Claims

1. An adsorbent for trimethylbenzene-based compounds,

which is characterized in that, relative to the total amount of X-type molecular sieve and matrix, it comprises 93-99wt% of X-type molecular sieve and 1-7wt% of matrix, the matrix is a substance after crystal transformation through in-situ crystallization of clay mineral, the adsorbent is modified with at least one bivalent cation selected from Mg^{2+}, Ca^{2+}, Sr^{2+}, Fe^{2+}, Co^{2+}, Ni^{2+} and Zn^{2+} (preferably Sr^{2+}) and optionally modified with at least one monovalent cation selected from Li^{+}, Na^{+}, K^{+}, Rb^{+} and Cs^{+} (preferably Li^{+}).

2. The adsorbent according to claim 1,

characterized in that, the adsorbent has at least one of the following features:

a water mass fraction of 1-10%, preferably 2-8%, more preferably 2.5-6.0%;

a BET specific surface area of not less than 560 m^2/g, preferably not less than 590 m^2/g;

an exchange degree of bivalent cation of not less than 75%, preferably not less than 85%, more preferably not less than 93%; and

a crushing rate at 130 N of 0.3%-1.0% (preferably 0.3%-0.6%), a bulk density of 0.40-0.95 g/cm^3 (preferably 0.75-0.78 g/cm^3).

3. The adsorbent according to claim 1,

characterized in that, the X-type molecular sieve has a crystal particle size of 0.5-2.0 micron, and/or, the X-type molecular sieve has a molar ratio of silica to alumina of 2.0-2.6, preferably 2.0-2.4.

4. The adsorbent according to claim 1,

characterized in that, the clay mineral is at least one of kaolin mineral, bentonite mineral, attapulgite mineral, sepiolite mineral, and illite mineral, and

the kaolin mineral is at least one of kaolinite, dickite, nacrite, firestone and halloysite,

the bentonite mineral is at least one of activated clay, natural bleaching earth, and organobentonite.

5. A method for preparing the adsorbent for trimethylbenzene-based compounds according to claim 1,

characterized in that said method comprises the following steps:

(1) shaping into particles: mixing an X molecular sieve and a clay mineral at a mass ratio of 91-98:2-9, shaping into particles, optionally drying, and then calcining at 500°C-680°C;

(2) in-situ crystallization: treating calcined particles with an alkali solution and then drying to produce particles as matrix, the concentration of hydroxide ions in the alkali solution is

0.2 mol/L - 2.0 mol/L (preferably 0.2 mol/L - 1.6 mol/L),

(3) ion exchange: subjecting the particles as matrix obtained in step (2) to the cation exchange with an exchange solution of a compound containing at least one bivalent cation selected from Mg^{2+}, Ca^{2+}, Sr^{2+}, Fe^{2+}, Co^{2+}, Ni^{2+} and Zn^{2+} (preferably Sr^{2+}), and optionally a compound containing at least one monovalent cation selected from Li^{+}, Na^{+}, K^{+}, Rb^{+} and Cs^{+} (preferably Li^{+}), and then drying the ion-exchanged solid, and

(4) optional activation step: activating the dried product of step (3), preferably at an activation temperature of 150°C-260°C, more preferably 180°C-250°C, and

the alkali solution is a solution of at least one of lithium hydroxide, potassium hydroxide, sodium hydroxide, and ammonium hydroxide, preferably a mixed solution of sodium hydroxide and potassium hydroxide, more preferably the molar ratio of K/(Na+K) in the alkali solution is 0-0.50 (preferably 0.15-0.40).

6. The preparation method according to claim 5,

characterized in that, the method has at least one of following condition:

the liquid/solid ratio of the alkali solution to the calcined particles is 1.5 L/kg - 5.0 L/kg,

in the step of in-situ crystallization, the crystallization temperature is 80°C-100°C,

in the step of in-situ crystallization, the particles as matrix obtained after drying have a particle size of 400 micron to 950 micron,

in the step of ion exchange, the compound containing at least one bivalent cation selected from Mg^{2+}, Ca^{2+}, Sr^{2+}, Fe^{2+}, Co^{2+}, Ni^{2+} and Zn^{2+} (preferably Sr^{2+}) is selected from at least one of nitrates and chlorides thereof, the compound containing at least one monovalent cation selected from Li^{+}, Na^{+}, K^{+}, Rb^{+} and Cs^{+} (preferably Li^{+}) is selected from at least one of nitrates, chlorides and carbonates thereof,

in the step of ion exchange, in the exchange solution, the concentration of the bivalent cation is not less than 0.15 mol/L, the volume ratio of the exchange solution to the particles is not less than 3, and the molar ratio of the bivalent cation to the monovalent cation in the exchange solution is not less than 3, preferably not less than 4.

7. A method for separating trimethylbenzene-based compounds, which comprises the following steps:

adsorption separation: contacting a heavy aromatic hydrocarbon raw material containing trimethylbenzene-based compounds with the adsorbent according to claim 1 or the adsorbent prepared with the preparation method according to claim 5 to adsorb trimethylbenzene-based compounds, and then performing the separation to produce

trimethylbenzene-based compounds,

optional raffinate separation step: a raffinate from the simulated moving bed apparatus is subjected to distillation to produce a desorbent and a heavy aromatic hydrocarbon component in which trimethylbenzene-based compounds have been separated by adsorption.

8. The separation method according to claim 7, relative to the unit mass of adsorbent, the flow rate of the heavy aromatic hydrocarbon raw material is not less than 0.16 kg/(h·kg adsorbent), preferably not less than 0.20 kg/(h·kg adsorbent), more preferably not less than 0.23kg /(h·kg adsorbent).

9. The separation method according to claim 7,

characterized in that, in the step of adsorption separation, a simulated moving bed apparatus is used, preferably, the simulated moving bed apparatus comprises multiple adsorption beds with loaded adsorbent, each bed has its material injection and withdrawing pipelines, materials that are withdrawn from and injected into the simulated moving bed apparatus divide adsorption beds therein into desorption zone, purification zone, adsorption zone and isolation zone, the adsorption beds between desorbent injection and extract withdrawing constitute the desorption zone, the adsorption beds between extract withdrawing and raw material injection constitute the purification zone, the adsorption beds between raw material injection and raffinate withdrawing constitute the adsorption zone, the adsorption beds between raffinate withdrawing and desorbent injection constitute the isolation zone.

10. The separation method according to claim 9,

characterized in that, the method further comprises at least one of following features:

during one step time, the withdrawing and injection order of each material in the material flowing direction of the simulated moving bed is desorbent, extract, raw material and raffinate,

the pressure of the simulated moving bed apparatus constitute is 0.5 MPa-1.2 MPa (preferably 0.6 MPa-1.0 MPa), the temperature is 120°C- 200°C (preferably 140°C-180°C), the ratio of mass flow rates of the desorbent and the heavy aromatic hydrocarbon raw material injected into the simulated moving bed apparatus (desorbent/heavy aromatic hydrocarbon raw material) is not greater than 3.6, preferably not greater than 3.4, more preferably not greater than 3.2,

the simulated moving bed apparatus comprises an adsorption zone, a purification zone, a desorption zone and an isolation zone, and has a ratio of bed numbers of

29±10%:37±15%:21±5%:13±4%,

the simulated moving bed apparatus has one cycle period of 18-60 minutes, preferably 25-35 minutes.

11. The separation method according to claim 7,

characterized in that, each adsorption bed of the simulated moving bed is provided with a grid, which is equipped with material injection and withdrawing pipelines of said bed, two flushing liquor pipelines are set up in parallel with material injection and withdrawing pipelines of each adsorption bed; each pipeline is provided with an on-off valve, the extract is used as the flushing liquor, the flushing liquor from one flushing liquor pipeline is injected into a bed that is located one bed upstream the raw material injection bed, and the flushing liquor from the other flushing liquor pipeline is injected into a bed that is located 2-4 beds downstream the extract withdrawing position,

the grid of each adsorption bed is equipped with one withdrawing and injection pipeline, and multiple parallel on-off valves are set up on the pipeline to control materials to be withdrawn from and injected into the adsorbent beds,

the withdrawing and injection pipelines of each adsorbent bed are provided with 6-7 on-off valves,

each adsorption bed is provided with a pipeline for which the flushing liquor is used as the desorbent, the injection position of which is one bed upstream the extract withdrawing position.

12. The separation method according to claim 7,

characterized in that, said method further comprises the following steps,

distillation step: trimethylbenzene-based compounds obtained from the adsorption separation are subjected to distillation to produce 1,3,5-trimethylbenzene, 1,2,4-trimethylbenzene, and 1,2,3-trimethylbenzene respectively, and 1,3,5-trimethylbenzene, 1,2,4-trimethylbenzene, and 1,2,3-trimethylbenzene obtained from the distillation step have purities of not less than 97.0 wt%, 98.0 wt% and 95.0 wt%, preferably not less than 98.5 wt%, 99.3 wt% and 97.0 wt% respectively, and

in the distillation step, an extract stream from the adsorption separation step is sent to a dividing wall column, 1,3,5-trimethylbenzene is produced from the top of the dividing wall column, 1,2,4-trimethylbenzene is produced from the side-line of the dividing wall column, 1,2,3-trimethylbenzene is produced from the bottom of the dividing wall column, or

in the distillation step, an extract stream from the adsorption separation step is sent to the

first distillation column, 1,3,5-trimethylbenzene is produced by separation from the column top of the first distillation column, the bottom product of the first distillation column is sent to a second distillation column, 1,2,4-trimethylbenzene is produced by separation from the column top of the second distillation column, 1,2,3-trimethylbenzene is produced from the column bottom of the second distillation column, or

in the distillation step, an extract stream from the adsorption separation step is sent to the first distillation column, 1,3,5-trimethylbenzene is produced by separation from the column top of the first distillation column, the bottom product of the first distillation column is sent to a second distillation column, 1,2,4-trimethylbenzene is produced by separation from the column top of the second distillation column, the bottom product of the second distillation column is sent to a third distillation column, 1,2,3-trimethylbenzene is produced by separation from the column top of the third distillation column, the bottom product is an aromatic solvent oil with high boiling point , or

in the distillation step, an extract stream from the adsorption separation step is sent to the first distillation column, 1,3,5-trimethylbenzene is produced by separation from the column top of the first distillation column, the column bottom stream is a mixture of 1,2,4-trimethylbenzene and 1,2,3-trimethylbenzene, 1,2,4-trimethylbenzene and 1,2,3-trimethylbenzene are further separated by using a crystallization process, or

in the distillation step, 1,2,3-trimethylbenzene can be separated from an extract stream from the adsorption separation step by using a crystallization process, a mixture stream of the residual 1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene is sent to the first distillation column, 1,3,5-trimethylbenzene is produced by separation from the column top of the first distillation column, the column bottom stream is 1,2,4-trimethylbenzene.

13. The separation method according to claim 7,

characterized in that, trimethylbenzene-based compounds obtained from the adsorption separation step have a total purity of not less than 99 wt%.

14. The separation method according to claim 7,

characterized in that, said method further comprises an isomerization step, the isomerization step is between the adsorption separation and the distillation step, and trimethylbenzene-based compounds are subjected to the isomerization, or the isomerization step is after the distillation step, at least one of 1,3,5-trimethylbenzene, 1,2,4-trimethylbenzene, and 1,2,3-trimethylbenzene is subjected to the isomerization, and,

after one trimethylbenzene or a mixture of trimethylbenzenes is isomerized, the obtained

mixture stream of trimethylbenzenes with a thermodynamic equilibrium concentration is returned to the adsorption separation step for separation.

15. An apparatus for separating trimethylbenzene-based compounds, which comprises the following units:

adsorption separation unit: having the adsorbent according to claim 1 or the adsorbent prepared with the preparation method according to claim 5, and used to adsorb and separate trimethylbenzene-based compounds from a heavy aromatic hydrocarbon raw material containing trimethylbenzene-based compounds to produce trimethylbenzene-based compounds,

optional distillation unit, which is connected to the downstream of the adsorption separation unit, receives a stream containing trimethylbenzene-based compounds from the adsorption separation unit, and performs the distillation to produce 1,3,5-trimethylbenzene, 1,2,4-trimethylbenzene, and 1,2,3-trimethylbenzene respectively,

optional raffinate distillation unit, which is connected to the downstream of the adsorption separation unit, receives a stream containing the heavy aromatic hydrocarbon component in which trimethylbenzene-based compounds have been separated by adsorption from the adsorption separation unit, and in which the distillation is performed, to produce a heavy aromatic hydrocarbon component in which trimethylbenzene-based compounds have been separated by adsorption and a desorbent respectively,

optional isomerization unit, which is located between the adsorption separation unit and the distillation unit, and used to receive a stream containing trimethylbenzene-based compounds from the adsorption separation unit, and in which the isomerization is performed; or which is connected to the downstream of the distillation unit, used to receive at least one of 1,3,5-trimethylbenzene, 1,2,4-trimethylbenzene, and 1,2,3-trimethylbenzene from the distillation unit, and in which the isomerization is performed.

16. The separation apparatus according to claim 15,

characterized in that, the adsorption separation unit adopts a simulated moving bed, preferably, the simulated moving bed comprises multiple adsorption beds with loaded adsorbent, each bed has its material injection and withdrawing pipelines, materials that are withdrawn from and injected into the simulated moving bed apparatus divide adsorption beds therein into desorption zone, purification zone, adsorption zone and isolation zone, the adsorption beds between desorbent injection and extract withdrawing constitute the desorption zone, the adsorption beds between extract withdrawing and raw material

injection constitute the purification zone, the adsorption beds between raw material injection and raffinate withdrawing constitute the adsorption zone, the adsorption beds between raffinate withdrawing and desorbent injection constitute the isolation zone.