the third crystallization in step (3) is (14-17) Na_2O : Al_2O_3 : (16-18) SiO_2 : (650-950) H_2O .

16. The method of any one of claims 6-15, wherein the crystallization temperature of step (3) is 90-100°C, the crystallization time is 8-12 hours.

17. The method of any of claims 6-16, wherein the silicon sources in step (1), step (2), and step (3) are the same or different, and each is independently one or more of water glass, silica sol, silica and sodium silicate;

the aluminum sources in step (1), step (2), and step (3) are the same or different, and each is independently one or more of sodium aluminate, sodium metaaluminate, aluminum powder, aluminum hydroxide and aluminum isopropoxide;

the alkali sources in step (1), step (2) and step (3) are the same or different, and each is independently one or more of sodium hydroxide, tetraethylammonium hydroxide and tetrapropylammonium hydroxide.