



(86) Date de dépôt PCT/PCT Filing Date: 2001/11/01
(87) Date publication PCT/PCT Publication Date: 2002/05/10
(45) Date de délivrance/Issue Date: 2009/09/08
(85) Entrée phase nationale/National Entry: 2003/04/29
(86) N° demande PCT/PCT Application No.: IB 2001/002051
(87) N° publication PCT/PCT Publication No.: 2002/036491
(30) Priorité/Priority: 2000/11/03 (US09/705,653)

(51) Cl.Int./Int.Cl. *C01B 39/48* (2006.01),
B01J 29/04 (2006.01), *B01J 29/70* (2006.01),
C01B 39/06 (2006.01), *C07C 2/12* (2006.01),
C07C 2/54 (2006.01), *C07C 5/22* (2006.01),
C07C 5/27 (2006.01), *C10G 45/64* (2006.01),
C10G 50/00 (2006.01)

(72) Inventeurs/Inventors:
LEWIS, GREGORY J., US;
MOSCOSO, JAIME G., US;
MILLER, MARK A., US;
WILSON, BEN A., US

(73) Propriétaire/Owner:
UOP LLC, US

(74) Agent: MACRAE & CO.

(54) Titre : COMPOSITION ZEOLITIQUE D'ALUMINOSILICATE CRISTALLIN (UZM-4) ET PROCEDES FAISANT APPEL A CETTE COMPOSITION

(54) Title: CRYSTALLINE ALUMINOSILICATE ZEOLITIC COMPOSITION: UZM-4 AND PROCESSES USING THE COMPOSITION

(57) **Abrégé/Abstract:**

Applicants have synthesized a new aluminosilicate zeolite identified as UZM-4. This new zeolite has the BPH morphology and is structurally related to zeolite Q. UZM-4 has an empirical formula of $M_m^{n+}R_r^{p+}Al_{1-x}E_xSi_yO_z$ where M is an alkali or alkaline earth metal ion, R can be a quaternary ammonium ion and E can be gallium, iron, boron, chromium, indium and mixtures thereof. The Si/Al ratio can range from 1.5 to 4.0. The zeolite can be used in various hydrocarbon conversion processes such as isomerization of alkylaromatic hydrocarbons.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
10 May 2002 (10.05.2002)

PCT

(10) International Publication Number
WO 02/36491 A1

(51) International Patent Classification⁷: **C01B 39/48**, 39/06, B01J 29/04, C10G 45/64, 50/00, C07C 5/22 (74) Common Representative: UOP LLC; John G. Tolomei, 25 East Algonquin Road, Des Plaines, IL 60017 (US).

(21) International Application Number: PCT/IB01/02051 (81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(22) International Filing Date:
1 November 2001 (01.11.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/705,653 3 November 2000 (03.11.2000) US

(71) Applicant (*for all designated States except US*): UOP LLC [US/US]; 25 East Algonquin Road, Des Plaines, IL 60017 (US).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): LEWIS, Gregory, J. [US/US]; c/o Uop LLC, 25 East Algonquin Road, Des Plaines, IL 60017 (US). MOSCOSO, Jaime, G. [US/US]; c/o Uop LLC, 25 East Algonquin Road, Des Plaines, IL 60017 (US). MILLER, Mark, A. [US/US]; c/o Uop LLC, 25 East Algonquin Road, Des Plaines, IL 60017 (US). WILSON, Ben, A. [US/US]; c/o Uop LLC, 25 East Algonquin Road, Des Plaines, IL 60017 (US).

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— with international search report
— before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: CRYSTALLINE ALUMINOSILICATE ZEOLITIC COMPOSITION: UZM-4 AND PROCESSES USING THE COMPOSITION

(57) Abstract: Applicants have synthesized a new aluminosilicate zeolite identified as UZM-4. This new zeolite has the BPH morphology and is structurally related to zeolite Q. UZM-4 has an empirical formula of $M_m^{n+}R_r^{p+}Al_{1-x}E_xSi_yO_z$ where M is an alkali or alkaline earth metal ion, R can be a quaternary ammonium ion and E can be gallium, iron, boron, chromium, indium and mixtures thereof. The Si/Al ratio can range from 1.5 to 4.0. The zeolite can be used in various hydrocarbon conversion processes such as isomerization of alkylaromatic hydrocarbons.



WO 02/36491 A1

CRYSTALLINE ALUMINOSILICATE ZEOLITIC COMPOSITION: UZM-4 AND PROCESSES USING THE COMPOSITION

BACKGROUND OF THE INVENTION

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. 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.

One particular zeolite, designated zeolite Q, was first disclosed in US-A-2,991,151. The general formula for zeolite Q is represented in terms of mole ratio of the oxides by the following:



where M designates at least one exchangeable cation, n represents the valence of M and x has a value from 0 to 5. The examples in the patent are prepared with M being potassium. Synthesis of zeolite Q was conducted at 25°C to 50°C. After activation at 130°C, zeolite Q was found to adsorb small polar molecules.

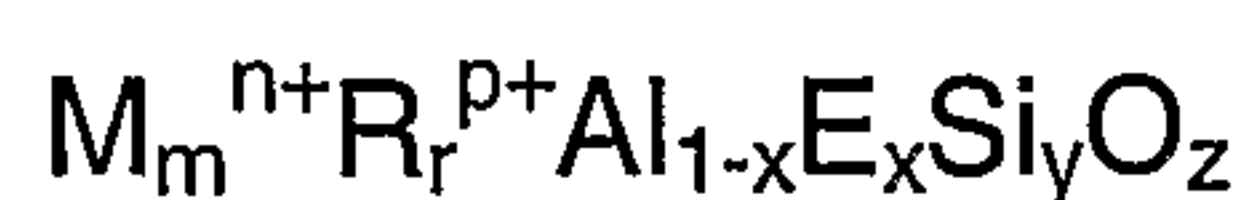
In a paper by John D. Sherman entitled, "Identification and Characterization of Zeolites Synthesized in the $\text{K}_2\text{O}-\text{Al}_2\text{O}_3-\text{SiO}_2-\text{H}_2\text{O}$ System," *Molecular Sieves* – II(102) 30, 1974, he reports that the zeolite Q of the '151 patent is the same zeolite as zeolite K-I reported by other researchers. Zeolite K-I was first reported by S.P. Zhdanov and M.E. Ovsepyon in *Doklady Chemistry. Proc. Acad. Sci. USSR*, **156**, 756 (1964). M. E. Ovsepyan and S.P. Zhdanov further reported on K-I zeolite in *Bull. Acad. Sci. USSR, Chem. Sci.* **1**, 8 (1965). R. M. Barrer et al. in *J. Chem. Soc. (A)* 2475 (1968) showed that K-I decomposed at 168°C. It is also reported by Sherman and other researchers that zeolite Q is unstable above 130°C and is totally disintegrated at 200°C. Owing to this thermal instability, zeolite Q has received little industrial interest. K. J. Andries et al., in *Zeolites*, **11**, 124 (1991) proposed the BPH topology for

zeolite Q. Synthesis of a pure form of zeolite Q was reported by K.J. Andries et al., in *Zeolites*, 11, 116 (1991). Finally, US-A-5,382,420 discloses a composition designated ECR-33, which is a partially rare earth (La) exchanged zeolite Q. In all of the above reports, the Si/Al ratio is 1.

Applicants have now synthesized a zeolite designated UZM-4, which appears to have a similar topology to that of zeolite Q, i.e., BPH, but has considerably different characteristics. The biggest difference is that UZM-4 has been synthesized with higher Si/Al ratios than zeolite Q, starting from a low of 1.5 and going higher. The most important characteristic of UZM-4 is the greater thermal stability associated with the higher Si/Al ratios. UZM-4 in its various forms is stable to at least 400°C and often up to greater than 600°C. The x-ray diffraction pattern of UZM-4 is noticeably different from that of zeolite-Q; and UZM-4 has smaller cell dimensions than that of zeolite Q, consistent with its higher Si/Al ratio.

DETAILED DESCRIPTION OF THE INVENTION

Applicants have prepared an aluminosilicate zeolite and substituted versions of the same whose topological structure is related to BPH as described in *Atlas of Zeolite Structure Types*, W. H. Meier, D.H. Olson, and C.H. Baerlocher, editors, Elsevier, (1996), 68-69, which has been designated UZM-4. As will be shown in detail, UZM-4 is different from zeolite Q in a number of its characteristics. The instant microporous crystalline zeolite (UZM-4) has an empirical composition in the as-synthesized form and on an anhydrous basis expressed by the empirical formula:



where M is at least one exchangeable cation and is selected from the group consisting of alkali and alkaline earth metals. Specific examples of the M cations include but are not limited to lithium, sodium, potassium, rubidium, cesium, calcium, strontium, barium and mixtures thereof. R is an organic cation and is selected from the group consisting of protonated amines, protonated diamines, quaternary ammonium ions, diquaternary ammonium ions, protonated alkanolamines and quaternized alkanolammonium ions. The value of "n" which

is the weighted average valence of M varies from 1 to 2. The value of "p" which is the weighted average valence of R varies from 1 to 2. The ratio of silicon to (Al + E) is represented by "y" which varies from 1.5 to 4.0. E is an element which is tetrahedrally coordinated, is present in the framework and is selected from the group consisting of gallium, iron, chromium, indium and boron. The mole fraction of E is represented by "x" and has a value from 0 to 0.5, while "z" is the mole ratio of O to (Al + E) and is given by the equation

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

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

$$M_m^{n+} = M_{m1}^{(n1)+} + M_{m2}^{(n2)+} + M_{m3}^{(n3)+} + \dots$$

and the weighted average valence "n" is given by the equation:

$$n = \frac{m_1 \cdot n_1 + m_2 \cdot n_2 + m_3 \cdot n_3 + \dots}{m_1 + m_2 + m_3 + \dots}$$

Similarly when only one R organic cation is present, the weighted average valence is the valence of the single R cation, i.e., +1 or +2. When more than one R cation is present, the total amount of R is given by the equation.

$$R_r^{p+} = R_{r1}^{(p1)+} + R_{r2}^{(p2)+} + R_{r3}^{(p3)+}$$

and the weighted average valence "p" is given by the equation

$$p = \frac{p_1 \cdot r_1 + p_2 \cdot r_2 + p_3 \cdot r_3 + \dots}{r_1 + r_2 + r_3 + \dots}$$

The microporous crystalline zeolite, UZM-4, is prepared by a hydrothermal crystallization of a reaction mixture prepared by combining reactive sources of M, R, aluminum, silicon and optionally E. The sources of aluminum include but are not limited to aluminum alkoxides, precipitated aluminas, aluminum metal, aluminum salts and alumina sols. Specific examples of

aluminum alkoxides include, but are not limited to aluminum ortho 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 the E elements include but are not limited to alkali borates, boric acid, precipitated gallium oxyhydroxide, gallium sulfate, ferric sulfate, ferric chloride, chromium nitrate and indium chloride. Sources of the M metals include the halide salts, nitrate salts, acetate salts, and hydroxides of the respective alkali or alkaline earth metals. When R is a quaternary ammonium cation or a quaternized alkanolammonium cation, the sources include the hydroxide, chloride, bromide, iodide and fluoride compounds. Specific examples include without limitation tetramethylammonium hydroxide, tetraethylammonium hydroxide, hexamethonium bromide, diethyldimethylammonium hydroxide, tetrapropylammonium hydroxide, tetramethylammonium chloride and choline chloride. R may also be introduced as an amine, diamine, or alkanolamine. Specific examples are N,N,N',N'-tetramethyl -1,6-hexanediamine, triethylamine, and triethanolamine.

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" varies from 0.05 to 1.5, "b" varies from 1.0 to 15, "c" varies from 0 to 0.5, "d" varies from 2.5 to 15, and "e" varies from 25 to 2500. If alkoxides are used, it is preferred to include a distillation or evaporative step to remove the alcohol hydrolysis products. The reaction mixture is now reacted at a temperature of 85°C to 225°C and preferably from 125°C to 150°C for a period of 1 day to 2 weeks and preferably for a time of 2 days to 4 days in a sealed reaction vessel under autogenous pressure. 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

The UZM-4 aluminosilicate zeolite, which is obtained from the above-described process, is characterized by the x-ray diffraction pattern, having the d-spacings and relative intensities set forth in Table A below.

Table A

2- θ	d(Å)	I/I ₀ %
6.45 - 6.75	13.69 - 13.08	m
7.52 - 7.80	11.75 - 11.33	vs
14.75 - 15.06	6.00 - 5.88	w-m
15.30 - 15.66	5.79 - 5.65	w
18.70 - 19.05	4.74 - 4.66	w-m
20.23 - 20.51	4.39 - 4.33	w-m
21.30 - 21.61	4.17 - 4.11	m
24.00 - 24.34	3.70 - 3.65	m
26.56 - 26.96	3.35 - 3.30	w-m
27.47 - 27.80	3.24 - 3.21	w-m
28.56 - 28.88	3.12 - 3.09	w
29.95 - 30.31	2.98 - 2.95	m
30.84 - 31.19	2.90 - 2.87	w
33.70 - 34.17	2.66 - 2.62	w
35.45 - 35.92	2.53 - 2.50	w
43.46 - 44.00	2.08 - 2.06	w

5 As will be shown in detail in the examples, the UZM-4 material is thermally stable up to a temperature of at least 400°C and preferably up to 600°C. The UZM-4 material has also been found to have a smaller unit cell size than zeolite Q, indicative of a higher Si/Al ratio. That is, a representative UZM-4 has a unit cell of $a=13.269 \text{ Å}$, $c=13.209 \text{ Å}$, versus a unit cell for zeolite Q of $a=13.501 \text{ Å}$ and $c=13.403 \text{ Å}$.

10 As synthesized, the UZM-4 material will contain some of the exchangeable or charge balancing cations in its pores. These exchangeable cations can be exchanged for other cations, or in the case of organic cations, they can be removed by heating under controlled conditions. Because UZM-4 is a large pore zeolite, it is also possible to remove some organic cations directly by ion exchange.

15 The crystalline UZM-4 zeolite of this invention can be used for separating mixtures of molecular species, removing contaminants through ion exchange and catalyzing various hydrocarbon conversion processes. Separation of

molecular species can be based either on the molecular size (kinetic diameter) or on the degree of polarity of the molecular species.

The UZM-4 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 both aromatics and isoparaffin, isomerization, 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-A-4,310,440 and US-A-4,440,871. Preferred hydrocarbon conversion processes are those in which hydrogen is a component such as hydrotreating or hydrofining, hydrogenation, hydrocracking, hydrodenitrogenation, hydrodesulfurization, etc.

Hydrocracking conditions typically include a temperature in the range of 204-649°C (400° to 1200°F), preferably between 316-510°C (600° and 950°F). Reaction pressures are in the range of atmospheric to 24,132 kPa g (3,500 psig), preferably between 1379 – 20,685 kPa g (200 and 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 178-8,888 std. m³/m³ (1,000 to 50,000 standard cubic feet (scf) per barrel of charge), preferably between 355-5,333 std. m³/m³ (2,000 and 30,000 scf per barrel of charge). Suitable hydrotreating conditions are generally within the broad ranges of hydrocracking conditions set out above.

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.

Catalytic cracking processes are preferably carried out with the UZM-4 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° to 593°C (850° to 1100°F), LHSV values of 0.5 to 10 hr⁻¹ and pressure conditions of from 1 to 34 kPa gauge (0 to 50 psig) are suitable.

Alkylation of aromatics usually involves reacting an aromatic (C₂ to C₁₂), especially benzene, with a monoolefin to produce a linear alkyl substituted aromatic. The process is carried out at an aromatic: olefin (e.g., benzene:olefin) ratio of between 5:1 and 30:1, a LHSV of 0.3 to 6 hr⁻¹, a temperature of 100° to 250°C and pressures of 1379 to 6895 kPa gauge (200 to 1000 psig). Further details on apparatus may be found in US-A-4,870,222.

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 6,894 kPa gauge (1,000 psig) and a weight hourly space velocity (WHSV) of 0.1 to 120 hr⁻¹. Details on paraffin alkylation may be found in US-A-5,157,196 and US-A-5,157,197.

The isomerization of an alkylaromatic feed mixture, preferably a non-equilibrium mixture of C₈ aromatics, involves contacting the feed with the isomerization catalyst at suitable alkylaromatic-isomerization conditions. The isomerization catalyst will comprise the instant zeolite along with a platinum group metal and optionally other components. Isomerization conditions comprise a temperature ranging from 0° to 600°C or more, and preferably in the range from 100° to 500°C. The pressure generally is from 101 to 10,132 kPa absolute (1 to 100 atmospheres absolute), preferably less than 5066 kPa (50 atmospheres). Sufficient catalyst is contained in the isomerization zone to provide a liquid hourly space velocity with respect to the hydrocarbon feed mixture of from 0.1 to 30 hr⁻¹ and preferably 0.5 to 10 hr⁻¹. The hydrocarbon feed mixture optimally is reacted in admixture with hydrogen at a hydrogen/hydrocarbon mole ratio of 0.5:1 to 25:1 or more. Other inert diluents such as nitrogen, argon and light hydrocarbons may be present.

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.

The structure of the UZM-4 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 samples were continuously scanned at 2° to 70° (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, " I_0 " being the intensity of the strongest line or peak, and " I " being the intensity of each of the other peaks.

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 $\pm 0.4^\circ$ 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 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, and w which represent very strong, strong, medium, and weak, respectively. In terms of $100 \times I/I_0$, the above designations are defined as

$$w = 0-15; m = 15-60; s = 60-80 \text{ and } vs = 80-100$$

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.

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.

EXAMPLES

The following abbreviations will be used in the examples:

	Al (Oi-Pr) ₃	— aluminum isopropoxide
10	Al (Osec-Bu) ₃	— aluminum sec-butoxide
	DEDMAOH	— diethyldimethylammonium hydroxide
	HM	— hexamethonium
	TEAOH	— tetraethylammonium hydroxide
	TEOS	— tetraethylorthosilicate
15	TMACl	— tetramethylammonium chloride
	TPAOH	— tetrapropylammonium hydroxide

Example 1

An aluminosilicate reaction mixture was prepared having the following composition:

20 1.6 TEAOH: 1 TEOS: 0.52 Al(Osec-Bu)₃ : 35 H₂O. The reaction mixture was aged with stirring overnight at 85°C and then distilled to 95°C to remove solvent, forming a mixture containing 3.4% Si. Separately, a solution was prepared by dissolving 27.62 g tetramethylammonium chloride (97%) and 5.34 g LiCl in 50.0 g deionized water. This solution was added over a 5 minute period
25 to 400.0 g of the above described aluminosilicate reaction mixture, using a high-speed mechanical stirrer. The resulting mixture was homogenized for 4 hr, placed in a 600 ml Parr Mini Stirred Reactor, ramped from room temperature to 150°C over a period of 5 hr, held at 150°C for 72 hr under autogenous pressure, and then cooled to room temperature. Solids were isolated by centrifugation,
30 washed with deionized water, and dried at room temperature.

Elemental analysis revealed the material to have a Si/Al ratio of 1.85, Li/Al = 0.46, and N/Al = 0.32 giving (Li + N)/Al of 0.78. X-ray powder diffraction analysis showed that the product had the BPH topology. The d-spacings and relative intensities of the x-ray diffraction (XRD) are given in the Table 1 below.

5 The product had a BET surface area of 483 m²/g and was identified as UZM-4.

Table 1

2- θ	d(Å)	I/I ₀ %
6.66	13.26	m
7.72	11.44	vs
13.38	6.61	m
14.96	5.92	w
15.50	5.71	w
16.82	5.27	w
19.00	4.67	m
20.10	4.41	w
20.42	4.35	m
21.52	4.13	m
24.26	3.67	m
24.48	3.63	w
26.86	3.32	m
27.72	3.22	m
27.96	3.19	w
28.82	3.10	w
30.16	2.96	m
31.08	2.88	w
34.00	2.63	w
35.78	2.51	w
36.63	2.45	w
43.84	2.06	w

Example 2

An aluminosilicate reaction mixture was prepared having the following composition: 1.6 TEAOH: 1 TEOS: 0.5 Al(Osec-Bu)₃: 35 H₂O. The reaction mixture was aged at 83°C overnight and then distilled at 95°C to remove solvents, forming a mixture containing 3.28% Si. Separately, a solution was prepared in which 1.33 g LiCl and 6.87 g TMACl (97%) were dissolved together in 15.0g deionized H₂O. This solution was added slowly to 103.1 g of the aluminosilicate reaction mixture described above. The reaction mixture was further homogenized for 3 hr, divided among 5 autoclaves and the mixtures were

digested under a variety of conditions at autogenous pressures. The solids were isolated by centrifugation, washed with deionized water, and dried at room temperature.

5 Elemental analyses revealed that the product digested at 150°C for 93 hr to have a Si/Al = 1.96, N/Al = 0.52, Li/Al = 0.38, and (N + Li)/Al = 0.90. X-ray powder diffraction analysis showed that the product had the BPH topology. The d-spacings and relative intensities of the x-ray diffraction (XRD) are given in Table 2.

Table 2

2- θ	d(Å)	I/I ₀ %
6.72	13.14	m
7.74	11.41	vs
13.42	6.59	w
15.02	5.89	w
15.56	5.69	w
16.88	5.25	w
19.00	4.67	m
20.44	4.34	m
21.56	4.12	m
24.28	3.66	m
26.86	3.32	m
27.74	3.21	m
28.82	3.10	w
30.22	2.96	m
31.06	2.88	w
34.08	2.63	w
35.80	2.51	w
43.84	2.06	w

Example 3

10

15

An aluminosilicate reaction mixture was prepared having the following composition: 1.2 TEAOH: 1 TEOS: 0.33 Al(Oi-Pr)₃: 35 H₂O. The reaction mixture was aged at 85°C for 2 hr and then heated to 96°C for 2.5 hr to remove solvents. The reaction mixture, which contained 3.54% Si, was allowed to cool. Separately, 38.53 g TMACl (97%) and 7.30 g LiOH·H₂O were dissolved together in 63.0 g deionized water. This solution was added slowly to 800.0 g of the aluminosilicate reaction mixture described above with vigorous mixing. The

resultant mixture was further homogenized for 2 hr, divided among 6 autoclaves, and the mixtures were digested under a variety of conditions at autogenous pressures. The products were isolated by centrifugation, washed with deionized water, and dried at room temperature.

5 A sample digested for 6 days at 100°C yielded a product with Si/Al = 1.85, Li/Al = 0.68, N/Al = 0.41, and (N + Li)/Al = 1.09 by elemental analysis. Analysis by x-ray powder diffraction showed the material to have the BPH topology. Typical lines observed in the x-ray diffraction pattern are shown in Table 3. Analysis of the size and morphology of the crystallites by scanning
10 electron microscopy (SEM) revealed mostly 0.1 μ – 0.3 μ diameter hexagonal plates.

Table 3

2- θ	d(Å)	I/I ₀ %
6.62	13.34	m
7.64	11.56	vs
13.32	6.64	m
14.88	5.95	m
15.40	5.75	m
16.72	5.30	w
18.90	4.69	m
20.10	4.41	m
20.32	4.37	m
21.42	4.14	m
24.14	3.68	m
26.78	3.33	m
27.62	3.23	m
28.76	3.10	w
30.08	2.97	m
30.96	2.89	m
33.94	2.64	m
35.63	2.52	w
36.53	2.46	w
43.70	2.07	w

Example 4

15 An aluminosilicate reaction mixture was prepared having the following composition: 1.6 TEAOH: 1 TEOS: 0.5 Al(Oi-Pr)₃: 35 H₂O. The reaction mixture was aged at 85°C for 1 hr before it was heated to 96°C to remove solvent. After

solvent removal, the reaction mixture, which contained 3.53%Si, was allowed to cool. Separately, a solution was prepared in which 1.84 g LiCl and 16.24 g hexamethonium bromide were dissolved together in 20.00 g deionized water. This solution was added quickly to 138.0 g of the aluminosilicate reaction mixture described above, with vigorous stirring. The reaction mixture was homogenized for another hour before it was divided among 6 autoclaves, and the mixtures were digested under a variety of conditions at autogenous pressures. The products were isolated by centrifugation, washed with deionized water, and dried at room temperature.

The reactions in which the mixtures were digested at 150°C and 175°C for both 2 and 7 days all yielded products with the BPH topology as determined by x-ray powder diffraction. The product isolated from the 2 day - 150°C digestion had $\text{Si/Al} = 1.92$, $\text{Li/Al} = 0.43$, $\text{N/Al} = 0.46$, and $(\text{N} + \text{Li})/\text{Al} = 0.89$. This sample was studied via variable temperature powder x-ray diffraction. The study was conducted with a flow of dry air over the sample. The BPH topology was observed to be stable to 600°C, the maximum temperature at which the study was conducted. A shift in some intensities of some of the lines was observed above the temperature where the organoammonium species decomposed. Table 4 gives the lines observed for the UZM-4 sample at room temperature and at 600°C. The results clearly establish the thermal stability of the UZM-4 composition.

Table 4

Room Temperature, $\text{Li}_{0.43}(\text{HM})_{0.23}\text{AlSi}_{1.92}\text{O}_{5.68}$			600°C, High Temperature XRD, $\text{Li}_{0.43}(\text{HM})_{0.23}\text{AlSi}_{1.92}\text{O}_{5.68}$		
2- θ	d(Å)	I/I ₀ %	2- θ	d(Å)	I/I ₀ %
6.48	13.63	m	6.84	12.91	w
7.60	11.62	vs	7.80	11.33	vs
			10.23	8.64	w
13.27	6.67	w	13.56	6.52	w
14.84	5.96	w	15.16	5.84	m
15.36	5.76	w	15.80	5.61	w
16.72	5.30	w			
18.84	4.71	m	19.24	4.61	w
20.32	4.37	m	20.57	4.32	w
21.44	4.14	m	21.76	4.08	w
24.16	3.68	m	24.80	3.59	w
26.80	3.32	m	27.08	3.29	w
27.64	3.23	m	27.93	3.19	w
28.68	3.11	w	29.08	3.07	w
30.12	2.96	m	30.60	2.92	w
31.04	2.88	m			
33.89	2.64	w	34.32	2.61	w
35.68	2.51	w			
43.80	2.07	w			

Example 5

An aluminosilicate reaction mixture was prepared having the following composition: 1.4 TEAOH: 1 TEOS: 0.4 Al(Osec-Bu)₃: 28 H₂O, employing vigorous stirring. The reaction mixture was aged at 75°C overnight, heated to 85°C for 3 hr to begin removing solvent, and finally held at 95°C for 1 hr to complete the solvent removal process. This reaction mixture, which contained 3.57% Si, was allowed to cool to room temperature. Separately, two solutions were prepared by dissolving 68.78 g TMACl (97%) in 140 g H₂O and the second by dissolving 13.35 g LiCl in 30 g H₂O. To 1228 g of the aluminosilicate reaction mixture described above, the tetramethylammonium chloride solution was added with vigorous stirring. This was followed by the addition of the lithium chloride solution. The resulting reaction mixture was further homogenized for 4 hr. The majority of the reaction mixture, 1100 g, was placed in the teflon liner of a 2-liter autoclave and the mixture was digested quiescently at 140°C for 3 days, while

the rest of the reaction mixture was divided among 4-45 ml teflon-lined autoclaves. Two of these autoclaves were placed in a rotisserie oven, tumbled at 60 rpm and heated to a temperature of 150°C for 2 and 4 days. The mixtures in the last two autoclaves were digested quiescently at 150°C for 2 and 4 days.

5 The solid products were isolated by centrifugation, washed with deionized water, and dried at room temperature.

The product isolated from the large quiescently digested sample had a Si/Al = 2.34, Li/Al = 0.49, N/Al = 0.54, and (Li + N)/Al = 1.03 as determined by elemental analyses. Analysis of the sample by powder x-ray diffraction showed the material to have the BPH topology, but there was a slight TMA-sodalite impurity. The lines observed in the x-ray diffraction pattern are given in Table 5. The samples digested in the 45 ml autoclaves, both quiescently and in the rotisserie oven, yielded products with the BPH topology only.

Table 5

2- θ	d(Å)	I/I _o %	phase
6.66	13.26	m	BPH
7.70	11.47	vs	BPH
13.30	6.65	m	BPH
13.96	6.34	w	TMA SOD
14.94	5.93	w	BPH
15.46	5.73	w	BPH
16.82	5.27	w	BPH
18.92	4.69	m	BPH
19.82	4.48	w	TMA SOD
20.36	4.36	m	BPH
21.52	4.13	m	BPH
24.24	3.67	m	BPH/TMA SOD
26.84	3.32	w	BPH
27.68	3.22	m	BPH
28.80	3.10	w	BPH
30.14	2.96	m	BPH
31.12	2.87	w	BPH
33.90	2.64	w	BPH
35.78	2.51	w	BPH
36.45	2.46	w	BPH
43.78	2.07	w	BPH

Example 6

An aluminosilicate reaction mixture was prepared by diluting 336.15 g TEAOH (35%) with 51.45 g H₂O, adding 52.04 g Al(Oi-Pr)₃, (98%), and then 75.0 g Ludox™ AS-40, with vigorous stirring over the course of the preparation.

5 The reaction mixture was heated to 100°C to remove some solvent before it was transferred to a teflon bottle and aged at 100°C for 66 hr. The reaction mixture was allowed to cool to room temperature. A solution was prepared in which 34.26 g TMACl (97%) and 5.29 g LiCl were dissolved together in 35.0 g deionized water. This was added to the aluminosilicate reaction mixture in a
10 single pour with vigorous stirring. The reaction mixture was homogenized for 2 hr before it was divided among 6 different autoclaves and digested under a variety of conditions at autogenous pressures. Solid products were isolated by centrifugation, washed with deionized water, and dried at room temperature.

The mixture digested at 125°C for both 49 hr and 172 hr as well as the
15 mixtures digested at 150°C for 26 hr and 49 hr yielded materials with the BPH topology as determined by x-ray powder diffraction studies. Small amounts of amorphous material were also observed in the XRD as a shoulder on the baseline at low angle. The lines observed for the sample prepared at 125°C for 49 hr are given in Table 6 below.

Table 6

2-θ	d(Å)	I/I_o%
6.46	13.67	w
7.56	11.68	vs
13.26	6.67	w
14.80	5.98	w
15.34	5.77	w
18.76	4.73	w
20.32	4.37	w
21.36	4.16	m
24.06	3.70	m
26.62	3.35	w
27.52	3.24	w
28.67	3.11	w
30.04	2.97	m
30.92	2.89	w
33.80	2.65	w
35.71	2.51	w
43.64	2.07	w

Example 7

An aluminosilicate reaction mixture was prepared with vigorous stirring having the following composition: 1 TEOS: 0.5 Al(Osec-Bu)₃: 0.8 TEAOH: 12.5 H₂O. The reaction mixture was aged at 75°C overnight, heated to 85°C to remove some solvent, and then finally heated to 95°C for an hour for complete removal of the solvent. The reaction mixture, which contained 7.5% Si, was recovered and cooled to room temperature. An 80.0 g portion of this reaction mixture was diluted with 20.0 g deionized water. Separately, 10.96 g TMACl (97%), 0.85 g LiCl, and 3.17 g Sr(NO₃)₂ were dissolved in 30.0 g deionized water. This solution was added to the diluted 100 g portion of the aluminosilicate reaction mixture described above with vigorous stirring. Once the addition was completed, the reaction mixture was homogenized for another 2 hr. The final reaction mixture was divided among 5 teflon-lined autoclaves, which mixtures were digested under a variety of conditions at autogenous pressures. The solid products were isolated by centrifugation, washed with deionized water, and dried at room temperature.

The samples digested at 150°C for 2 and 3 days had the BPH topology, as determined by x-ray powder diffraction. A small amount of an unidentified

impurity was also observed. This example shows that the BPH structure can be formed in a system containing much less organoammonium hydroxide than seen in the other examples above. A representative set of lines observed in the x-ray powder diffraction patterns of these samples is given in Table 7 below.

5

Table 7

2-θ	d(Å)	I/I_o%	Phase
6.60	13.38	m	BPH
7.68	11.50	vs	BPH
10.16	8.70	w	BPH
13.30	6.65	m	BPH
14.00	6.32	w	Impurity
14.86	5.96	w	BPH
15.48	5.72	w	BPH
16.02	5.53	w	Impurity
18.94	4.68	m	BPH
20.42	4.35	m	BPH
21.48	4.13	m	BPH
24.28	3.66	m	BPH
26.84	3.32	m	BPH
27.72	3.22	w	BPH
28.80	3.10	m	BPH
30.10	2.97	m	BPH
31.06	2.88	w	BPH
33.94	2.64	m	BPH
34.64	2.59	w	BPH
35.74	2.51	w	BPH
36.58	2.45	w	BPH
41.50	2.17	w	BPH
43.76	2.07	w	BPH

Example 8

An aluminosilicate reaction mixture was prepared having the following composition: 1 TEOS: 0.5 Al(Osec-Bu)₃: 1.6 TPAOH: 35 H₂O. The reaction mixture was stirred overnight at 85°C and was first distilled at 95°C for one hour to remove solvent before continuing the distillation at 97°C for an additional hour before allowing the reaction mixture to cool. A 300 g portion of this reaction mixture, which contained 2.88% Si, was placed in a teflon beaker and stirred with a high-speed mixer. Separately a solution was prepared by dissolving 18.76

10

g tetramethylammonium chloride (97%) and 3.52 g LiCl together in 20.0 g deionized water. This solution was added slowly to the aluminosilicate reaction mixture and homogenized for 4 hr. The homogenous reaction mixture was then divided among 6 teflon-lined autoclaves and the mixtures digested at autogenous pressures under a variety of temperatures and times. The solid products were isolated by centrifugation, washed with deionized water, and dried at room temperature.

Reaction mixtures digested at 125°C (2 and 4 days), 150°C (2 days), and 175°C (2 days) yielded products with the BPH structure. A slight impurity was detected in the XRD in the form of a single peak at $d = 9.39\text{\AA}$. The patterns from all four of these samples were similar, representative lines for the material prepared at 175°C are given in Table 8 below.

Table 8

2- θ	$d(\text{\AA})$	$I/I_0\%$	Phase
6.64	13.29	w	BPH
7.68	11.50	vs	BPH
9.41	9.39	w	Impurity
13.28	6.66	w	BPH
14.88	5.95	m	BPH
15.52	5.71	w	BPH
16.78	5.28	w	BPH
18.90	4.70	m	BPH
20.09	4.42	w	BPH
20.38	4.35	m	BPH
21.48	4.13	m	BPH
24.24	3.67	m	BPH
24.36	3.65	m	BPH
26.80	3.32	m	BPH
27.68	3.22	m	BPH
27.92	3.19	w	BPH
28.80	3.10	w	BPH
30.12	2.96	m	BPH
31.04	2.88	w	BPH
33.92	2.64	w	BPH
34.12	2.63	w	BPH
35.76	2.51	w	BPH
36.66	2.45	w	BPH
43.78	2.07	w	BPH

Example 9

An aluminosilicate reaction mixture was prepared having the following composition: 1 TEOS: 0.5 Al(Osec-Bu)₃: 1.6 TPAOH: 35 H₂O. The reaction mixture was stirred overnight at 85°C and was first distilled at 95°C for one hour to remove solvent before continuing the distillation at 97°C for an additional hour before allowing the reaction mixture to cool. A 200 g portion of this reaction mixture, which contained 2.88% Si, was placed in a teflon beaker and stirred with a high-speed mixer. Separately a solution was prepared by dissolving 20.62 g hexamethonium bromide and 2.34 g LiCl together in 25.0 g deionized water. This solution was added slowly to the aluminosilicate reaction mixture and homogenized for 4 hr. The homogenous reaction mixture was then divided among 4 teflon-lined autoclaves, and the mixtures were digested at autogenous pressures at a variety of temperatures and times. The solid products were isolated by centrifugation, washed with deionized water, and dried at room temperature.

Reaction mixtures digested at 150°C (7 days), 175°C (2 and 4 days), and 200°C (2 days) yielded products with the BPH structure. The patterns from all four of these samples were similar; representative lines for the material prepared at 200°C are given in Table 9 below.

Table 9

2- θ	d(Å)	I/I ₀ %
6.58	13.42	w
7.74	11.41	vs
13.42	6.59	w
14.96	5.92	w
15.62	5.67	w
16.75	5.29	w
18.98	4.67	w
19.86	4.47	w
20.46	4.34	m
21.56	4.12	m
24.18	3.68	m
26.90	3.31	w
27.74	3.21	w
28.82	3.10	w
30.24	2.95	m
31.08	2.88	w
33.96	2.64	w
35.82	2.50	w
43.90	2.06	w

Example 10

An aluminosilicate reaction mixture was prepared having the following composition: 1 SiO₂: 0.25 Al₂O₃: 1 TEAOH: 20 H₂O. To 253.6 g of a solution of aluminum chlorhydrol (23% Al₂O₃), there were added 268 g of NH₄OH (29% NH₃) with stirring. The resulting alumina precipitate was isolated by filtration, washed with 3 L deionized water, and then transferred to a beaker containing 962.5 g TEAOH (35%). Once the alumina had been added, 343.2 g of Ludox™ AS-40 was added to the reaction mixture. After homogenizing for an hour, the reaction mixture was aged in a teflon bottle for 2 days at 100°C. After the aging period, the reaction mixture was allowed to cool and was transferred to another bottle for storage. This reaction mixture contained 4.17% Si and 1.90% Al and is designated Mixture A. A portion of Mixture A, 150 g, was treated with 56.22 g TEAOH (35%) and vigorously homogenized for 30 minutes. Separately, an additional solution was prepared by dissolving 11.89 g TMACl (97%) and 2.24 g LiCl together in 13.0 g deionized water. This latter solution was then added dropwise to the aluminosilicate reaction mixture and homogenized further for 4

hr. The reaction mixture was then split among 4 different autoclaves and the mixtures were digested under a variety of conditions at autogenous pressures. The solid products were isolated by centrifugation, washed with deionized water and dried at room temperature.

5 Two of the mixtures were digested for 52 hrs, one at 125°C and the other at 150°C. The sample digested at 125°C was in a rotisserie oven, which was tumbled at 60 rpm. Analysis by x-ray powder diffraction showed that the products from both of these reactions had the BPH topology. Representative lines for the product isolated from the 125°C reaction is shown in Table 10
10 below.

Table 10

2-θ	d(Å)	I/I_o%
6.67	13.24	m
7.68	11.50	vs
13.37	6.62	m
14.90	5.94	m
15.46	5.73	w
16.79	5.28	w
18.94	4.68	m
20.17	4.40	w
20.39	4.35	m
21.48	4.13	m
24.22	3.67	m
24.47	3.63	w
26.82	3.32	m
27.67	3.22	m
27.88	3.20	w
28.77	3.10	w
30.16	2.96	m
31.05	2.88	w
33.92	2.64	w
35.71	2.51	w
36.63	2.45	w
37.46	2.40	w
38.38	2.34	w
39.11	2.30	w
39.84	2.26	w
40.69	2.22	w
41.40	2.18	w
43.75	2.07	w
44.23	2.05	w
47.35	1.92	w
49.48	1.84	w
50.15	1.82	w

Example 11

An aluminogallosilicate UZM-4 was prepared as follows. A gallosilicate reaction mixture was prepared by diluting 245.90 g TEAOH (35%) with 146.45 g deionized water, adding 86.66 g Ludox™ AS-40 and finally 116 g of freshly precipitated Ga(OH)₃. The reaction mixture was vigorously stirred for 1 hr and then aged at 95°C in a teflon bottle for a day. After aging, the reaction mixture, which will be designated Mixture B, contained 2.81% Si and 2.38% Ga. An

aluminosilicate reaction mixture, Mixture A described in Example 10, 87.29 g, was placed in a teflon beaker equipped with a high-speed stirrer. With vigorous stirring, 45.02 g of Mixture B was added. This was followed by the addition of 49.59 g TEAOH (35%) and homogenization for an hour. Separately a solution was prepared by dissolving 1.63 g LiCl and 8.68 g TMACl (97%) in 5.3 g deionized water. This solution was added to the aluminogallosilicate reaction mixture after the initial hour of homogenization. The reaction mixture was further homogenized for 2 hours before it was divided among 6 teflon-lined autoclaves and the mixtures were digested under a variety of conditions at autogenous pressures. The products were isolated by centrifugation, washed with deionized water, and dried at 100°C.

All of the products contained BPH species, but those that were formed under the mild conditions of 125°C for either 2 or 4 days showed only BPH topology in their x-ray diffraction patterns. Representative lines in the x-ray diffraction pattern are given in Table 11. Elemental analysis of the sample gave $\text{Si}/(\text{Al} + \text{Ga}) = 1.77$, $\text{Ga}/(\text{Al} + \text{Ga}) = 0.048$, for the framework elements and $\text{Li}/(\text{Al} + \text{Ga}) = 0.64$, $\text{N}/(\text{Al} + \text{Ga}) = 0.50$ and $(\text{Li} + \text{N})/(\text{Ga} + \text{Al}) = 1.14$ for the cation balance.

Table 11

2-θ	d(Å)	I/I₀%
6.58	13.42	m
7.62	11.60	vs
13.26	6.67	m
14.82	5.97	m
15.34	5.77	m
16.68	5.31	w
18.82	4.71	m
20.06	4.42	m
20.28	4.38	m
21.36	4.16	m
24.12	3.69	m
26.70	3.34	m
27.52	3.24	m
27.86	3.20	m
28.62	3.12	w
30.02	2.97	s
30.92	2.89	m
33.80	2.65	m
35.56	2.52	w
36.46	2.46	w
39.04	2.31	w
40.50	2.23	w
41.34	2.18	w
43.56	2.08	m

Example 12

An aluminosilicate reaction mixture was prepared by the addition of 38.76 g aluminum hydroxide (52.5% Al₂O₃) to 1428.6 g DEDMAOH (20%) with vigorous stirring. Colloidal silica (Ludox™ AS-40), 300 g was then added to the stirring mixture, which was homogenized further for 4 hr. The mixture was then placed in a teflon bottle and digested overnight at 100°C. Elemental analysis showed the mixture to contain 3.26% Si. This aluminosilicate mixture is designated Mixture C and will be used in another example. A portion of Mixture C, 100 g, was placed in a teflon beaker equipped with a high-speed stirrer. Separately, 0.5 g LiCl was dissolved in 3 g deionized water. This solution was added to the aluminosilicate reaction mixture with vigorous stirring. After 3 hr of homogenization, the reaction mixture was split among several teflon-lined autoclaves, which were sealed, placed in ovens and digested at autogenous

pressures. The products were isolated by centrifugation, washed with deionized water, and dried at 100°C.

The product resulting from a digestion at 100°C for 6 days exhibited a powder x-ray diffraction pattern consistent with the BPH topology of UZM-4.

5 Elemental analysis showed the product to have $\text{Si/Al} = 2.21$, $\text{Li/Al} = 0.43$, $\text{N/Al} = 0.41$ and for the cation balance $(\text{Li} + \text{N})/\text{Al} = 0.84$. Characteristic lines of this product are given in Table 12.

Table 12

2-θ	d(Å)	I/I_o%
6.60	13.38	m
7.64	11.57	vs
10.12	8.74	w
13.30	6.65	m
14.88	5.95	w
15.38	5.76	m
16.74	5.29	w
18.90	4.69	m
20.10	4.41	m
20.36	4.36	m
21.46	4.14	s
24.16	3.68	s
24.44	3.64	m
26.82	3.32	m
27.64	3.22	m
28.74	3.10	m
30.12	2.96	s
31.04	2.88	m
33.92	2.64	m
35.72	2.51	w
36.58	2.45	w
37.31	2.41	w
38.40	2.34	w
39.18	2.30	w
39.84	2.26	w
40.72	2.21	w
41.40	2.18	m
43.74	2.07	m
44.38	2.04	w
47.36	1.92	w
49.54	1.84	w
50.16	1.82	m

Example 13

The aluminosilicate reaction mixture designated as Mixture C in example 12 was used as a source of Si and Al in this example. Mixture C, 100 g, was placed in a teflon beaker equipped with a stirrer. To the stirring mixture 2.68 g
5 TMACl (97%) was added. Separately, 0.5 g LiCl was dissolved in 2.0 g deionized water. The reaction mixture was allowed to stir for several hours. After homogenization, the reaction mixture was divided among 4 teflon-lined autoclaves, which were digested under a variety of reaction conditions at autogenous pressures. The products were isolated by centrifugation, washed
10 with deionized water, and dried at 95°C.

All of the products contained UZM-4 as determined by powder x-ray diffraction. A sample digested for 6 days at 125°C was well-crystallized; characteristic x-ray lines for the product are shown in Table 13. Elemental analysis of this product revealed an Si/Al ratio of 2.53.

Table 13

2-θ	d(Å)	I/I₀%
6.64	13.30	m
7.60	11.62	vs
13.28	6.66	m
14.86	5.96	w
15.42	5.74	w
16.76	5.29	w
18.88	4.70	m
20.38	4.35	m
21.44	4.14	m
24.20	3.67	m
26.78	3.33	m
27.64	3.22	m
28.80	3.10	w
30.12	2.96	m
31.04	2.88	m
33.98	2.64	m
35.72	2.51	w
36.64	2.45	w
40.72	2.21	w
41.40	2.18	w
43.74	2.07	m

Example 14

US-A-2,991,151 discloses that zeolite Q is synthesized using potassium as the charge balancing ion. As a comparison, the process used in the previous examples was carried out using potassium as the charge-balancing ion. An aluminosilicate reaction mixture was prepared by combining 1 TEOS: 0.5 Al(Osec-Bu)₃: 1.6 TEAOH: 41.5 H₂O, employing vigorous stirring. The resulting mixture was placed in a teflon bottle and aged for 3 days in a 100°C oven. The reaction mixture, which contained 2.93% Si, was then allowed to cool to room temperature. A portion of this reaction mixture, 130.0 g, was placed in a teflon beaker and agitated with a high speed stirrer. A potassium chloride solution, prepared by dissolving 10.15 g KCl in 30.0 g H₂O, was added to the aluminosilicate reaction mixture slowly with vigorous stirring. The resulting mixture was homogenized for a half hour before it was divided among 7 teflon-lined autoclaves, which mixtures were digested under a variety of conditions at

autogenous pressures. The digestion conditions employed were typical for the formation of the BPH topology aluminosilicates disclosed in the examples given above. The solid products were isolated by centrifugation, washed with deionized water, and dried at room temperature.

5 The mixtures in three of the autoclaves were digested at 150°C for 2, 6, and 10 days. A fourth autoclave was digested at 100°C for 6 days. All of these conditions yielded well-crystallized products with the MER topology, there was no sign of material with the BPH topology. Representative lines from the x-ray powder diffraction pattern are shown in Table 14 below.

10

Table 14

2-θ	d(Å)	I/I₀%	Phase
8.83	10.00	w	MER
10.84	8.16	m	MER
12.50	7.07	s	MER
16.59	5.34	m	MER
17.76	4.99	s	MER
19.87	4.47	m	MER
20.36	4.36	w	MER
20.85	4.26	m	MER
21.80	4.07	w	MER
22.89	3.88	w	impurity
24.41	3.64	w	MER
26.01	3.42	w	impurity
27.56	3.23	vs	MER
28.26	3.16	vs	MER
30.38	2.94	m	MER
32.93	2.72	m	MER
33.56	2.67	m	MER
35.37	2.54	m	MER
37.12	2.42	w	MER
38.24	2.35	w	MER

Example 15

The UZM-4 material prepared in example 5 was tested for ion exchange using the following procedure. About 10-12 g of the zeolite was treated with a chloride or nitrate solution of the exchanging cation. The pH of the cation exchange solution was adjusted to the range of 7 – 8 by using KOH or LiOH. The resulting slurry was heated to 75°C with stirring for 1-2 hr before the product

15

was isolated by filtration and washed. This procedure was carried out 5-6 times. Data is presented for the compositions of the parent zeolite, the exchanged zeolite, the calcined exchanged zeolite, and the structure of the exchanged material after calcination. Table 15 shows the compositions as determined by elemental analyses, where cation deficiencies with respect to the charge balance on the zeolite are assumed to be accounted for by H^+ , which is included in the formulations below even though it was not directly determined by the analyses. It should be pointed out in the examples below the ease with which the organic cations are exchanged from these UZM-4 materials. This is consistent with the large 12-ring pore system known for the BPH topology.

Table 15

Exchange Cation	Composition Exchanged Zeolite	Composition Calcined Exchanged Zeolite/Calcination Temp	Structure of Calcined Exchanged Zeolite
	Parent Zeolite: Example 5, $\text{Li}_{0.49}(\text{NR}_4)_{0.54}\text{AlSi}_{2.34}\text{O}_{6.69}$		
NH_4^+	$\text{N}_{0.83}\text{Li}_{0.03}\text{AlSi}_{2.36}\text{O}_{6.72}$	$\text{H}_{0.97}\text{Li}_{0.03}\text{AlSi}_{2.36}\text{O}_{6.72}/500^\circ\text{C}$	Amorphous
K^+	$\text{K}_{0.84}\text{Li}_{0.04}(\text{NR}_4)_{0.08}\text{AlSi}_{2.31}\text{O}_{6.62}$	$\text{H}_{0.06}\text{K}_{0.84}\text{Li}_{0.04}\text{N}_{0.06}\text{AlSi}_{2.31}\text{O}_{6.62}/350^\circ\text{C}$	BPH
	Parent Zeolite: $\text{Li}_{0.49}(\text{NR}_4)_{0.50}\text{AlSi}_{2.17}\text{O}_{6.34}$		
Ca^{2+}	$\text{Ca}_{0.46}\text{Li}_{0.04}(\text{NR}_4)_{0.08}\text{AlSi}_{2.15}\text{O}_{6.32}$	$\text{H}_{0.07}\text{Ca}_{0.44}\text{Li}_{0.05}\text{AlSi}_{2.13}\text{O}_{6.23}/430^\circ\text{C}$	BPH
La^{3+}	$\text{La}_{0.28}\text{Li}_{0.15}(\text{NR}_4)_{0.14}\text{AlSi}_{2.17}\text{O}_{6.41}$	$\text{H}_{0.11}\text{Li}_{0.14}\text{La}_{0.25}\text{AlSi}_{2.14}\text{O}_{6.28}/430^\circ\text{C}$	BPH
Li^+	$(\text{NR}_4)_{0.13}\text{Li}_{0.94}\text{AlSi}_{2.18}\text{O}_{6.40}$	$\text{H}_{0.05}\text{Li}_{0.95}\text{AlSi}_{2.16}\text{O}_{6.32}/430^\circ\text{C}$	BPH

Example 16

UZH-4 was analyzed by ^{29}Si and ^{27}Al NMR and is compared to the NMR spectrum of zeolite Q in the literature. Zeolite Q has been studied by Andries, Bosmans, and Grobert, in *Zeolites*, vol. 11, p.116-131 (1991). The zeolite Q sample with Si/Al = 1 showed in the ^{29}Si nmr spectrum, three lines with chemical shifts that were consistent with 4 Al in the Si environment. The narrow linewidths observed for these lines indicated that there was Si and Al ordering in the framework. In contrast, ^{29}Si nmr spectra of a typical higher Si/Al BPH topology UZH-4 sample showed five broad lines (each line is actually multiple lines), corresponding to Si in a variety of environments, differing by the number of aluminums (0 – 4) in the immediate coordination sphere of Si. This broader distribution of coordination environments is expected for materials with an excess of Si over Al, see G.Engelhardt, D. Michel, *High Resolution Solid State NMR of Silicates and Zeolites*, 1987, John Wiley and Sons, p. 134 – 157. ^{27}Al nmr showed that all the Al is tetrahedral in the UZH-4 material. This is also the case for zeolite Q reported by Andries. The ^{29}Si and ^{27}Al chemical shifts are given for zeolite Q and the higher silica UZH-4 samples in Table 15 below, along with possible interpretations, see G.Engelhardt, D. Michel, *High Resolution Solid State NMR of Silicates and Zeolites*, 1987, John Wiley and Sons, p. 134 – 157. The differences between the UZH-4 and zeolite Q are quite apparent.

Table 16

Sample	Chemical shift(ppm)/interpretation
Zeolite Q, ^{29}Si nmr (Andries et al.)	-84.8, -86.0, -89.9/ $\text{Q}^4(4\text{Al})$
Zeolite Q, ^{27}Al nmr (Andries et al.)	61.2/tetrahedral Al
UZH-4, ^{29}Si nmr (this work)	-84.8 $\text{Q}^4(4\text{Al})$; -89.7 $\text{Q}^4(3\text{Al})$, $\text{Q}^4(4\text{Al})$; -93.6/ $\text{Q}^4(2\text{Al})$; -100.0/ $\text{Q}^4(1\text{Al})$; -104.8/ $\text{Q}^4(0\text{Al})$
UZH-4, ^{27}Al nmr (this work)	57.1 /tetrahedral Al

CLAIMS:

1. A microporous crystalline zeolite having a three dimensional framework of at least AlO_2 and SiO_2 tetrahedral units and an empirical composition on an as synthesized and anhydrous basis expressed by an empirical formula of:



where M is at least one exchangeable cation selected from the group consisting of alkali and alkaline earth metals, "m" is the mole ratio of M to (Al + E) and varies from 0.05 to 0.95, R is at least one organic cation selected from the group consisting of protonated amines, quaternary ammonium ions, 10 diquaternary ammonium ions, protonated alkanolamines and quaternized alkanolammonium ions, "r" is the mole ratio of R to (Al + E) and has a value of 0.05 to 0.95, "n" is the weighted average valence of M and has a value of 1 to 2, "p" is the weighted average valence of R and has a value of 1 to 2, E is an element selected from the group consisting of gallium, iron, boron, 15 chromium, indium and mixtures thereof, "x" is the mole fraction of E and has a value from 0 to 0.5, "y" is the mole ratio of Si to Al and varies from 1.5 to 4.0 and "z" is the mole ratio of O to Al and has a value determined by the equation:

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

20 and is characterized in that it has the x-ray diffraction pattern having the d spacings and intensities set forth in Table A:

Table A

2- θ	d(Å)	I/I ₀ %
6.45 - 6.75	13.69 - 13.08	m
7.52 - 7.80	11.75 - 11.33	vs
14.75 - 15.06	6.00 - 5.88	w-m
15.30 - 15.66	5.79 - 5.65	w
18.70 - 19.05	4.74 - 4.66	w-m
20.23 - 20.51	4.39 - 4.33	w-m
21.30 - 21.61	4.17 - 4.11	m
24.00 - 24.34	3.70 - 3.65	m
26.56 - 26.96	3.35 - 3.30	w-m
27.47 - 27.80	3.24 - 3.21	w-m
28.56 - 28.88	3.12 - 3.09	w
29.95 - 30.31	2.98 - 2.95	m
30.84 - 31.19	2.90 - 2.87	w
33.70 - 34.17	2.66 - 2.62	w
35.45 - 35.92	2.53 - 2.50	w
43.46 - 44.00	2.08 - 2.06	w

and is thermally stable up to a temperature of 400°C.

2. The zeolite of Claim 1 where said zeolite is thermally stable up to a temperature of 600°C.

5 3. The zeolite of Claims 1 or 2 where M is selected from the group consisting of lithium, sodium, cesium, strontium, barium and mixtures thereof and R is a quaternary ammonium ion.

10 4. A process for preparing the microporous crystalline zeolite according to any one of Claims 1-3 comprising forming a reaction mixture containing reactive sources of M, R, Al, Si and optionally E at a temperature of 85°C to 225°C, the reaction mixture having a composition expressed in terms of mole ratios of the oxides of:



15 Where "a" has a value of 0.05 to 1.5, "b" has a value of 1.0 to 15, "c" has a value of 0 to 0.5, "d" has a value of 2.5 to 15, "e" has a value of 25 to 2500.

5. The process of Claim 4 where the aluminum sources are selected from the group consisting of aluminum isopropoxide, aluminum sec-butoxide, precipitated alumina and aluminum metal.
- 5 6. The process of Claim 4 where the silicon sources are selected from the group consisting of tetraethylorthosilicate, colloidal silica, fumed silica and precipitated silica.
- 10 7. The process of Claim 4 where the E sources are selected from the group consisting of alkali borates, boric acid, gallium oxyhydroxide, gallium sulfate, ferric sulfate, ferric chloride, chromium nitrate, indium chloride and mixtures thereof.
8. The use of the zeolite according to any one of Claims 1-3 in a hydrocarbon conversion process comprising contacting the hydrocarbon with the zeolite composite at hydrocarbon conversion conditions to give a converted product.
- 15 9. The process of Claim 8 where the hydrocarbon conversion process is selected from the group consisting of alkylation, isomerization, olefin dimerization, olefin oligomerization and dewaxing.
10. The process of Claim 9 where the hydrocarbon conversion process is isomerization of aromatic compounds.