

AROMATIC TRANSFORMATION USING UZM-44 ALUMINOSILICATE ZEOLITE

STATEMENT OF PRIORITY

[0001] This application claims priority to U.S. Application 61/736,319, filed December 12, 2012, the contents of which are hereby incorporated by reference in its entirety.

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FIELD OF THE INVENTION

[0002] This invention relates to a new family of aluminosilicate zeolites designated UZM-44 as the catalytic composite for aromatic transformation reactions. They are represented by the empirical formula of:

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where M represents a metal or metals from zinc or Group 1 (IUPAC 1), Group 2 (IUPAC 2), Group 3 (IUPAC 3) or the lanthanide series of the periodic table, T is the organic directing agent or agents derived from reactants R and Q where R is an A, Ω -dihalosubstituted alkane such as 1,5-dibromopentane and Q is at least one neutral amine having 6 or fewer carbon atoms such as 1-methylpyrrolidine. E is a framework element such as gallium.

BACKGROUND OF THE INVENTION

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[0003] Zeolites are crystalline aluminosilicate compositions which are microporous and which are formed from corner sharing AlO_2 and SiO_2 tetrahedra. Numerous zeolites, both naturally occurring and synthetically prepared, are used in various industrial processes. Synthetic zeolites are prepared via hydrothermal synthesis employing suitable sources of Si, Al and structure directing agents such as alkali metals, alkaline earth metals, amines, or organoammonium cations. The structure directing agents reside in the pores of the zeolite and are largely responsible for the particular structure that is ultimately formed. These species balance the framework charge associated with aluminum and can also serve as space fillers. Zeolites are characterized by having pore openings of uniform dimensions, having a significant ion exchange capacity, and being capable of reversibly desorbing an adsorbed phase which is dispersed throughout the internal voids of the crystal without significantly

displacing any atoms which make up the permanent zeolite crystal structure. Zeolites can be used as catalysts for hydrocarbon conversion reactions, which can take place on outside surfaces as well as on internal surfaces within the pore.

[0004] A particular zeolite, IM-5, was first disclosed by Benazzi, et al. in 1996 (FR96/12873; WO98/17581) who describe the synthesis of IM-5 from the flexible dicationic structure directing agent, 1,5-bis(N-methylpyrrolidinium)pentane dibromide or 1,6-bis(N-methylpyrrolidinium)hexane dibromide in the presence of sodium. After the structure of IM-5 was solved by Baerlocher et al. (Science, 2007, 315, 113-6), the International Zeolite Structure Commission gave the code of IMF to this zeolite structure type, see Atlas of Zeolite Framework Types. The IMF structure type was found to contain three mutually orthogonal sets of channels in which each channel is defined by a 10-membered ring of tetrahedrally coordinated atoms, however, connectivity in the third dimension is interrupted every 2.5nm, therefore diffusion is somewhat limited. In addition, multiple different sizes of 10-membered ring channels exist in the structure.

[0005] Applicants have successfully prepared a new family of materials designated UZM-44. The topology of the materials is similar to that observed for IM-5. The materials are prepared via the use of a mixture of simple commercially available structure directing agents, such as 1,5-dibromopentane and 1-methylpyrrolidine. UZM-44 may be used as a catalyst in aromatic transformation reactions.

SUMMARY OF THE INVENTION

[0006] As stated, the present invention relates to using a new catalytic composite comprising a new aluminosilicate zeolite designated UZM-44 in a process for aromatic transformation. Accordingly, one embodiment of the invention is a material having a three-dimensional framework of at least AlO_2 and SiO_2 tetrahedral units and an empirical composition in the as synthesized and anhydrous basis expressed by an empirical formula of:



where “n” is the mole ratio of Na to (Al + E) and has a value from 0.05 to 0.5, M represents at least one metal selected from the group consisting of zinc, Group 1 (IUPAC 1), Group 2 (IUPAC 2), Group 3 (IUPAC 3), and the lanthanide series of the periodic table, and any combination thereof, “m” is the mole ratio of M to (Al + E) and has a value from 0 to 0.5, “k” is

the average charge of the metal or metals M, T is the organic structure directing agent or agents derived from reactants R and Q where R is an A, Ω -dihalogen substituted alkane having 5 carbon atoms and Q is at least one neutral monoamine having 6 or fewer carbon atoms, “t” is the mole ratio of N from the organic structure directing agent or agents to (Al + E) and has a value of
 5 from 0.5 to 1.5, E is an element selected from the group consisting of gallium, iron, boron and combinations thereof, “x” is the mole fraction of E and has a value from 0 to 1.0, “y” is the mole ratio of Si to (Al + E) and varies from greater than 9 to 25 and “z” is the mole ratio of O to (Al + E) and has a value determined by the equation:

$$z = (n + k \bullet m + 3 + 4 \bullet y)/2$$

10 **[0007]** Another embodiment of the catalytic composite of the invention is a microporous crystalline zeolite having a three-dimensional framework of at least AlO₂ and SiO₂ tetrahedral units and an empirical composition in the as synthesized and anhydrous basis expressed by an empirical formula of:

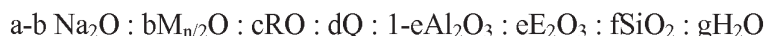


15 where “n” is the mole ratio of Na to (Al + E) and has a value from 0.05 to 0.5, M represents a metal or metals from Group 1 (IUPAC 1), Group 2 (IUPAC 2), Group 3 (IUPAC 3), the lanthanide series of the periodic table or zinc, “m” is the mole ratio of M to (Al + E) and has a value from 0 to 0.5, “k” is the average charge of the metal or metals M, T is the organic structure directing agent or agents derived from reactants R and Q where R is an A, Ω -dihalogen
 20 substituted alkane having 5 carbon atoms and Q is at least one neutral monoamine having 6 or fewer carbon atoms, “t” is the mole ratio of N from the organic structure directing agent or agents to (Al + E) and has a value of from 0.5 to 1.5, E is an element selected from the group consisting of gallium, iron, boron and combinations thereof, “x” is the mole fraction of E and has a value from 0 to 1.0, “y” is the mole ratio of Si to (Al + E) and varies from greater than 9 to
 25 25 and “z” is the mole ratio of O to (Al + E) and has a value determined by the equation:

$$z = (n + k \bullet m + 3 + 4 \bullet y)/2$$

and the zeolite is characterized in that it has the x-ray diffraction pattern having at least the d-spacings and intensities set forth in Table A. The zeolite is thermally stable up to a temperature of greater than 600°C in one embodiment and at least 800°C in another embodiment.

[0008] Another embodiment of the invention is a process for preparing the crystalline microporous zeolite described above. The process comprises forming a reaction mixture containing reactive sources of Na, R, Q, Al, Si and optionally E and/or M and heating the reaction mixture at a temperature of 160°C to 180°C, or 165°C to 175°C, for a time sufficient to form the zeolite. The reaction mixture has a composition expressed in terms of mole ratios of the oxides of:



where “a” has a value of 10 to 30, “b” has a value of 0 to 30, “c” has a value of 1 to 10, “d” has a value of 2 to 30, “e” has a value of 0 to 1.0, “f” has a value of 30 to 100, “g” has a value of 100 to 4000. With this number of reactive reagent sources, many orders of addition can be envisioned. Typically, the aluminum reagent is dissolved in the sodium hydroxide prior to adding the silica reagents. Reagents R and Q can be added together or separately in many different orders of addition.

[0009] Yet another embodiment of the invention is a hydrocarbon conversion process using the above-described zeolite. The process comprises contacting the hydrocarbon with the zeolite at conversion conditions to give a converted hydrocarbon. Specifically, the zeolite is useful as the catalytic composite in aromatic transformation reactions. At least a first aromatic is contacted with the zeolite to produce at least a second aromatic. One specific embodiment of the process is a process for producing methylaromatics by contacting at least one C2-C6 alkane and benzene with the UZM-44 zeolite to generate at least one methylated aromatic. Examples of commercially important methylated aromatics include toluene and xylenes. The reactions may involve cracking, aromatic alkylation, and transalkylation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG.1 is an XRD pattern of the UZM-44 zeolite formed in Example 1. This pattern shows the UZM-44 zeolite in the as-synthesized form.

[0011] FIG.2 is also an XRD pattern of the UZM-44 zeolite formed in Example 1. This pattern shows the UZM-44 zeolite in the H^+ form.

[0012] FIG.3 is a plot derived from the N_2 BET experiment where $dV/d\log(D)$ is plotted against the pore diameter. This plot shows the incremental amount of nitrogen adsorbed at each pore diameter measured.

DETAILED DESCRIPTION OF THE INVENTION

[0013] Applicants have prepared a catalytic component suitable for catalyzing aromatic transformation reactions where the catalytic component is an aluminosilicate zeolite whose topological structure is related to IMF as described in Atlas of Zeolite Framework Types, which is maintained by the International Zeolite Association Structure Commission at <http://www.iza-structure.org/databases/>, the member of which has been designated IM-5. As will be shown in detail, UZM-44 is different from IM-5 in a number of its characteristics including its micropore volume. The instant microporous crystalline zeolite, UZM-44, has an empirical composition in the as synthesized and anhydrous basis expressed by an empirical formula of:



where “n” is the mole ratio of Na to (Al + E) and has a value from 0.05 to 0.5, M represents a metal or metals selected from the group consisting of zinc, Group 1 (IUPAC 1), Group 2 (IUPAC 2), Group 3 (IUPAC 3), the lanthanide series of the periodic table, and any combination thereof, “m” is the mole ratio of M to (Al + E) and has a value from 0 to 0.5, “k” is the average charge of the metal or metals M, T is the organic structure directing agent or agents derived from reactants R and Q where R is an A, Ω -dihalogen substituted alkane having 5 carbon atoms and Q is at least one neutral monoamine having 6 or fewer carbon atoms, “t” is the mole ratio of N from the organic structure directing agent or agents to (Al + E) and has a value of from 0.5 to 1.5, E is an element selected from the group consisting of gallium, iron, boron and combinations thereof, “x” is the mole fraction of E and has a value from 0 to 1.0, “y” is the mole ratio of Si to (Al + E) and varies from greater than 9 to 25 and “z” is the mole ratio of O to (Al + E) and has a value determined by the equation:

$$z = (n + k \bullet m + 3 + 4 \bullet y)/2$$

Where M is only one metal, then the weighted average valence is the valence of that one metal, i.e. +1 or +2. However, when more than one M metal is present, the total amount of:

$$\text{M}_m^{k+} = \text{M}_{m1}^{(k1)+} + \text{M}_{m2}^{(k2)+} + \text{M}_{m3}^{(k3)+} + \text{M}_{m4}^{(k4)+} + \dots$$

and the weighted average valence “k” is given by the equation:

$$k = \frac{m1 \cdot k1 + m2 \cdot k2 + m3 \cdot k3 \dots}{m1 + m2 + m3 \dots}$$

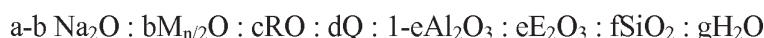
5 **[0014]** In one embodiment, the microporous crystalline zeolite, UZM-44, is synthesized by a hydrothermal crystallization of a reaction mixture prepared by combining reactive sources of sodium, organic structure directing agent or agents T, aluminum, silicon, and optionally E, M, or both. The reaction mixture does not comprise seeds of a layered material L. The sources of aluminum include but are not limited to aluminum alkoxides, precipitated
10 aluminas, aluminum metal, aluminum hydroxide, sodium aluminate, aluminum salts and alumina sols. Specific examples of aluminum alkoxides include, but are not limited to aluminum sec-butoxide and aluminum ortho isopropoxide. Sources of silica include but are not limited to tetraethylorthosilicate, colloidal silica, precipitated silica and alkali silicates. Sources of sodium include but are not limited to sodium hydroxide, sodium bromide, sodium
15 aluminate, and sodium silicate.

[0015] T is the organic structure directing agent or agents derived from reactants R and Q where R is an A, Ω -dihalogen substituted alkane having 5 carbon atoms and Q comprises at least one neutral monoamine having 6 or fewer carbon atoms. R may be an A, Ω -dihalogen substituted alkane having 5 carbon atoms selected from the group consisting of 1,5-
20 dichloropentane, 1,5-dibromopentane, 1,5-diiodopentane, and combinations thereof. Q comprises at least one neutral monoamine having 6 or fewer carbon atoms such as 1-ethylpyrrolidine, 1-methylpyrrolidine, 1-ethylazetidine, 1-methylazetidine, triethylamine, diethylmethylaniline, dimethylethylaniline, trimethylamine, dimethylbutylaniline, dimethylpropylaniline, dimethylisopropylaniline, methylethylpropylaniline,
25 methylethylisopropylaniline, dipropylaniline, diisopropylaniline, cyclopentylaniline, methylcyclopentylaniline, hexamethyleneimine. Q may comprise combinations of multiple neutral monoamines having 6 or fewer carbon atoms.

[0016] M represents at least one exchangeable cation of a metal or metals from Group 1 (IUPAC 1), Group 2 (IUPAC 2), Group 3 (IUPAC 3) or the lanthanide series of the periodic
30 table and or zinc. Specific examples of M include but are not limited to lithium, potassium, rubidium, cesium, magnesium, calcium, strontium, barium, zinc, yttrium, lanthanum, gadolinium, and mixtures thereof. Reactive sources of M include, but are not limited to, the group consisting of halide, nitrate, sulfate, hydroxide, or acetate salts. E is an element

selected from the group consisting of gallium, iron, boron and combinations thereof, and suitable reactive sources include, but are not limited to, boric acid, gallium oxyhydroxide, gallium nitrate, gallium sulfate, ferric nitrate, ferric sulfate, ferric chloride and mixtures thereof.

- 5 **[0017]** The reaction mixture containing reactive sources of the desired components can be described in terms of molar ratios of the oxides by the formula:



where “a” has a value of 10 to 30, “b” has a value of 0 to 30, “c” has a value of 1 to 10, “d” has a value of 2 to 30, “e” has a value of 0 to 1.0, “f” has a value of 30 to 100, “g” has a value of 100 to 4000.

- 10 **[0018]** The examples demonstrate specific orders of addition for the reaction mixture which leads to UZM-44. However, as there are at least 6 starting materials, many orders of addition are possible. Also, if alkoxides are used, it is preferred to include a distillation or evaporative step to remove the alcohol hydrolysis products. While the organic structure directing agents R and Q
15 can be added separately or together to the reaction mixture at a number of points in the process, it is preferred to mix R and Q together at room temperature and add the combined mixture to a cooled mixture of reactive Si, Al and Na sources maintained at 0-10°C. Alternatively, the mixture of R and Q, after mixing at room temperature, could be cooled and the reactive sources of Si, Al, and Na added to the organic structure directing agent mixture while maintaining a
20 temperature of 0-10°C. In an alternative embodiment, the reagents R and Q could be added, separately or together, to the reaction mixture at room temperature

- [0019]** The reaction mixture is then reacted at a temperature of 160°C to 180°C, or 165°C to 175°C, for a period of 1 day to 3 weeks and preferably for a time of 3 days to 14 days in a stirred, sealed reaction vessel under autogenous pressure. Static crystallization does not yield
25 UZM-44. After crystallization is complete, the solid product is isolated from the heterogeneous mixture by means such as filtration or centrifugation, and then washed with deionized water and dried in air at ambient temperature up to 100°C.

- [0020]** The as-synthesized UZM-44 is characterized by the x-ray diffraction pattern, having at least the d-spacings and relative intensities set forth in Table A below. Diffraction
30 patterns herein were obtained using a typical laboratory powder diffractometer, utilizing the K_α line of copper; Cu K alpha. From the position of the diffraction peaks represented by the

angle 2theta, the characteristic interplanar distances d_{hkl} of the sample can be calculated using the Bragg equation. The intensity is calculated on the basis of a relative intensity scale attributing a value of 100 to the line representing the strongest peak on the X-ray diffraction pattern, and then: very weak (vw) means less than 5; weak (w) means less than 15; medium (m) means in the range 15 to 50; strong (s) means in the range 50 to 80; very strong (vs) means more than 80. Intensities may also be shown as inclusive ranges of the above. The X-ray diffraction patterns from which the data (d spacing and intensity) are obtained are characterized by a large number of reflections some of which are broad peaks or peaks which form shoulders on peaks of higher intensity. Some or all of the shoulders may not be resolved. This may be the case for samples of low crystallinity, of particular coherently grown composite structures or for samples with crystals which are small enough to cause significant broadening of the X-rays. This can also be the case when the equipment or operating conditions used to produce the diffraction pattern differ significantly from those used in the present case.

[0021] The X-ray diffraction pattern for UZM-44 contains many peaks; an example of the x-ray diffraction patterns for an as-synthesized UZM-44 product is shown in FIG 1. Those peaks characteristic of UZM-44 are shown in Table A. Additional peaks, particularly those of very weak intensity, may also be present. All peaks of medium or higher intensity present in UZM-44 are represented in Table A.

[0022] The zeolite may be further characterized by the x-ray diffraction pattern having at least the d-spacings and intensities set forth in Table A.

TABLE A

2-Theta	d(Å)	I/I _o %
7.72	11.45	m
8.88	9.95	m
9.33	9.47	m
12.47	7.09	w-m
12.85	6.88	vw
14.62	6.05	vw-w
15.27	5.80	w
15.57	5.68	w
16.60	5.34	w
17.70	5.01	vw-w
18.71	4.74	w-m

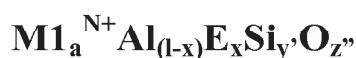
19.30	4.59	w
22.55	3.94	m
23.03	3.86	vs
23.39	3.80	s
24.17	3.68	m
25.01	3.56	m
26.19	3.40	vw-w
26.68	3.34	w-m
28.76	3.10	w-m
30.07	2.97	w
35.72	2.51	vw-w
45.08	2.01	w
45.83	1.98	vw-w
46.77	1.94	vw-w

[0023] As will be shown in detail in the examples, the UZM-44 material is thermally stable up to a temperature of at least 600°C and in another embodiment, up to at least 800°C. Also as shown in the examples, the UZM-44 material may have a micropore volume as a percentage of total pore volume of less than 60%.

5 **[0024]** Characterization of the UZM-44 product by high-resolution scanning electron microscopy shows that the UZM-44 forms in lathes which assemble into rectangular rod colonies.

[0025] As synthesized, the UZM-44 material will contain some exchangeable or charge balancing cations in its pores. These exchangeable cations can be exchanged for other
10 cations, or in the case of organic cations, they can be removed by heating under controlled conditions. It is also possible to remove some organic cations from the UZM-44 zeolite directly by ion exchange. The UZM-44 zeolite may be modified in many ways to tailor it for use in a particular application. Modifications include calcination, ion-exchange, steaming, various acid extractions, ammonium hexafluorosilicate treatment, or any combination thereof,
15 as outlined for the case of UZM-4M in US 6,776,975 B1 which is incorporated by reference in its entirety. Conditions may be more severe than shown in US 6,776,975. Properties that are modified include porosity, adsorption, Si/Al ratio, acidity, thermal stability, and the like.

[0026] After calcination, ion-exchange and calcination and on an anhydrous basis, the microporous crystalline zeolite UZM-44 has a three-dimensional framework of at least AlO_2
20 and SiO_2 tetrahedral units and an empirical composition in the hydrogen form expressed by an empirical formula of



where M1 is at least one exchangeable cation selected from the group consisting of alkali, alkaline earth metals, rare earth metals, ammonium ion, hydrogen ion and combinations thereof, “a” is the mole ratio of M1 to (Al + E) and varies from 0.05 to 50, “N” is the weighted average valence of M1 and has a value of +1 to +3, E is an element selected from the group consisting of gallium, iron, boron, and combinations thereof, x is the mole fraction of E and varies from 0 to 1.0, y’ is the mole ratio of Si to (Al + E) and varies from greater than 9 to virtually pure silica and z’’ is the mole ratio of O to (Al + E) and has a value determined by the equation:

$$z'' = (a \cdot N + 3 + 4 \cdot y')/2$$

10 [0027] In the hydrogen form, after calcination, ion-exchange and calcination to remove NH₃, UZM-44 displays the x-ray diffraction pattern having at least the d-spacings and intensities set forth in Table B. Those peaks characteristic of UZM-44 are shown in Tables B. Additional peaks, particularly those of very weak intensity, may also be present. All peaks of medium or higher intensity present in UZM-44 are indicated in Table B.

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TABLE B

2-Theta	d(Å)	I/I ₀ %
7.71	11.47	m-s
8.84	10.00	m-s
9.24	9.56	m
11.76	7.52	vw-w
12.46	7.10	m
14.38	6.15	vw
14.64	6.05	w
15.26	5.80	w
15.52	5.70	w-m
16.58	5.34	w
17.72	5.00	w-m
18.64	4.76	w
22.56	3.94	w-m
23.06	3.85	vs
23.40	3.80	s
24.12	3.69	m
25.06	3.55	m
26.16	3.40	vw-w
26.74	3.33	w-m

28.82	3.10	w-m
30.12	2.96	w
35.86	2.50	vw-w
45.32	2.00	w
46.05	1.97	vw-w
46.92	1.93	vw-w

[0028] Similar to the as-synthesized material, the modified UZM-44 materials are thermally stable up to a temperature of at least 600°C and in another embodiment, up to at least 800°C and may have a micropore volume as a percentage of total pore volume of less than 60%.

[0029] Surface area, micropore volume and total pore volume may be determined, for example, by N₂ adsorption using the conventional BET method of analysis (J. Am. Chem. Soc., 1938, 60, 309-16) coupled with t-plot analysis of the adsorption isotherm as implemented in Micromeritics ASAP 2010 software. The t-plot is a mathematical representation of multi-layer adsorption and allows determination of the amount of N₂ adsorbed in the micropores of the zeolitic material under analysis. In particular, for the materials described herein, points at 0.45, 0.50, 0.55, 0.60, and 0.65 P/P₀ are used to determine the slope of the t-plot line, the intercept of which is the micropore volume. Total pore volume is determined at 0.98 P/P₀. The UZM-44 of the instant invention has a micropore volume of less than 0.155 mL/g, typically less than 0.150 mL/g, and often less than 0.145 mL/g. Additionally, by looking at the dV/dlog D versus pore diameter plot (the differential volume of nitrogen adsorbed as a function of pore diameter), as shown in Figure 3, the UZM-44 of the instant invention contains no feature at around 200-300Å. As can be seen in Figure. 3, the material of Example 2, not in accordance with the invention, does contain a feature at around 200-300Å. Instead, UZM-44 has an adsorption feature occurring at greater than 450Å. In an embodiment, greater than 0.1mL N₂/gÅ is differentially adsorbed at a pore diameter of 475Å. Preferably, greater than 0.1 mL N₂/gÅ is differentially adsorbed at pore diameters greater than 475Å where differentially adsorbed indicates the differential volume of nitrogen adsorbed at a particular pore diameter.

[0030] In specifying the proportions of the zeolite starting material or adsorption properties of the zeolite product and the like herein, the “anhydrous state” of the zeolite will be intended unless otherwise stated. The term “anhydrous state” is employed herein to refer to a zeolite substantially devoid of both physically adsorbed and chemically adsorbed water.

[0031] The UZM-44 zeolite of this invention can also be used as a catalyst or catalyst support in various hydrocarbon conversion processes. Hydrocarbon conversion processes are well known in the art and include cracking, hydrocracking, alkylation of aromatics or isoparaffins, isomerization of paraffins, olefins, or poly-alkylbenzenes such as xylene, trans-alkylation of poly-alkylbenzene with benzene or mono-alkylbenzene, disproportionation of mono-alkylbenzene, polymerization, reforming, hydrogenation, dehydrogenation, transalkylation, dealkylation, hydration, dehydration, hydrotreating, hydrodenitrogenation, hydrodesulfurization, methanation and syngas shift process. Specific reaction conditions and the types of feeds which can be used in these processes are set forth in US 4,310,440 and US 4,440,871 which are hereby incorporated by reference. Preferred hydrocarbon conversion processes are those in which hydrogen is a component such as hydrotreating or hydrofining, hydrogenation, hydrocracking, hydrodenitrogenation, hydrodesulfurization, etc.

[0032] The zeolite as outlined above, or a modification thereof, may be in a composite with commonly known binders. The UZM-44 is used as a catalyst or catalyst support in various reactions. The UZM-44 preferably is mixed with a binder for convenient formation of catalyst particles in a proportion of 5 to 100 mass % UZM-44 zeolite and 0 to 95 mass-% binder, with the UZM-44 zeolite preferably comprising from 5 to 100 mass-% of the composite. The binder should preferably be porous, have a surface area of 5 to 800 m² /g, and be relatively refractory to the conditions utilized in the hydrocarbon conversion process. Non-limiting examples of binders are alumina, titania, zirconia, zinc oxide, magnesia, boria, silica-alumina, silica-magnesia, chromia-alumina, alumina-boria, aluminophosphates, silica-zirconia, silica, silica gel, and clays. Preferred binders are amorphous silica and alumina, including gamma-, eta-, and theta-alumina, with gamma- and eta-alumina being especially preferred.

[0033] The UZM-44 zeolite with or without a binder can be formed into various shapes such as pills, pellets, extrudates, spheres, etc. Preferred shapes are extrudates and spheres. Extrudates are prepared by conventional means which involves mixing of the composition either before or after adding metallic components, with the binder and a suitable peptizing agent to form a homogeneous dough or thick paste having the correct moisture content to allow for the formation of extrudates with acceptable integrity to withstand direct calcination. The dough then is extruded through a die to give the shaped extrudate. A multitude of different extrudate shapes are possible, including, but not limited to, cylinders, cloverleaf,

dumbbell and symmetrical and asymmetrical polylobates. It is also within the scope of this invention that the extrudates may be further shaped to any desired form, such as spheres, by any means known to the art.

[0034] Spheres can be prepared by the well known oil-drop method which is described in U.S. Pat. No 2,620,314 which is incorporated by reference. The method involves dropping a mixture of zeolite, and for example, alumina sol, and gelling agent into an oil bath maintained at elevated temperatures. The droplets of the mixture remain in the oil bath until they set and form hydrogel spheres. The spheres are then continuously withdrawn from the oil bath and typically subjected to specific aging treatments in oil and an ammoniacal solution to further improve their physical characteristics. The resulting aged and gelled particles are then washed and dried at a relatively low temperature of 50 to 200°C and subjected to a calcination procedure at a temperature of 450 to 700°C for a period of 1 to 20 hours. This treatment effects conversion of the hydrogel to the corresponding alumina matrix.

[0035] Hydrocracking conditions typically include a temperature in the range of 204°C to 649°C (400° to 1200°F) or 316°C to 510°C (600° F and 950°F). Reaction pressures are in the range of atmospheric to 24,132 kPa g (3,500 psig), or between 1379 to 20,685 kPa g (200 to 3000 psig). Contact times usually correspond to liquid hourly space velocities (LHSV) in the range of 0.1 hr⁻¹ to 15 hr⁻¹, preferably between 0.2 and 3 hr⁻¹. Hydrogen circulation rates are in the range of 178 to 8,888 std. m³/m³ (1,000 to 50,000 standard cubic feet (scf) per barrel of charge), or 355 to 5,333 std. m³/m³ (2,000 to 30,000 scf per barrel of charge). Suitable hydrotreating conditions are generally within the broad ranges of hydrocracking conditions set out above.

[0036] The reaction zone effluent is normally removed from the catalyst bed, subjected to partial condensation and vapor-liquid separation and then fractionated to recover the various components thereof. The hydrogen, and if desired some or all of the unconverted heavier materials, are recycled to the reactor. Alternatively, a two-stage flow may be employed with the unconverted material being passed into a second reactor. Catalysts of the subject invention may be used in just one stage of such a process or may be used in both reactor stages.

[0037] Catalytic cracking processes are preferably carried out with the UZM-44 composition using feedstocks such as gas oils, heavy naphthas, deasphalted crude oil residua, etc. with gasoline being the principal desired product. Temperature conditions of 454°C to

593°C (850°F to 1100°F), LIHSV values of 0.5 to 10 and pressure conditions of from 0 to 344 kPa g (0 to 50 psig) are suitable.

[0038] Alkylation of isoparaffins with olefins to produce alkylates suitable as motor fuel components is carried out at temperatures of -30° to 40°C, pressures from atmospheric to 6,895 kPa (1,000 psig) and a weight hourly space velocity (WHSV) of 0.1 to 120. Details on paraffin alkylation may be found in US 5,157,196 and US 5,157,197, which are incorporated by reference.

[0039] Alkylation of aromatics usually involves reacting an aromatic (C₂ to C₁₂), especially benzene, with a monoolefin to produce an alkyl substituted aromatic. The process is carried out at an aromatic: olefin (e.g., benzene:olefin) ratio of between 1:1 and 30:1, a olefin LHSV of 0.3 to 10 hr⁻¹, a temperature of 100° to 250°C and pressures of 1379 kPa g to 6895 kPa g (200 to 1000 psig). Further details on apparatus may be found in US 4,870,222 which is incorporated by reference.

[0040] Dealkylation of aromatics usually involves passing an alkyl substituted aromatic, especially ethylbenzene or toluene, over a catalytic composite to produce an olefin and a dealkylated aromatic, especially benzene. Typically, the olefin is hydrogenated to yield a paraffin. Additional examples of dealkylation of aromatics include the dealkylation of methylethylbenzene (ethyltoluene) to toluene, ethylbenzene, and/or benzene and the dealkylation of isopropylmethylbenzene (cymene) to toluene, isopropylbenzene (cumene), and/or benzene. Typical dealkylation conditions include a temperature in the range from 100° to 600°C and pressure from 10kPa to 5 MPa. The LHSV is from 0.1 to 50 hr⁻¹. The hydrocarbon contacts the catalyst in admixture with a gaseous hydrogen-containing stream in a line at a hydrogen-to-hydrocarbon mole ratio of from 0.1:1 to 15:1 or more, and preferably a ratio of from 0.1 to 10. Further details on apparatus may be found in US 8,134,037 which is hereby incorporated by reference.

[0041] Methylaromatic formation is an alternative process to generate toluene and xylenes from benzene and a paraffin source having at least one paraffin having from 2 to 6 carbon atoms, referred to herein as a C₂ - C₆ paraffin source. In another embodiment, a paraffin source comprising at least one paraffin having from 3 to 6 carbon atoms, may be used. The reactions involved may include cracking, aromatic alkylation, and transalkylation.

[0042] The C₂-C₆ paraffin source can include at least one of, independently, one or more cycloalkanes and alkanes, and may comprise at least 5%, by weight, of the feed. Optionally,

the paraffin source may also include one or more olefins. The cycloalkane preferably has at least three, and desirably five, carbon atoms in the ring. The feed may include at least 10%, by weight, one or more cycloalkanes, or 10 - 70%, by weight, one or more cycloalkanes with respect to the weight of the feed. Moreover, the feed may include up to 50%, by weight, of one or more C2-C6 hydrocarbons with respect to the weight of the feed. Usually, the feed is substantially absent of methylating agents containing one or more hetero-atoms. As an example, the feed can have less than 1%, preferably less than 0.1%, by weight, of one or more methylating agents.

[0043] Typically, the feed can include aromatic compounds as well. The aromatic compounds can include benzene, toluene, one or more xylenes, naphthalene, ethylbenzene, and one or more polynuclear aromatics. In an embodiment, benzene is preferred. Typically, the feed can comprise 20 - 95%, by weight, of one or more aromatics, such as benzene, with respect to the weight of the feed. In some other embodiments, the benzene content of the feed can be 15 - 25%, by weight, with respect to the weight of the feed.

[0044] The reaction zone in which the C2-C6 paraffin source and aromatic compound are reacted over the UZM-44 catalytic composite can operate under any suitable conditions in the liquid or gas phase, however gas phase reaction is preferred to facilitate the cracking of C2-C6 alkanes. Particularly, the reaction zone can operate at a temperature of 250 - 700°C, preferably 350 - 600°C, a pressure of 100 - 21,000 kPa, preferably 1,379 - 6,895 kPa, and a weight hourly space velocity (WHSV) of 0.1 - 100 hr⁻¹, preferably 2 - 10 hr⁻¹. The feed can also contact the catalyst in admixture with a gaseous hydrogen-containing stream in a line at a hydrogen-to-hydrocarbon mole ratio of from 0:1 to 5:1, and preferably a ratio of from 0 to 1.

[0045] Additional processes and processing conditions where the catalytic composite UZM-44 may be employed are discussed in US 20110178356, US 20110178354, and US 20110174692, each of which are hereby incorporated by reference in their entirety.

[0046] Generally, a downstream process can utilize one or more products, such as benzene, para-xylene, meta-xylene and ortho-xylene, of the embodiments disclosed herein. Particularly, para-xylene, upon oxidation, can yield terephthalic acid used in the manufacture of textiles, fibers, and resins. Moreover, para-xylene can be used as a cleaning agent for steel and silicon wafers and chips, a pesticide, a thinner for paint, and in paints and varnishes. Meta-xylene can be used as an intermediate to manufacture plasticizers, azo dyes, wood

preservatives and other such products. Ortho-xylene can be a feedstock for phthalic anhydride production. Additionally, xylenes generally may be used as a solvent in the printer, rubber, and leather industries. Moreover, the methyl groups on xylenes can be chlorinated for use as lacquer thinners. Benzene can be used as a feed to make cyclohexane, which in turn
5 may be used to make nylons. Also, benzene can be used as an intermediate to make styrene, ethylbenzene, cumene, and cyclohexane among other products.

[0047] The following examples are presented in illustration of this invention and are not intended as undue limitations on the generally broad scope of the invention as set out in the appended claims.

10 **[0048]** The structure of the UZM-44 zeolite of this invention was determined by x-ray analysis. The x-ray patterns presented in the following examples were obtained using standard x-ray powder diffraction techniques. The radiation source was a high-intensity, x-ray tube operated at 45 kV and 35 ma. The diffraction pattern from the copper K-alpha radiation was obtained by appropriate computer based techniques. Flat compressed powder
15 samples were continuously scanned at 2° to 56° (2θ). Interplanar spacings (d) in Angstrom units were obtained from the position of the diffraction peaks expressed as θ where θ is the Bragg angle as observed from digitized data. Intensities were determined from the integrated area of diffraction peaks after subtracting background, “I₀” being the intensity of the strongest line or peak, and “I” being the intensity of each of the other peaks.

20 **[0049]** As will be understood by those skilled in the art the determination of the parameter 2θ is subject to both human and mechanical error, which in combination can impose an uncertainty of ±0.4° on each reported value of 2θ. This uncertainty is, of course, also manifested in the reported values of the d-spacings, which are calculated from the 2θ values. This imprecision is general throughout the art and is not sufficient to preclude the
25 differentiation of the present crystalline materials from each other and from the compositions of the prior art. In some of the x-ray patterns reported, the relative intensities of the d-spacings are indicated by the notations vs, s, m, w and vw which represent very strong, strong, medium, weak, and very weak respectively. In terms of 100 x I/I₀, the above designations are defined as:

30 vw=<5; w = 6-15; m = 16-50; s = 51-80; and vs = 80-100

[0050] In certain instances the purity of a synthesized product may be assessed with reference to its x-ray powder diffraction pattern. Thus, for example, if a sample is stated to be pure, it is intended only that the x-ray pattern of the sample is free of lines attributable to crystalline impurities, not that there are no amorphous materials present.

5 [0051] In order to more fully illustrate the invention, the following examples are set forth. It is to be understood that the examples are only by way of illustration and are not intended as an undue limitation on the broad scope of the invention as set forth in the appended claims.

EXAMPLE 1

[0052] 5.28 g of NaOH, (97%) was dissolved in 111.88 g water. 1.16 g Al(OH)₃, (29.32 wt.-% Al), was added to the sodium hydroxide solution. Upon the mixture becoming a solution,
10 33.75 g Ludox AS-40 was added and the solution was stirred vigorously for 1-2 hours and then cooled to 0°C-4°C. Separately, 8.89 g 1,5-dibromopentane, (97%) was mixed with 9.56 g 1-methylpyrrolidine, (97%) to form a second mixture. The second mixture was added to the cooled mixture to create the final reaction mixture. The final reaction mixture was vigorously
15 stirred and transferred to a 300 cc stirred autoclave. The final reaction mixture was digested at 170°C for 120 hours with stirring at 100 rpm. The product was isolated by filtration. The product was identified as UZM-44 by XRD. Analytical results showed this material to have the following molar ratios, Si/Al of 11.77, Na/Al of 0.21, N/Al of 1.02, C/N of 7.75. The product generated by this synthesis was calcined under flowing air at 600° for 6 hours. It was then ion
20 exchanged four times with 1 M ammonium nitrate solution at 75°C followed by a calcination at 500°C under air for 2 hours to convert NH₄⁺ into H⁺. Analysis for the calcined, ion-exchanged sample shows 39.1% Si, 3.26% Al, 90ppm Na with a BET surface area of 299 m²/g, pore volume of 0.239 cm³/g, and micropore volume of 0.139 cm³/g.

COMPARATIVE EXAMPLE 2

25 [0053] 10.8g of Aerosil 200 was added, while stirring, to a solution of 12.24g 1,5-bis(N-methylpyrrolidinium)pentane dibromide in 114g H₂O. A very thick gel was formed. Separately, a solution was made from 60g H₂O, 3.69g NaOH (99%), 0.95g sodium aluminate (26.1% Al by analysis), and 1.86g NaBr (99%). This second solution was added to the above mixture. The final mixture was divided equally between 7 45cc Parr vessels. One vessel, which was digested
30 for 12 days at 170°C in a rotisserie oven at 15 rpm, yielded a product which was determined by

XRD as having the IMF structure. The product was isolated by filtration. Analytical results showed this material to have the following molar ratios, Si/Al of 12.12, Na/Al of 0.08, N/Al of 1.03, C/N of 7.43. The product generated by this synthesis was calcined under flowing air at 600° for 6 hours. It was then ion exchanged four times with 1 M ammonium nitrate solution at 75°C followed by a calcination at 500°C under air for 2 hours to convert NH_4^+ into H^+ . Analysis for the calcined, ion-exchanged sample shows 38.8% Si, 2.99% Al, 190ppm Na with a BET surface area of 340 m^2/g , pore volume of 0.260 cm^3/g , and micropore volume of 0.160 cm^3/g .

EXAMPLE 3

[0054] 544g of NaOH, (97%) was dissolved in 9.53 kg water. 118 g $\text{Al}(\text{OH})_3$ was added to the sodium hydroxide solution while stirring. Of Ludox AS-40, 3.83 kg was added and the solution was stirred vigorously for 2 hours and then cooled to 0°C-5°C. A solution containing 941 g H_2O , 453 g 1,5-dibromopentane and 325 g N-methylpyrrolidine was added to the cooled mixture to create the final reaction mixture. The final reaction mixture was vigorously stirred and transferred to a 5 gallon stirred autoclave before digestion at 160°C for 11 days. The product was isolated by filtration. The product was identified as UZM-44 by XRD. Analytical results showed this material to have the following molar ratios, Si/Al of 11.77, Na/Al of 0.21, N/Al of 1.02, C/N of 7.75. The product generated by this synthesis was calcined under flowing air at 600° for 6 hours. Analysis for the calcined sample shows a BET surface area of 301 m^2/g , pore volume of 0.238 cm^3/g , and micropore volume of 0.142 cm^3/g .

EXAMPLE 4.

[0055] A UZM-44 in the H^+ form was loaded into a vertical steamer. The UZM-44 was exposed to 100% steam at 725°C for 12 hours or 24 hours. The starting UZM-44 had a BET surface area of 340 m^2/g , pore volume of 0.301 cm^3/g , and micropore volume of 0.154 cm^3/g . After 12 hours of steaming, the UZM-44 was still identified as UZM-44 by XRD though the intensity of the first 3 peaks had increased to very strong, very strong - strong, and very strong - strong respectively. All other peaks were at positions and intensities described in Table B. The material had a BET surface area of 274 m^2/g , pore volume of 0.257 cm^3/g , and micropore volume of 0.127 cm^3/g . After 24 hours of steaming, the UZM-44 was still identified as UZM-44 by XRD though the intensity of the first 3 peaks had increased to very strong, very strong - strong, and very strong - strong respectively. All other peaks were at

positions and intensities described in Table B. The material had a BET surface area of 276 m²/g, pore volume of 0.262 cm³/g, and micropore volume of 0.128 cm³/g.

EXAMPLE 5

[0056] UZM-44 was synthesized from a gel of composition 1 Al₂O₃: 43.6 SiO₂: 11.6 Na₂O :
5 6.52 1,5-dibromopentane : 18.95 N-methylpyrrolidine : 1321 H₂O by dissolving NaOH in water
and then liquid sodium aluminate was added to the sodium hydroxide solution. Ultrasil VN3
was then added as the silica source followed by 1,5-dibromopentane and N-methylpyrrolidine to
form the final reaction mixture. The final reaction mixture was vigorously stirred and transferred
to a 2L stirred autoclave. The final reaction mixture was digested at 50°C for 24h then at 160°C
10 for 12 days while stirring. The product was isolated by filtration. The product was identified as
UZM-44 by XRD. The product generated by this synthesis was calcined under flowing air at
600° for 6 hours. It was then ion-exchanged with 1 M ammonium nitrate solution.

EXAMPLE 6

[0057] The product generated by the synthesis described in Example 1 was bound with
15 Al₂O₃ in a 75:25 weight ratio and extruded in 1/8" cylinders to form UZM-44/Al₂O₃. The
extrudates were then calcined using a 2°C/minute ramp to 550°C, holding for 3 hours and then
cooling to room temperature. The 20 to 60 mesh fraction was isolated and then used as the
catalytic composite in a chemical reaction to form ethylbenzene and xylenes.

[0058] Benzene and propane were fed at a 2:1 mole ratio into a reactor at 400 psig along
20 with a hydrogen stream such that the hydrogen to hydrocarbon mole ratio was 1.0. At 500°C and
2.5WHSV, conversion of benzene was 63wt% and conversion of propane was 90wt%. Yield of
aromatic compounds at these conditions included 25wt% to toluene, 1wt% to ethylbenzene,
7wt% to xylenes and 5% to C₉ aromatics.

EXAMPLE 7

25 [0059] 250mg of H⁺-UZM-44 was pressed and sieved to 40-60 mesh before loading into a
catalytic test apparatus. The catalytic composite was heated under N₂ flow of 50 mL/min to
550°C and held for 60 min. The apparatus was then cooled to 400°C before the feed was
switched from N₂ to N₂ saturated with toluene at the same flow rate. Toluene transalkylation
was performed at temperatures ranging from 400°C to 550°C.

TABLE 1

Temperature	UZM-44 Xylene Yield
400°C	12.9
450°C	15.5
500°C	18.4
550°C	19.2

CLAIMS

The invention claimed is:

1. An aromatic transformation process comprising contacting a feed comprising at least a first aromatic compound with a microporous crystalline zeolitic catalytic composite at hydrocarbon conversion conditions to produce at least a second aromatic, the catalytic composite comprising a first microporous crystalline zeolite, UZM-44, having a three-dimensional framework of at least AlO_2 and SiO_2 tetrahedral units and an empirical composition in the as synthesized and anhydrous basis expressed by an empirical formula of:



where “n” is the mole ratio of Na to (Al+E) and has a value from approximately 0.05 to 0.5, M represents a metal or metals selected from the group consisting of zinc, Group 1 (IUPAC 1), Group 2 (IUPAC 2), Group 3 (IUPAC 3), the lanthanide series of the periodic table, and any combination thereof, “m” is the mole ratio of M to (Al+E) and has a value from 0 to 0.5, “k” is the average charge of the metal or metals M, T is the organic structure directing agent or agents derived from reactants R and Q where R is an A, Ω -dihalogen substituted alkane having 5 carbon atoms and Q is at least one neutral monoamine having 6 or fewer carbon atoms, “t” is the mole ratio of N from the organic structure directing agent or agents to (Al+E) and has a value of from 0.5 to 1.5, E is an element selected from the group consisting of gallium, iron, boron and combinations thereof, “x” is the mole fraction of E and has a value from 0 to about 1.0, “y” is the mole ratio of Si to (Al+E) and varies from greater than 9 to about 25 and “z” is the mole ratio of O to (Al+E) and has a value determined by the equation:

$$z=(n+k\cdot m+3+4\cdot y)/2$$

wherein the microporous crystalline zeolite, UZM-44, is further characterized in that it has the x-ray diffraction pattern having at least the d-spacings and intensities set forth in Table A:

TABLE A

2-Theta	d(†)	I/Io %
7.72	11.45	m
8.88	9.95	m
9.33	9.47	m
12.47	7.09	w-m
12.85	6.88	vw
14.62	6.05	vw-w
15.27	5.80	w
15.57	5.68	w
16.60	5.34	w
17.70	5.01	vw-w
18.71	4.74	w-m
19.30	4.59	w
22.55	3.94	m
23.03	3.86	vs
23.39	3.80	s
24.17	3.68	m
25.01	3.56	m
26.19	3.40	vw-w
26.68	3.34	w-m
28.76	3.10	w-m
30.07	2.97	w
35.72	2.51	vw-w
45.08	2.01	w
45.83	1.98	vw-w
46.77	1.94	vw-w.

2. The process of claim 1 wherein the microporous crystalline zeolitic catalytic composite is thermally stable up to a temperature of greater than 600° C.
3. The process of claim 1 wherein the microporous crystalline zeolitic catalytic composite has a micropore volume as a percentage of total pore volume of less than 60%.
4. The process of claim 1 wherein the microporous crystalline zeolitic catalytic composite has micropore volume of less than 0.155 mL/g.
5. The process of claim 1 wherein the microporous crystalline zeolitic catalytic composite has micropore volume of less than 0.150 mL/g.
6. The process of claim 1 wherein the microporous crystalline zeolitic catalytic composite exhibits no feature at 200-300 Å on a dV/dlog D versus pore diameter plot of differential volume of nitrogen adsorbed as a function of pore diameter.
7. The process of claim 1 wherein the microporous crystalline zeolitic catalytic composite exhibits adsorption occurring at greater than 450 Å on a dV/dlog D versus pore diameter plot of differential volume of nitrogen adsorbed as a function of pore diameter.
8. The process of claim 1 wherein the differential volume of nitrogen adsorbed by the catalytic composite at a pore diameter of 475 Å is greater than 0.1 mL N₂/gÅ on a dV/dlog D versus pore diameter plot of differential volume of nitrogen adsorbed as a function of pore diameter.
9. The process of claim 1 wherein the differential volume of nitrogen adsorbed by the catalytic composite at pore diameters greater than 475 Å is greater than 0.1 mL N₂/gÅ on a dV/dlog D versus pore diameter plot of differential volume of nitrogen adsorbed as a function of pore diameter.
10. The process of claim 1 wherein the feed further comprises at least one alkane having from 2 to about 6 carbon atoms.
11. The process of claim 1 wherein the first aromatic is benzene.
12. The process of claim 1 wherein the first aromatic is benzene and the second aromatic is toluene or xylene.
13. The process of claim 1 further comprising removing an effluent comprising the second aromatic, fractionating the effluent, and recovering the second aromatic.
14. The process of claim 13 further comprising, subjecting the effluent to partial condensation and vapor-liquid separation prior to fractionation.
15. The process of claim 14 further comprising recycling at least a portion of the effluent to the catalyst.

16. The process of claim 1 wherein the aromatic transformation process is the dealkylation of aromatics and the second aromatic is at least one dealkylated aromatic, and wherein the process is operated at a hydrogen:hydrocarbon mole ratio of between 0.1:1 and 15:1, a LHSV of about 0.1 to about 50 hr⁻¹, a temperature of about 100° to about 600° C. and a pressure of about 10 kPa to about 5 MPa.

17. The process of claim 1 wherein the aromatic transformation process is the alkylation of aromatics and the second aromatic is at least one linear alkyl substituted aromatic, and wherein the process is operated at an aromatic:olefin mole ratio of between 5:1 and 30:1, a LHSV of about 0.3 to about 6 hr⁻¹, a temperature of about 100° to about 250° C. and a pressures of about 200 to about 1000 psig.