

ITQ-27, NEW CRYSTALLINE MICROPOROUS MATERIALBACKGROUND OF THE INVENTION

[0001] Microporous materials, including zeolites and silicoaluminophosphates, are widely used in the petroleum industry as absorbents, catalysts and catalyst supports. Their crystalline structures consist of three-dimensional frameworks containing uniform pore openings, channels and internal cages of dimensions ($<20\text{\AA}$) similar to most hydrocarbons. The composition of the frameworks can be such that they are anionic, which requires the presence of non-framework cations to balance the negative charge. These non-framework cations, such as alkali or alkaline earth metal cations, are exchangeable, either entirely or partially with another type of cation utilizing ion exchange techniques in a conventional manner. If these non-framework cations are converted to the proton form by, for example, acid treatments or exchange with ammonium cations followed by calcination to remove the ammonia, it imparts the material with Bronstead acid sites having catalytic activity. The combination of acidity and restricted pore openings gives these materials catalytic properties unavailable with other materials due to their ability to exclude or restrict some of the products, reactants, and/or transition states in many reactions. Non-reactive materials, such as pure silica and aluminophosphate frameworks are also useful and can be used in absorption and separation processes of liquids, gases, and reactive molecules such as alkenes.

[0002] The family of crystalline microporous compositions known as molecular sieves, which exhibit the ion- exchange and/or adsorption characteristics of zeolites are the aluminophosphates, identified by the acronym AlPO, and substituted aluminophosphates as disclosed in U.S. Pat. Nos. 4,310,440 and 4,440,871. U.S. Pat. No. 4,440,871 discloses a class of silica aluminophosphates, which are identified by the acronym SAPO and which have different structures as identified by their X-ray diffraction pattern. The structures

are identified by a numerical number after AIPO, SAPO, MeAPO (Me = metal), etc. (Flanigen et al., *Proc. 7th Int. Zeolite Conf.*, p. 103 (1986) and may include Al and P substitutions by B, Si, Be, Mg, Ge, Zn, Fe, Co, Ni, etc. The present invention is a new molecular sieve having a unique framework structure.

[0003] ExxonMobil and others extensively use various microporous materials, such as faujasite, mordenite, and ZSM-5 in many commercial applications. Such applications include reforming, cracking, hydrocracking, alkylation, oligomerization, dewaxing and isomerization. Any new material has the potential to improve the catalytic performance over those catalysts presently employed.

[0004] There are currently over 150 known microporous framework structures as tabulated by the International Zeolite Association. There exists the need for new structures, having different properties than those of known materials, for improving the performance of many hydrocarbon processes. Each structure has unique pore, channel and cage dimensions, which gives its particular properties as described above. ITQ-27 is a new framework material.

SUMMARY OF THE INVENTION

[0005] ITQ-27 (INSTITUTO DE TECNOLOGÍA QUÍMICA number 27) is a new crystalline microporous material having a framework of tetrahedral atoms connected by bridging atoms, the tetrahedral atom framework being defined by the interconnections between the tetrahedrally coordinated atoms in its framework. ITQ-27 is stable to calcination in air, absorbs hydrocarbons, and is catalytically active for hydrocarbon conversion.

[0006] In one embodiment, the present invention is directed to a new crystalline material which is a silicate compound having a composition $mR:aX_2O_3:YO_2 \cdot nH_2O$ where R is an organic compound, X is any metal capable of tetrahedral coordination such as one or more of B, Ga, Al, Fe, Li, Be, P, Zn, Cr, Mg, Co, Ni, Be, Mn, As, In, Sn, Sb, Ti, and Zr, more preferably one or more

trivalent metals capable of tetrahedral coordination, and even more preferably one or more of the elements B, Ga, Al, and Fe, and Y is Si alone or in combination with any other tetravalent metal capable of tetrahedral coordination such as Ge and Ti and where $m = 0.01 - 1$, $a = 0.00 - 0.2$, and $n = 0 - 10$ and having a unique diffraction pattern as given in Table 2.

[0007] In a more specific embodiment, the present invention is directed to a calcined crystalline silicate compound which has a composition $aX_2O_3:YO_2 \cdot nH_2O$, where X is any metal capable of tetrahedral coordination such as one or more of B, Ga, Al, Fe, Li, Be, P, Zn, Cr, Mg, Co, Ni, Be, Mn, As, In, Sn, Sb, Ti, and Zr, more preferably one or more trivalent metals capable of tetrahedral coordination, and even more preferably one or more of the elements B, Ga, Al, and Fe, and Y is Si alone or in combination with any other tetravalent metal capable of tetrahedral coordination such as Ge and Ti and where $a = 0.00 - 0.2$ and $n = 0 - 10$ and having a unique diffraction pattern as given in Table 3.

[0008] The present invention also includes a method of synthesizing a crystalline silicate compound having the diffraction pattern similar to Table 2, by mixing together a source of silica, organic structure directing agent (SDA), water, and optional metal and heating at a temperature and time sufficient to crystallize the silicate.

[0009] The invention includes the use of ITQ-27 to separate hydrocarbons from a hydrocarbon containing stream.

[0010] The invention also includes the use of ITQ-27 as a hydrocarbon conversion catalyst for converting an organic feedstock to conversion products.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIGURE 1 is a representation of diphenyl dimethyl phosphonium the organic structure directing agent (SDA).

[0012] FIGURE 2 shows the framework structure of ITQ-27 showing only the tetrahedral atoms. There are four unit cells, whose edges are defined by the gray boxes.

[0013] FIGURE 3 shows the X-ray diffraction pattern of as-synthesized ITQ-27 and of calcined/dehydrated ITQ-27.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] The present invention is a new structure of crystalline material. As with any porous crystalline material, the structure of ITQ-27 can be defined by the interconnections between the tetrahedrally coordinated atoms in its framework. In particular, ITQ-27 has a framework of tetrahedral (T) atoms connected by bridging atoms, wherein the tetrahedral atom framework is defined by connecting the nearest tetrahedral (T) atoms in the manner shown in **Table 1**.

Table 1
ITQ-27 tetrahedral atom interconnections

T atom	Connected to:
T1	T43, T49, T115, T129
T2	T44, T50, T116, T130
T3	T41, T51, T113, T131
T4	T42, T52, T114, T132
T5	T41, T53, T119, T132
T6	T42, T54, T120, T131
T7	T43, T55, T117, T130
T8	T44, T56, T118, T129
T9	T47, T57, T123, T133
T10	T48, T58, T124, T134
T11	T45, T59, T121, T135
T12	T46, T60, T122, T136
T13	T45, T61, T127, T136
T14	T46, T62, T128, T135
T15	T47, T63, T125, T134
T16	T48, T64, T126, T133
T17	T35, T65, T99, T137
T18	T36, T66, T100, T138
T19	T33, T67, T97, T139
T20	T34, T68, T98, T140
T21	T33, T69, T103, T140
T22	T34, T70, T104, T139
T23	T35, T71, T101, T138

T24	T36, T72, T102, T137
T25	T39, T73, T107, T141
T26	T40, T74, T108, T142
T27	T37, T75, T105, T143
T28	T38, T76, T106, T144
T29	T37, T77, T111, T144
T30	T38, T78, T112, T143
T31	T39, T79, T109, T142
T32	T40, T80, T110, T141
T33	T19, T21, T43, T145
T34	T20, T22, T44, T145
T35	T17, T23, T41, T146
T36	T18, T24, T42, T146
T37	T27, T29, T47, T147
T38	T28, T30, T48, T147
T39	T25, T31, T45, T148
T40	T26, T32, T46, T148
T41	T3, T5, T35, T149
T42	T4, T6, T36, T149
T43	T1, T7, T33, T150
T44	T2, T8, T34, T150
T45	T11, T13, T39, T151
T46	T12, T14, T40, T151
T47	T9, T15, T37, T152
T48	T10, T16, T38, T152
T49	T1, T54, T55, T56
T50	T2, T53, T55, T56
T51	T3, T53, T54, T56
T52	T4, T53, T54, T55
T53	T5, T50, T51, T52
T54	T6, T49, T51, T52
T55	T7, T49, T50, T52
T56	T8, T49, T50, T51
T57	T9, T62, T63, T64
T58	T10, T61, T63, T64
T59	T11, T61, T62, T64
T60	T12, T61, T62, T63
T61	T13, T58, T59, T60
T62	T14, T57, T59, T60
T63	T15, T57, T58, T60
T64	T16, T57, T58, T59
T65	T17, T70, T71, T72
T66	T18, T69, T71, T72
T67	T19, T69, T70, T72
T68	T20, T69, T70, T71
T69	T21, T66, T67, T68
T70	T22, T65, T67, T68
T71	T23, T65, T66, T68
T72	T24, T65, T66, T67
T73	T25, T78, T79, T80

T74	T26, T77, T79, T80
T75	T27, T77, T78, T80
T76	T28, T77, T78, T79
T77	T29, T74, T75, T76
T78	T30, T73, T75, T76
T79	T31, T73, T74, T76
T80	T32, T73, T74, T75
T81	T88, T97, T104, T129
T82	T87, T98, T103, T130
T83	T86, T99, T102, T131
T84	T85, T100, T101, T132
T85	T84, T105, T112, T133
T86	T83, T106, T111, T134
T87	T82, T107, T110, T135
T88	T81, T108, T109, T136
T89	T96, T113, T120, T137
T90	T95, T114, T119, T138
T91	T94, T115, T118, T139
T92	T93, T116, T117, T140
T93	T92, T121, T128, T141
T94	T91, T122, T127, T142
T95	T90, T123, T126, T143
T96	T89, T124, T125, T144
T97	T19, T81, T115, T122
T98	T20, T82, T116, T121
T99	T17, T83, T113, T124
T100	T18, T84, T114, T123
T101	T23, T84, T119, T126
T102	T24, T83, T120, T125
T103	T21, T82, T117, T128
T104	T22, T81, T118, T127
T105	T27, T85, T114, T123
T106	T28, T86, T113, T124
T107	T25, T87, T116, T121
T108	T26, T88, T115, T122
T109	T31, T88, T118, T127
T110	T32, T87, T117, T128
T111	T29, T86, T120, T125
T112	T30, T85, T119, T126
T113	T3, T89, T99, T106
T114	T4, T90, T100, T105
T115	T1, T91, T97, T108
T116	T2, T92, T98, T107
T117	T7, T92, T103, T110
T118	T8, T91, T104, T109
T119	T5, T90, T101, T112
T120	T6, T89, T102, T111
T121	T11, T93, T98, T107
T122	T12, T94, T97, T108
T123	T9, T95, T100, T105

T124	T10, T96, T99, T106
T125	T15, T96, T102, T111
T126	T16, T95, T101, T112
T127	T13, T94, T104, T109
T128	T14, T93, T103, T110
T129	T1, T8, T81, T145
T130	T2, T7, T82, T145
T131	T3, T6, T83, T146
T132	T4, T5, T84, T146
T133	T9, T16, T85, T147
T134	T10, T15, T86, T147
T135	T11, T14, T87, T148
T136	T12, T13, T88, T148
T137	T17, T24, T89, T149
T138	T18, T23, T90, T149
T139	T19, T22, T91, T150
T140	T20, T21, T92, T150
T141	T25, T32, T93, T151
T142	T26, T31, T94, T151
T143	T27, T30, T95, T152
T144	T28, T29, T96, T152
T145	T33, T34, T129, T130
T146	T35, T36, T131, T132
T147	T37, T38, T133, T134
T148	T39, T40, T135, T136
T149	T41, T42, T137, T138
T150	T43, T44, T139, T140
T151	T45, T46, T141, T142
T152	T47, T48, T143, T144

[0015] Tetrahedral atoms are those capable of having tetrahedral coordination, including one or more of, but not limiting, lithium, beryllium, boron, magnesium, aluminum, silicon, phosphorous, titanium, chromium, manganese, iron, cobalt, nickel, copper, zinc, zirconium, gallium, germanium, arsenic, indium, tin, and antimony.

[0016] In one embodiment, this new crystalline silicate compound has a composition $mR:aX_2O_3:YO_2 \cdot nH_2O$ where R is an organic compound, and X is any metal capable of tetrahedral coordination such as one or more of B, Ga, Al, Fe, Li, Be, P, Zn, Cr, Mg, Co, Ni, Be, Mn, As, In, Sn, Sb, Ti, and Zr, more preferably one or more trivalent metals capable of tetrahedral coordination, and even more preferably one or more of the elements B, Ga, Al, and Fe, and Y is Si alone or in combination with any other tetravalent metal capable of tetrahedral

coordination such as Ge and Ti, and where $m = 0.01 - 1$, $a = 0.00 - 0.2$, and $n = 0 - 10$. This compound has the unique diffraction pattern given in **Table 2** and shown in Figure 3.

Table 2

d(Å)	relative int. (%)
14.1-13.3	60-100
13.1-12.3	5-50
11.4-10.8	80-100
6.99-6.77	20-70
4.93-4.82	60-100
4.77-4.67	20-70
4.73-4.63	20-70
4.51-4.42	20-70
4.29-4.21	60-100
4.11-4.03	30-80
3.86-3.79	50-90
3.65-3.59	30-80
3.53-3.47	20-70
3.48-3.43	30-80
3.42-3.37	5-50
3.38-3.33	60-100
3.23-3.18	5-50
3.06-3.02	5-50

[0017] Other embodiments of the new structure include a calcined compound of composition $aX_2O_3:YO_2 \cdot nH_2O$, where X is any metal capable of tetrahedral coordination such as one or more of B, Ga, Al, Fe, Li, Be, P, Zn, Cr, Mg, Co, Ni, Be, Mn, As, In, Sn, Sb, Ti, and Zr, more preferably one or more trivalent metals capable of tetrahedral coordination, and even more preferably one or more of the elements B, Ga, Al, Fe, and Y is Si alone or in combination with any other tetravalent metal capable of tetrahedral coordination such as Ge and Ti and where $a = 0.00 - 0.2$, and $n = 0 - 10$. This compound has the unique diffraction pattern given in **Table 3** and Figure 3.

Table 3

d(Å)	relative int. (%)
14.2-13.4	80-100
11.3-10.8	50-90
4.93-4.83	30-80
4.72-4.62	50-90
4.49-4.41	5-40
4.26-4.18	30-80
4.06-3.99	20-70
3.87-3.80	30-80
3.63-3.58	30-80
3.49-3.44	20-70
3.36-3.31	30-80
3.21-3.16	5-40
3.06-3.02	5-40
2.545-2.518	5-40

[0018] This new compound is made by the method of mixing together a source of silica, organic structure directing agent (SDA), water, and optional source of metal and heating at a temperature and time sufficient to crystallize the silicate. The method is described below.

[0019] The synthetic porous crystalline material of this invention, ITQ-27, is a crystalline phase which has a unique 2-dimensional channel system comprising intersecting 12-membered rings of tetrahedrally coordinated atoms. The 12-membered ring channels have cross-sectional dimensions between the bridging oxygen atoms of about 7.4 Angstroms by about 7.1 Angstroms.

[0020] Variations in the X-ray diffraction pattern may occur between the different chemical composition forms of ITQ-27, such that the exact ITQ-27 structure can vary due its particular composition and whether or not it has been calcined and rehydrated.

[0021] In the as-synthesized form ITQ-27 has a characteristic X-ray diffraction pattern, the essential lines of which are given in Table 2 measured with Cu K α radiation. Variations occur as a function of specific composition

and its loading in the structure. For this reason the intensities and d-spacings are given as ranges.

[0022] The ITQ-27 material of the present invention may be calcined to remove the organic templating agent without loss of crystallinity. This is useful for activating the material for subsequent absorption of other guest molecules such as hydrocarbons. The essential lines, which uniquely define calcined/dehydrated ITQ-27 are shown in **Table 3** measured with Cu K α radiation. Variations occur as a function of specific composition, temperature and the level of hydration in the structure.

[0023] In addition, to describing the structure of ITQ-27 by the interconnections of the tetrahedral atoms as in Table 1 above, it may be defined by its unit cell, which is the smallest repeating unit containing all the structural elements of the material. The pore structure of ITQ-27 is illustrated in FIGURE 2 (which shows only the tetrahedral atoms) down the direction of the 12-membered ring channel. There is a single unit cell unit in FIGURE 2, whose limits are defined by the box. **Table 4** lists the typical positions of each tetrahedral atom in the unit cell in units of Angstroms. Each tetrahedral atom is bonded to bridging atoms, which are also bonded to adjacent tetrahedral atoms. Tetrahedral atoms are those capable of having tetrahedral coordination, including one or more of, but not limiting, lithium, beryllium, boron, magnesium, aluminum, silicon, phosphorous, titanium, chromium, manganese, iron, cobalt, nickel, copper, zinc, zirconium, gallium, germanium, arsenic, indium, tin, and antimony. Bridging atoms are those capable of connecting two tetrahedral atoms, examples which include, but not limiting, oxygen, nitrogen, fluorine, sulfur, selenium, and carbon atoms.

[0024] In the case of oxygen, it is also possible that the bridging oxygen is also connected to a hydrogen atom to form a hydroxyl group (-OH-). In the case of carbon it is also possible that the carbon is also connected to two hydrogen atoms to form a methylene group (-CH₂-). For example, bridging methylene

groups have been seen in the zirconium diphosphonate, MIL-57. See: C. Serre, G. Férey, *J. Mater. Chem.* **12**, p. 2367 (2002). Bridging sulfur and selenium atoms have been seen in the UCR-20-23 family of microporous materials. See: N. Zheng, X. Bu, B. Wang, P. Feng, *Science* **298**, p. 2366 (2002). Bridging fluorine atoms have been seen in lithium hydrazinium fluoroberyllate, which has the ABW structure type. See: M.R. Anderson, I.D. Brown, S. Vilminot, *Acta Cryst.* **B29**, p. 2626 (1973). Since tetrahedral atoms may move about due to other crystal forces (presence of inorganic or organic species, for example), or by the choice of tetrahedral and bridging atoms, a range of ± 0.5 Angstrom is implied for the x coordinate positions and a range of ± 1.0 Angstrom for the y and z coordinate positions.

Table 4

Positions of tetrahedral (T) atoms for the ITQ-27 structure. Values, in units of Angstroms, are approximate and are typical when T = silicon and the bridging atoms are oxygen.

Atom	x(Å)	y(Å)	z(Å)
T1	2.766	2.569	4.038
T2	11.191	23.531	4.038
T3	11.191	2.569	23.712
T4	2.766	23.531	23.712
T5	11.191	23.531	23.712
T6	2.766	2.569	23.712
T7	2.766	23.531	4.038
T8	11.191	2.569	4.038
T9	2.766	15.619	17.913
T10	11.191	10.481	17.913
T11	11.191	15.619	9.837
T12	2.766	10.481	9.837
T13	11.191	10.481	9.837
T14	2.766	15.619	9.837
T15	2.766	10.481	17.913
T16	11.191	15.619	17.913
T17	9.744	2.569	17.913
T18	4.213	23.531	17.913
T19	4.213	2.569	9.837
T20	9.744	23.531	9.837
T21	4.213	23.531	9.837
T22	9.744	2.569	9.837

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T23	9.744	23.531	17.913
T24	4.213	2.569	17.913
T25	9.744	15.619	4.038
T26	4.213	10.481	4.038
T27	4.213	15.619	23.712
T28	9.744	10.481	23.712
T29	4.213	10.481	23.712
T30	9.744	15.619	23.712
T31	9.744	10.481	4.038
T32	4.213	15.619	4.038
T33	2.929	0.000	8.443
T34	11.028	0.000	8.443
T35	11.028	0.000	19.307
T36	2.929	0.000	19.307
T37	2.929	13.050	22.318
T38	11.028	13.050	22.318
T39	11.028	13.050	5.432
T40	2.929	13.050	5.432
T41	9.908	0.000	22.318
T42	4.049	0.000	22.318
T43	4.049	0.000	5.432
T44	9.908	0.000	5.432
T45	9.908	13.050	8.443
T46	4.049	13.050	8.443
T47	4.049	13.050	19.307
T48	9.908	13.050	19.307
T49	1.516	1.574	1.546
T50	12.441	24.526	1.546
T51	12.441	1.574	26.204
T52	1.516	24.526	26.204
T53	12.441	24.526	26.204
T54	1.516	1.574	26.204
T55	1.516	24.526	1.546
T56	12.441	1.574	1.546
T57	1.516	14.624	15.421
T58	12.441	11.476	15.421
T59	12.441	14.624	12.329
T60	1.516	11.476	12.329
T61	12.441	11.476	12.329
T62	1.516	14.624	12.329
T63	1.516	11.476	15.421
T64	12.441	14.624	15.421
T65	8.494	1.574	15.421
T66	5.463	24.526	15.421
T67	5.463	1.574	12.329
T68	8.494	24.526	12.329
T69	5.463	24.526	12.329
T70	8.494	1.574	12.329
T71	8.494	24.526	15.421
T72	5.463	1.574	15.421

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T73	8.494	14.624	1.546
T74	5.463	11.476	1.546
T75	5.463	14.624	26.204
T76	8.494	11.476	26.204
T77	5.463	11.476	26.204
T78	8.494	14.624	26.204
T79	8.494	11.476	1.546
T80	5.463	14.624	1.546
T81	0.000	5.086	7.648
T82	0.000	21.014	7.648
T83	0.000	5.086	20.102
T84	0.000	21.014	20.102
T85	0.000	18.136	21.523
T86	0.000	7.964	21.523
T87	0.000	18.136	6.227
T88	0.000	7.964	6.227
T89	6.978	5.086	21.523
T90	6.978	21.014	21.523
T91	6.978	5.086	6.227
T92	6.978	21.014	6.227
T93	6.978	18.136	7.648
T94	6.978	7.964	7.648
T95	6.978	18.136	20.102
T96	6.978	7.964	20.102
T97	2.956	5.057	8.417
T98	11.001	21.043	8.417
T99	11.001	5.057	19.333
T100	2.956	21.043	19.333
T101	11.001	21.043	19.333
T102	2.956	5.057	19.333
T103	2.956	21.043	8.417
T104	11.001	5.057	8.417
T105	2.956	18.107	22.292
T106	11.001	7.993	22.292
T107	11.001	18.107	5.458
T108	2.956	7.993	5.458
T109	11.001	7.993	5.458
T110	2.956	18.107	5.458
T111	2.956	7.993	22.292
T112	11.001	18.107	22.292
T113	9.934	5.057	22.292
T114	4.023	21.043	22.292
T115	4.023	5.057	5.458
T116	9.934	21.043	5.458
T117	4.023	21.043	5.458
T118	9.934	5.057	5.458
T119	9.934	21.043	22.292
T120	4.023	5.057	22.292
T121	9.934	18.107	8.417
T122	4.023	7.993	8.417

T123	4.023	18.107	19.333
T124	9.934	7.993	19.333
T125	4.023	7.993	19.333
T126	9.934	18.107	19.333
T127	9.934	7.993	8.417
T128	4.023	18.107	8.417
T129	0.000	2.598	5.641
T130	0.000	23.502	5.641
T131	0.000	2.598	22.109
T132	0.000	23.502	22.109
T133	0.000	15.648	19.516
T134	0.000	10.452	19.516
T135	0.000	15.648	8.234
T136	0.000	10.452	8.234
T137	6.978	2.598	19.516
T138	6.978	23.502	19.516
T139	6.978	2.598	8.234
T140	6.978	23.502	8.234
T141	6.978	15.648	5.641
T142	6.978	10.452	5.641
T143	6.978	15.648	22.109
T144	6.978	10.452	22.109
T145	0.000	0.000	7.528
T146	0.000	0.000	20.222
T147	0.000	13.050	21.403
T148	0.000	13.050	6.347
T149	6.978	0.000	21.403
T150	6.978	0.000	6.347
T151	6.978	13.050	7.528
T152	6.978	13.050	20.222

[0025] The complete structure of ITQ-27 is built by connecting multiple unit cells as defined above in a fully-connected three-dimensional framework. The tetrahedral atoms in one unit cell are connected to certain tetrahedral atoms in all of its adjacent unit cells. While **Table 1** lists the connections of all the tetrahedral atoms for a given unit cell of ITQ-27, the connections may not be to the particular atom in the same unit cell but to an adjacent unit cell. All of the connections listed in **Table 1** are such that they are to the closest tetrahedral (T) atoms, regardless of whether they are in the same unit cell or in adjacent unit cells.

[0026] Although the Cartesian coordinates given in **Table 4** may accurately reflect the positions of tetrahedral atoms in an idealized structure, the true

structure can be more accurately described by the connectivity between the framework atoms as shown in Table 1 above.

[0027] Another way to describe this connectivity is by the use of coordination sequences as applied to microporous frameworks by W.M. Meier and H.J. Moeck, in the *Journal of Solid State Chemistry* **27**, p. 349 (1979). In a microporous framework, each tetrahedral atom, N_0 , (T-atom) is connected to $N_1 = 4$ neighboring T-atoms through bridging atoms (typically oxygen). These neighboring T-atoms are then connected to N_2 T-atoms in the next shell. The N_2 atoms in the second shell are connected to N_3 T-atoms in the third shell, and so on. Each T-atom is only counted once, such that, for example, if a T-atom is in a 4-membered ring, at the fourth shell the N_0 atom is not counted second time, and so on. Using this methodology, a coordination sequence can be determined for each unique T-atom of a 4-connected net of T-atoms. The following line lists the maximum number of T-atoms for each shell.

$$N_0 = 1 \quad N_1 \leq 4 \quad N_2 \leq 12 \quad N_3 \leq 36 \quad N_k \leq 4 \cdot 3^{k-1}$$

Table 5

Coordination sequence for ITQ-27 structure.

atom number	atom label	coordination sequence														
1	T(1)	4	12	20	32	50	74	101	135	167	203	254	307	347		
2	T(2)	4	12	22	32	45	69	101	137	167	199	244	303	362		
3	T(3)	4	9	18	32	52	78	105	130	164	213	264	310	350		
4	T(4)	4	12	20	34	50	67	100	141	178	214	232	278	364		
5	T(5)	4	11	21	34	49	72	101	138	177	204	243	292	353		
6	T(6)	4	12	20	28	49	69	100	136	166	201	245	292	353		
7	T(7)	4	12	24	32	40	66	108	136	168	196	240	298	368		

[0028] One way to determine the coordination sequence for a given structure is from the atomic coordinates of the framework atoms using the computer program zeoTsites (see G. Sastre, J.D. Gale, *Microporous and mesoporous Materials* **43**, p. 27 (2001)).

[0029] The coordination sequence for the ITQ-27 structure is given in. The T-atom connectivity as listed in Table 1 and is for T-atoms only. Bridging

atoms, such as oxygen usually connects the T-atoms. Although most of the T-atoms are connected to other T-atoms through bridging atoms, it is recognized that in a particular crystal of a material having a framework structure, it is possible that a number of T-atoms may not be connected to one another. Reasons for non-connectivity include, but are not limited by, T-atoms located at the edges of the crystals and by defects sites caused by, for example, vacancies in the crystal. The framework listed in **Table 1** and **Table 5** is not limited in any way by its composition, unit cell dimensions or space group symmetry. space group symmetry.

[0030] While the idealized structure contains only 4-coordinate T-atoms, it is possible under certain conditions that some of the framework atoms may be 5- or 6-coordinate. This may occur, for example, under conditions of hydration when the composition of the material contains mainly phosphorous and aluminum T-atoms. When this occurs it is found that T-atoms may be also coordinated to one or two oxygen atoms of water molecules ($-\text{OH}_2$), or of hydroxyl groups ($-\text{OH}$). For example, the molecular sieve $\text{AlPO}_4\text{-34}$ is known to reversibly change the coordination of some aluminum T-atoms from 4-coordinate to 5- and 6-coordinate upon hydration as described by A. Tuel et al. in *J. Phys. Chem. B* **104**, p. 5697 (2000). It is also possible that some framework T-atoms can be coordinated to fluoride atoms ($-\text{F}$) when materials are prepared in the presence of fluorine to make materials with 5-coordinate T-atoms as described by H. Koller in *J. Am. Chem Soc.* **121**, p. 3368 (1999).

[0031] The invention also includes a method of synthesizing a crystalline silicate composition of ITQ-27 having the diffraction pattern similar to **Table 2** by mixing together a source of silica, organic structure directing agent (SDA), water, and optional metal, X, with a composition, in terms of mole ratios, within the following ranges:

R/YO ₂	0.01 - 1
H ₂ O/ YO ₂	2-50
X/ YO ₂	0 - .2

and preferably within the following ranges:

R/ YO ₂	0.1 - .5
H ₂ O/ YO ₂	5 - 20
X/ YO ₂	0 - .1

and X is any metal capable of tetrahedral coordination such as one or more of B, Ga, Al, Fe, Li, Be, P, Zn, Cr, Mg, Co, Ni, Be, Mn, As, In, Sn, Sb, Ti, and Zr, more preferably one or more trivalent metals capable of tetrahedral coordination, and even more preferably one or more of the elements B, Ga, Al, and Fe, and Y is Si alone or in combination with any other tetravalent metal capable of tetrahedral coordination such as Ge and Ti.

[0032] Said organic structure directing agent (SDA) is preferably diphenyl-dimethyl-phosphonium. See FIGURE 1. Sources of silica can be colloidal, fumed or precipitated silica, silica gel, sodium or potassium silicates, or organic silicon such as tetraethylorthosilicate, etc. Sources of metal can be boric acid, germanium(IV) ethoxide, germanium oxide, germanium nitrate, aluminum nitrate, sodium aluminate, aluminum sulfate, aluminum hydroxide, aluminum chloride and various salts of the metals X such as iron nitrate, iron chloride, and gallium nitrate, etc. The mixture is then heated at a temperature and time sufficient to crystallize the silicate.

[0033] To the extent desired and depending on the X₂O₃/YO₂ molar ratio of the material, any cations present in the as-synthesized ITQ-27 can be replaced in accordance with techniques well known in the art by ion exchange with other cations. Preferred replacing cations include metal ions, hydrogen ions, and hydrogen precursor, e.g., ammonium ions and mixtures thereof. Particularly preferred cations are those which tailor the catalytic activity for certain

hydrocarbon conversion reactions. These include hydrogen, rare earth metals and metals of Groups IIA, IIIA, IVA, VA, IB, IIB, IIIB, IVB, VB, VIB, VIIB and VIII of the Periodic Table of the Elements.

[0034] The crystalline material of this invention can be used to catalyze a wide variety of chemical conversion processes, particularly organic compound conversion processes, including many of present commercial/industrial importance. Examples of chemical conversion processes which are effectively catalyzed by the crystalline material of this invention, by itself or in combination with one or more other catalytically active substances including other crystalline catalysts, include those requiring a catalyst with acid activity.

[0035] Thus, in its active form ITQ-27 can exhibit a high acid activity, which can be measured with the alpha test. Alpha value is an approximate indication of the catalytic cracking activity of the catalyst compared to a standard catalyst and it gives the relative rate constant (rate of normal hexane conversion per volume of catalyst per unit time). It is based on the activity of silica-alumina cracking catalyst taken as an Alpha of 1 (Rate Constant=0.016 sec⁻¹). The Alpha Test is described in U. S. Pat. No. 3,354,078; in the *Journal of Catalysis* 4, 527 (1965); 6, 278 (1966); and 61, 395 (1980), each incorporated herein by reference as to that description. The experimental conditions of the test used herein include a constant temperature of 538° C. and a variable flow rate as described in detail in the *Journal of Catalysis* 61, 395 (1980).

[0036] When used as a catalyst, the crystalline material of the invention may be subjected to treatment to remove part or all of any organic constituent. This is conveniently effected by thermal treatment in which the as-synthesized material is heated at a temperature of at least about 370° C for at least 1 minute and generally not longer than 20 hours. While subatmospheric pressure can be employed for the thermal treatment, atmospheric pressure is desired for reasons of convenience. The thermal treatment can be performed at a temperature up to about 927° C. The thermally treated product, especially in its metal, hydrogen

and ammonium forms, is particularly useful in the catalysis of certain organic, e.g., hydrocarbon, conversion reactions.

[0037] When used as a catalyst, the crystalline material can be intimately combined with a hydrogenating component such as tungsten, vanadium, molybdenum, rhenium, nickel, cobalt, chromium, manganese, or a noble metal such as, but not limited to, platinum or palladium where a hydrogenation-dehydrogenation function is to be performed. Such component can be in the composition by way of co-crystallization, exchanged into the composition to the extent a Group IIIA element, e.g., aluminum, is in the structure, impregnated therein or intimately physically admixed therewith. Such component can be impregnated in or on to it such as, for example, by, in the case of platinum, treating ITQ-27 with a solution containing a platinum metal-containing ion. Thus, suitable platinum compounds for this purpose include chloroplatinic acid, platinous chloride and various compounds containing the platinum amine complex.

[0038] The crystalline material of this invention, when employed either as an adsorbent or as a catalyst in an organic compound conversion process should be dehydrated, at least partially. This can be done by heating to a temperature in the range of 100° C to about 370° C. in an atmosphere such as air, nitrogen, etc., and at atmospheric, subatmospheric or superatmospheric pressures for between 30 minutes and 48 hours. Dehydration can also be performed at room temperature merely by placing the ITQ-27 in a vacuum, but a longer time is required to obtain a sufficient amount of dehydration.

[0039] As in the case of many catalysts, it may be desirable to incorporate the new crystal with another material resistant to the temperatures and other conditions employed in organic conversion processes. Such materials include active and inactive materials and synthetic or naturally occurring zeolites as well as inorganic materials such as clays, silica and/or metal oxides such as alumina. The latter may be either naturally occurring or in the form of gelatinous

precipitates or gels including mixtures of silica and metal oxides. Use of a material in conjunction with the new crystal, i.e., combined therewith or present during synthesis of the new crystal, which is active, tends to change the conversion and/or selectivity of the catalyst in certain organic conversion processes. Inactive materials suitably serve as diluents to control the amount of conversion in a given process so that products can be obtained economically and orderly without employing other means for controlling the rate of reaction. These materials may be incorporated into naturally occurring clays, e.g., bentonite and kaolin, to improve the crush strength of the catalyst under commercial operating conditions. Said materials, i.e., clays, oxides, etc., function as binders for the catalyst. It is desirable to provide a catalyst having good crush strength because in commercial use it is desirable to prevent the catalyst from breaking down into powder-like materials. These clay and/or oxide binders have been employed normally only for the purpose of improving the crush strength of the catalyst.

[0040] Naturally occurring clays which can be composited with the new crystal include the montmorillonite and kaolin family, which families include the subbentonites, and the kaolins commonly known as Dixie, McNamee, Georgia and Florida clays or others in which the main mineral constituent is halloysite, kaolinite, dickite, nacrite, or anauxite. Such clays can be used in the raw state as originally mined or initially subjected to calcination, acid treatment or chemical modification. Binders useful for compositing with the present crystal also include inorganic oxides, such as silica, zirconia, titania, magnesia, beryllia, alumina, and mixtures thereof.

[0041] In addition to the foregoing materials, the new crystal can be composited with a porous matrix material such as silica-alumina, silica-magnesia, silica-zirconia, silica-thoria, silica-beryllia, silica-titania as well as ternary compositions such as silica-alumina-thoria, silica-alumina-zirconia, silica-alumina-magnesia and silica-magnesia-zirconia.

[0042] The relative proportions of finely divided crystalline material and inorganic oxide matrix vary widely, with the crystal content ranging from about 1 to about 90 percent by weight and more usually, particularly when the composite is prepared in the form of beads, in the range of about 2 to about 80 weight percent of the composite.

[0043] In order to more fully illustrate the nature of the invention and the manner of practicing same, the following examples are presented.

EXAMPLES

EXAMPLE 1: Synthesis of diphenyl-dimethyl-phosphonium

[0044] The diphenyl-dimethyl-phosphonium template, as shown in FIGURE 1, was obtained by methylation of diphenylphosphine with methyl iodide in chloroform in the presence of K_2CO_3 . It was then converted to the corresponding hydroxide with an anionic exchange resin in batch overnight. 10.80 g (0.058 mol) of diphenylphosphine was dissolved in 50 ml of isopropanol under nitrogen atmosphere (or in absence of water). 9.55 g of potassium carbonate sesquihydrate was then added and the mixture was stirred. Finally, 24.60 g (0.173 mol) of methyl iodide was added dropwise. After 48 hours, 8 g of methyl iodide was added again and the mixture was left for a total time of five days.

[0045] Using standard methods, the isopropanol was eliminated and the solid washed with chloroform. The product was then dissolved in chloroform. The chloroform was evaporated and the solid was washed with diethyl ether and dried under vacuum. 18.426 g of diphenyl-dimethyl-phosphonium iodide was obtained (93.2 %wt. yield).

[0046] This 18.426 g of diphenyl-dimethyl-phosphonium iodide, previously dissolved in water, was converted to the corresponding hydroxide with 58.15 g of an anionic exchange resin in batch overnight, yielding 183.52 g of a 0.27 M

solution of diphenyl-dimethyl-phosphonium hydroxide (92 % of exchange yield) that will be used as SDA source.

EXAMPLE 2: Synthesis of ITQ-27

[0047] The synthesis was carried out under hydrothermal conditions in Teflon-lined stainless steel autoclaves and continuous stirring from a gel of composition:



[0048] In this synthesis, 9.73 g of tetraethylorthosilicate (TEOS) and 0.28 g of aluminium isopropoxide were hydrolyzed in 86.01 g of diphenyl-dimethyl-phosphonium hydroxide ($\text{Me}_2\text{Ph}_2\text{POH}$) solution with a concentration of 0.27 mol/1000 g of solution. Then, the mixture was stirred at room temperature until the Si and Al precursors were completely hydrolysed and the gel concentration was reached. Finally, 0.97 g of a HF solution (48 %wt.) was added and the mixture was homogenized by stirring and autoclaved at 150°C under tumbling for 64 days. The solid recovered by filtration, washed with distilled water and dried at 373 K is pure ITQ-27.

EXAMPLE 3: Synthesis of ITQ-27

[0049] The synthesis of ITQ-27 was carried out by hydrolyzing 0.32 g of aluminum isopropoxide and 11.50 g of tetraethylorthosilicate (TEOS) in 95.04 g of diphenyl-dimethyl-phosphonium ($\text{Me}_2\text{Ph}_2\text{P}$) hydroxide with a concentration of 0.29 mol/1000 g of solution. This mixture was concentrated under stirring and the alcohols formed in the hydrolysis were totally evaporated. 1.14 g of a HF solution (48.1 %wt.) was added and the mixture was left under stirring until complete evaporation of the excess water. Seeding crystals of ITQ-27 with a small amount of amorphous material were added (5 %wt. respect to the total silica in the mixture). The composition of the gel was:



The mixture was heated under tumbling in Teflon-lined stainless steel autoclaves for 48 days. The product was pure ITQ-27. The sample was calcined in air to 580°C for 3 hours.

[0050] The X-ray diffraction pattern of this material as made and calcined is shown in FIGURE 3 and given in **Table 6** and **Table 7**. The porosity of the calcined ITQ-27 sample was measured by adsorbing nitrogen and argon. The results obtained are:

- Bet surface area: 450 m²/g
- Micropore area: 434 m²/g
- Micropore, volume: 0.21 cm³/g
- Pore diameter: 6.7 Å

Table 6
X-ray diffraction lines for as-made ITQ-27

2Theta ± 0.2 (°)	d-spacing (Å)	I/I ₀ (%)
6.45	13.69	94
6.96	12.69	25
7.98	11.07	100
9.47	9.34	17
12.64	7.00	12
12.86	6.88	31
14.36	6.17	18
18.19	4.87	83
18.80	4.72	39
18.96	4.68	30
19.48	4.55	9
19.85	4.47	41
20.91	4.24	82
21.83	4.07	58
23.23	3.83	75
24.59	3.62	66
25.42	3.50	45
25.78	3.45	64
26.24	3.39	21
26.58	3.35	96
27.81	3.21	24
29.32	3.04	25
30.03	2.97	17
32.18	2.78	16
35.68	2.51	11
38.92	2.31	8

Table 7
X-ray diffraction lines for calcined ITQ-27

2Theta $\pm$ 0.2 ($^{\circ}$)	d-spacing ($\text{\AA}$)	I/I ₀ (%)
6.40	13.79	100
7.01	12.59	13
8.01	11.04	78
9.49	9.31	11
12.76	6.93	11
12.89	6.86	11
18.17	4.88	52
19.00	4.67	73
19.94	4.45	17
21.04	4.22	60
22.06	4.03	38
23.18	3.83	57
24.68	3.60	58
25.42	3.50	13
25.71	3.46	32
25.92	3.43	13
26.41	3.37	11
26.68	3.34	60
27.99	3.18	18
29.32	3.04	15
30.00	2.98	8
32.17	2.78	7
35.43	2.53	14
35.98	2.49	7
37.73	2.38	7
38.49	2.34	10

CLAIMS:

1. A synthetic crystalline material having a framework of tetrahedral atoms (T) connected by bridging atoms, the tetrahedral atom framework being defined by connecting the nearest tetrahedral (T) atoms in the manner shown in **Table 1** of the specification.
2. The crystalline material of claim 1 wherein said tetrahedral atoms include one or more elements selected from the group consisting of Li, Be, Al, P, Si, Ga, Ge, Zn, Cr, Mg, Fe, Co, Ni, Be, Mn, As, In., Sn, Sb, Ti, and Zr.
3. The crystalline material of claim 1 wherein said bridging atoms include one or more elements selected from the group consisting of O, N, F, S, Se, and C.
4. A synthetic porous crystalline material, as synthesized, characterized by an X-ray diffraction pattern including the peaks as substantially set forth in Table 2 of the specification.
5. The crystalline material of Claim 4 wherein said crystalline material has a composition $mR:aX_2O_3:YO_2 \cdot nH_2O$ where R is an organic compound, X is one or more metals selected from the group consisting of B, Ga, Al and Fe, and Y is one or more metals selected from the group consisting of Si, Ge and Ti, and m, a, and n are real numbers less than or equal to 10.
6. A calcined dehydrated material characterized by an X-ray diffraction pattern including the most significant lines substantially, as set forth in Table 3 of the specification.
7. The calcined dehydrated material of Claim 6 wherein said crystalline material has a composition $aX_2O_3:YO_2 \cdot nH_2O$ where X is one or more metals selected from the group consisting of B, Ga, Al and Fe, and Y is

one or more metals selected from the group consisting of Si, Ge and Ti, and a and n are real numbers less than or equal to 10.

8. A process for the separation of hydrocarbons from a hydrocarbon-containing stream using any of the materials of claims 1 through claim 7.

9. A process for converting a feedstock comprising organic compounds to at least one conversion product which comprises contacting said feedstock at organic compound conversion conditions with a catalyst comprising an active form of any of the materials of claims 1 through claim 7.

10. The process for converting a feedstock as in claim 9 wherein the catalyst is combined with a hydrogenating metal.

11. The process for converting a feedstock as in claim 10 wherein said hydrogenating metal is one or more metals selected from the group consisting of tungsten, vanadium, molybdenum, rhenium, nickel, cobalt, chromium, manganese, or a noble metal

12. A method of synthesizing a crystalline silicate composition of ITQ-27 having the diffraction pattern similar to **Table 2** by mixing together a source of silica, organic structure directing agent (R), water, and optional metal (X), with a composition, in terms of mole ratios, within the following ranges:

R/YO ₂	0.01 - 1
H ₂ O/ YO ₂	2-50
X/ YO ₂	0 - .2

and wherein X is any trivalent metal capable of tetrahedral coordination and Y is silicon and optionally any other tetravalent metal capable of tetrahedral coordination.

13. The method according to claim 12 wherein X is one or more metals selected from the group consisting of B, Ga, Al or Fe and Y is silicon and may include one or more metals selected from the group consisting of Ge and Ti.

14. A method of synthesizing a crystalline silicate composition of ITQ-27 having the diffraction pattern similar to Table 2 by mixing together a source of silica, organic structure directing agent (R), water, and optional metal (X), with a composition, in terms of mole ratios, within the following ranges:

R/YO ₂	0.01 - 1
H ₂ O/ YO ₂	2-50
X/ YO ₂	0 - .2

and wherein X is one or more metals selected from the group consisting of B, Ga, Al, Fe, Li, Be, P, Zn, Cr, Mg, Co, Ni, Be, Mn, As, In, Sn, Sb, Ti, and Zr , and Y is silicon and may include one or more metals selected from the group consisting of Ge and Ti.

15. The method of any of claims 12 through 14 wherein said molar ratio ranges are

R/ YO ₂	0.1 - .5
H ₂ O/ YO ₂	5 - 20
X/ YO ₂	0 - .1

16. A method of synthesizing a crystalline silicate composition of any of the claims 12 through 14 wherein said organic structure directing agent (SDA) is diphenyl-dimethyl-phosphonium.

17. A method of synthesizing a crystalline silicate composition of claim 15 wherein said organic structure directing agent (SDA) is diphenyl-dimethyl-phosphonium.

18. The product produced using the method of any of claims 12, 13, 14 and 17.

19. The product produced using the method of claim 15.
20. The product produced using the method of claim 16.