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(54) Title: SYNTHETIC LAYERED MATERIAL, MCM-56, ITS SYNTHESIS AND USE

(57) Abstract

A synthetic layered material, MCM-56, has a composition comprising the molar relationship X_2O_3:(n)YO_2, wherein n is less than about 35, X is a trivalent element, and Y is a tetravalent element, and is further characterized by a sorption capacity for 1,3,5-trimethylbenzene of at least about 35 μl/gram of calcined synthetic material, an initial uptake of 15 mg of 2,2-dimethylbutane/gram of calcined synthetic material of less than about 20 seconds, and an X-ray diffraction pattern for the calcined synthetic material having d-spacing maxima at 12.4 ± 0.2, 9.9 ± 0.3, 6.9 ± 0.1, 6.2 ± 0.1, 3.55 ± 0.07, and 3.42 ± 0.07 Angstroms.

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SYNTHETIC LAYERED MATERIAL, MCM-56, ITS SYNTHESIS AND USE

This invention relates to a synthetic layered material, MCM-56, to a method for its preparation and to its use as a sorbent or catalyst component for conversion of organic compounds.

Porous inorganic solids have found utility as catalysts and separations media for industrial application. The openness of their microstructure allows molecules access to the relatively large surface areas of these materials that enhance their catalytic and sorptive activity. The porous materials in use today can be sorted into three broad categories using the details of their microstructure as a basis for classification. These categories are the amorphous and paracrystalline supports, the crystalline molecular sieves and modified layered materials. The detailed differences in the microstructures of these materials manifest themselves as important differences in the catalytic and sorptive behavior of the materials, as well as in differences in various observable properties used to characterize them, such as their surface area, the sizes of pores and the variability in those sizes, the presence or absence of X-ray diffraction patterns and the details in such patterns, and the appearance of the materials when their microstructure is studied by transmission electron microscopy and electron diffraction methods.

Amorphous and paracrystalline materials represent an important class of porous inorganic solids that have been used for many years in industrial applications. Typical examples of these materials are the amorphous silicas commonly used in catalyst formulations and the paracrystalline transitional aluminas used as solid acid catalysts and petroleum reforming catalyst supports. The term "amorphous" is used here to indicate a material with no long range order and can be somewhat misleading, since almost all materials are ordered to some degree, at least on the local scale. An alternate term that has been used to describe these materials is "X-ray indifferent". The microstructure of the silicas consists of 100-250 Angstrom particles of dense amorphous silica (Kirk-Othmer Encyclopedia of Chemical Technology, 3rd Edition, Vol. 20, John Wiley & Sons, New York, p. 766-781, 1982), with the porosity resulting from voids between the particles. Since there is no long range order in these materials, the pores tend to be distributed over a rather large range. This lack of order also manifests itself in the X-ray diffraction pattern, which is usually featureless.

Paracrystalline materials such as the transitional aluminas also have a wide distribution of pore sizes, but better defined X-ray diffraction patterns usually consisting of a few broad peaks. The microstructure of these materials consists of tiny crystalline regions of condensed alumina phases and the porosity of the materials results from irregular voids between these regions (K. Wefers and Chanakya Misra, "Oxides and Hydroxides of Aluminum", Technical Paper No. 19 Revised, Alcoa Research Laboratories, p. 54-59, 1987). Since, in the case of either material, there is no long range order controlling the sizes of pores in the material, the variability in pore size is typically quite high. The sizes of pores in these materials fall into a regime called the mesoporous range, including, for example, pores within the range of 15 to 200 Angstroms.

In sharp contrast to these structurally ill-defined solids are materials whose pore size distribution is very narrow because it is controlled by the precisely repeating crystalline nature of the materials' microstructure. For example, zeolites are ordered, porous crystalline materials, typically aluminosilicates, having a definite crystalline structure as determined by X-ray diffraction, within which there are a large number of small cavities which may be interconnected by a number of smaller channels or pores. These cavities and pores are uniform in size within a specific zeolitic material. Since the dimensions of these pores are such as to accept for adsorption molecules of certain dimensions while rejecting those of larger dimensions, these materials are known as "molecular sieves" and are utilized in a variety of ways to take advantage of these properties.

Prior art techniques have resulted in the formation of a great variety of synthetic zeolites. Many of these zeolites have come to be designated by letter or other convenient symbols, as illustrated by zeolites A (U.S. Patent 2,882,243); X (U.S. Patent 2,882,244); Y (U.S. Patent 3,130,007); ZK-5 (U.S. Patent 3,247,195); ZK-4 (U.S. Patent 3,314,752); ZSM-5 (U.S. Patent 3,702,886); ZSM-11 (U.S. Patent 3,709,979); ZSM-12 (U.S. Patent 3,832,449), ZSM-20 (U.S. Patent 3,972,983); ZSM-35 (U.S. Patent 4,016,245); ZSM-23 (U.S. Patent 4,076,842); MCM-22 (U.S. Patent 4,954,325); MCM-35 (U.S. Patent 4,981,663); MCM-49 (WO 92/22498); and PSH-3 (U.S. Patent 4,439,409).

U.S. Patent 4,439,409 refers to a crystalline molecular sieve composition of matter named PSH-3 and its synthesis from a reaction mixture containing hexamethyleneimine, an organic compound which acts as directing agent for synthesis of the present layered MCM-56. A composition of matter appearing to be identical to the PSH-3 of U.S. Patent 4,439,409, but with additional structural components, is taught in European Patent Publication No. 293,032. Hexamethyleneimine is also taught for use in synthesis of crystalline molecular sieves MCM-22 in U.S. Patent 4,954,325; MCM-35 in U.S. Patent 4,981,663; MCM-49 in WO 92/22498; and ZSM-12 in U.S. Patent 5,021,141. A molecular sieve composition of matter referred to as zeolite SSZ-25 is taught in U.S. Patent 4,826,667 and European Patent Publication No. 231,860, said zeolite being synthesized from a reaction mixture containing an adamantane quaternary ammonium ion.

Certain layered materials, which contain layers capable of being spaced apart with a swelling agent, may be pillared to provide materials having a large degree of porosity. Examples of such layered materials include clays. Such clays may be swollen with water, whereby the layers of the clay are spaced apart by water molecules. Other layered materials are not swellable with water, but may be swollen with certain organic swelling agents such as amines and quaternary ammonium compounds. Examples of such non-water swellable layered materials are described in U.S. Patent 4,859,648 and include layered silicates, magadiite, kenyaite, trititanates and perovskites. Another example of a non-water swellable layered material, which can be swollen with certain organic swelling agents, is a vacancy-containing titanometallate material, as described in U.S. Patent 4,831,006.

Once a layered material is swollen, the material may be pillared by interposing a thermally stable substance, such as silica, between the spaced apart layers. For example, the aforementioned U.S. Patents 4,831,006 and 4,859,648 describe methods for pillaring the non-water swellable layered materials described therein. Other patents teaching pillaring of layered materials and the pillared products include U.S. Patents 4,216,188; 4,248,739; 4,176,090; and 4,367,163; and European Patent Publication No. 205,711.

The X-ray diffraction patterns of pillared layered materials can vary considerably, depending on the degree that swelling and pillaring disrupt the otherwise usually well-ordered layered microstructure. The regularity of the microstructure in some pillared layered materials is so badly disrupted that only one peak in the low angle region on the X-ray diffraction pattern is observed, at a d-spacing corresponding to the interlayer repeat in the pillared material. Less disrupted materials may show several peaks in this region that are generally orders of this fundamental repeat. X-ray reflections from the crystalline structure of the layers are also sometimes observed. The pore size distribution in these pillared layered materials is narrower than those in amorphous and paracrystalline materials but broader than that in crystalline framework materials.

The present invention is directed to a synthetic layered material, referred to herein as MCM-56, having a composition comprising the molar relationship

$$X_2O_3:(n)YO_2,$$

wherein n is less than about 35, X is a trivalent element, and Y is a tetravalent element, said material further characterized by a sorption capacity for 1,3,5-trimethylbenzene of at least about 35 µl/gram of calcined synthetic material, an initial uptake of 15 mg of 2,2-dimethylbutane/gram of calcined synthetic material of less than about 20 seconds, and an X-ray diffraction pattern for the calcined synthetic material having d-spacing maxima at 12.4 ± 0.2, 9.9 ± 0.3, 6.9 ± 0.1, 6.2 ± 0.1, 3.55 ± 0.07, and 3.42 ± 0.07 Angstroms.

The MCM-56 of this invention is distinguished from, but exhibits certain similarities with a number of crystalline framework materials, notably MCM-22 and MCM-49, and with certain other layered materials. MCM-56 has an average unit cell c-parameter of about 25.5 Angstroms without interlayer bridges having been formed. When as-synthesized MCM-56 is calcined at, for example, 540°C, the structure does not condense but remains in layered form. Calcined MCM-56 adsorbs at least about 35 µl/g of 1,3,5-trimethylbenzene, e.g., at least about 4 times as much 1,3,5-trimethylbenzene as calcined MCM-22 or MCM-49. Sorption data also distinguishes calcined MCM-56 from calcined MCM-22 and MCM-49 by its initial rapid uptake of 2,2-dimethylbutane. MCM-56 exhibits unique sorption and catalytic utilities when compared to MCM-22 and MCM-49.

Specifically, the MCM-56 material of the invention appears to be essentially pure with little or no detectable impurity crystal or layer phases and has an X-ray diffraction pattern which is distinguished by the combination of line positions and intensities from the patterns of other known as-synthesized or thermally treated materials as shown below in Table I (as synthesized) and Table II (calcined). In these tables, intensities are defined relative to the d-spacing line at 12.4 Angstroms.

TABLE I

MCM-56		Closest Relative Layered Material		Closest Relative 3-Dimensional Material MCM-49	
Interplanar d-Spacing (A)	Relative Intensity	Interplanar d-Spacing (A)	Relative Intensity	Interplanar d-spacing (A)	Relative Intensity
--	--	13.5	m	--	--
12.4 ± 2	vs	12.4	m-vs	12.5	vs
--	--	11.1	m	11.2	m-s
9.9 ± 0.3	m	--	--	--	--
--	--	9.2	m	9.0	m
6.9 ± 0.1	w	6.9	w	6.9	w
6.4 ± 0.3	w	6.7	w	6.4	w
6.2 ± 0.1	w	6.2	w	6.2	m
3.57 ± 0.07	m-s	3.56	w-m	3.55	w-m
3.44 ± 0.07	vs	3.43	s-vs	3.44	vs

TABLE II

MCM-56		MCM-22		MCM-49	
Interplanar d-Spacing (A)	Relative Intensity	Interplanar d-Spacing (A)	Relative Intensity	Interplanar d-spacing (A)	Relative Intensity
12.4 ± 0.2	vs	12.4	m-vs	12.4	vs
--	--	11.0	m-s	11.1	s
9.9 ± 0.3	m-s	--	--	--	--
--	--	8.8	m-vs	8.9	m-s
6.9 ± 0.1	w	6.9	w-m	6.9	w
6.2 ± 0.1	s	6.2	m-vs	6.2	m
3.55 ± 0.07	m-s	3.56	w-m	3.57	w
3.42 ± 0.07	vs	3.42	vs	3.43	s-vs

The materials used for generation of the data in Table I were wet cake layered MCM-56, wet cake layered material synthesized with the same organic directing agent which, when calcined, transforms into MCM-22, and wet cake crystalline MCM-49. The materials used for the data in Table II were the calcined materials used for Table I. Calcination of each material was in air at 540°C for 2-20 hours. The most effective diagnostic feature allowing the initial differentiation between MCM-56 and the other members of this family (MCM-22 and MCM-49-type materials) is observed in the region of 8.8-11.2 Angstroms d-spacing. The latter species exhibit two resolved maxima at approximately 8.8-9.2 Angstroms and 10.8-11.2 Angstroms with a distinct depression between them. MCM-56 is characterized by a broad band centered around d-spacing 9.9 Angstroms. While the band may have asymmetric profile, for example with an inflection point, the emergence of a depression may be indicative of the onset of MCM-49 formation and the loss of MCM-56.

These X-ray diffraction data were collected with a Scintag diffraction system, equipped with a germanium solid state detector, using copper K-alpha radiation. The diffraction data were recorded by step-scanning at 0.02 degrees of two-theta, where theta is the Bragg angle, and a counting time of 10 seconds for each step. The interplanar spacings, d's, were calculated in Angstrom units (A), and the relative intensities of the lines, I/I_o is one-hundredth of the intensity of the strongest line, above background, were derived with the use of a profile fitting routine (or second derivative algorithm). The intensities are uncorrected for Lorentz and polarization effects. The relative intensities are given in terms of the symbols vs = very strong (60-100), s = strong (40-60), m = medium (20-40) and w = weak (0-20). It should be understood that diffraction data listed for this sample as single lines may consist of multiple overlapping lines which under certain conditions, such as differences in crystallographic changes, may appear as resolved or partially resolved lines. Typically, crystallographic changes can include minor changes in unit cell parameters and/or a change in crystal symmetry, without a change in the structure. These minor effects, including changes in relative intensities, can also occur as a result of differences in cation content, framework composition, nature and degree of pore filling, and thermal and/or hydrothermal history. Other changes in diffraction patterns can be indicative of important differences between materials, which is the case for comparing MCM-56 with similar materials, e.g., MCM-49, MCM-22, and PSH-3.

The significance of differences in the X-ray diffraction patterns of these materials can be explained from a knowledge of the structures of the materials. MCM-22 and PSH-3 are members of an unusual family of materials because, upon calcination, there are changes in the X-ray diffraction pattern that can be explained by a significant change in one axial dimension. This is indicative of a profound change in the bonding within the materials and not a simple loss of organic material used in synthesis. The precursor members of this family can be clearly distinguished by X-ray diffraction from the calcined members (e.g., compare middle columns of Tables I and II). An examination of the X-ray diffraction patterns of both precursor and calcined forms shows a number of reflections with very similar position and intensity, while other peaks are different. Some of these differences are directly related to the changes in the axial dimension and bonding.

Crystalline MCM-49 has an axial dimension similar to those of the calcined members of the family and, hence, there are similarities in their X-ray diffraction patterns. Nevertheless, the MCM-49 axial dimension is different from that observed in the calcined materials. For example, the changes in axial dimensions in MCM-22 can be determined from the positions of peaks particularly sensitive to these changes. Two such peaks occur at ~ 13.5 Angstroms and ~ 6.75 Angstroms in precursor MCM-22, at ~ 12.8 Angstroms and ~ 6.4 Angstroms in as-synthesized MCM-49, and at ~ 12.6 Angstroms and ~ 6.30 Angstroms in the calcined MCM-22. The ~ 12.8 Angstroms peak in MCM-49 is very close to the intense ~ 12.4 Angstroms peak observed for all three materials, and is frequently not fully separated from it. Likewise, the ~ 12.6 Angstroms peak of the calcined MCM-22 material is usually only visible as a shoulder on the intense ~ 12.4 Angstroms peak.

Other features which collectively distinguish MCM-56 from the similar materials described above are summarized in Table III below.

TABLE III

Feature	MCM-22	MCM-49	MCM-56
As-synthesized:			
Structure	layered	3-dimensional	layered
Swellable	yes	no	yes
Condenses upon Calcination	yes	yes	no
Calcined:			
Sorption capacity for 1,3,5-trimethyl benzene[1]	low	low	high
Initial uptake of 2,2-dimethylbutane[2]	slow	slow	fast

[1] Low sorption capacity is defined as less than about 8 to 10 $\mu l/g$. High capacity is at least about 4 times the low capacity. Calcined MCM-56 sorbs at least about 35 $\mu l/g$.

[2] Initial uptake is defined as time to adsorb the first 15 mg of 2,2-dimethylbutane/gram of sorbent. Fast uptake is less than 20 seconds; slow uptake is at least 5 times the fast value.

One gram of calcined MCM-56 sorbs 15 mg of 2,2-dimethylbutane in less than about 20 seconds, e.g., less than about 15 seconds.

The unique layered material MCM-56 of this invention has a composition involving the molar relationship:

$$X_2O_3:(n)YO_2,$$

wherein X is a trivalent element, such as aluminum, boron, iron and/or gallium, preferably aluminum; Y is a tetravalent element such as silicon and/or germanium, preferably silicon; and n is less than about 35, e.g., from 5 to less than about 25, usually from 10 to less than 20, more usually from 13 to 18. In the as-synthesized form, the material has a formula, on an anhydrous basis and in terms of moles of oxides per n moles of YO_2, as follows:

$$(0\text{-}2)M_2O:(1\text{-}2)R:X_2O_3:(n)YO_2$$

wherein M is an alkali or alkaline earth metal, and R is an organic moiety. The M and R components are associated with the material as a result of their presence during sunthesis, and are easily removed by post-synthesis methods hereinafter more particularly described.

The MCM-56 material of the invention may be thermally treated and in the calcined form exhibits high surface area (greater than 300 m^2/gm) and unusually large sorption capacity for certain large molecules when compared to previously described materials such as calcined PSH-3, SSZ-25, MCM-22, and MCM-49. The MCM-56 wet cake, i.e., as-synthesized MCM-56, is swellable indicating the absence of interlayer bridges, in contrast with MCM-49 which is unswellable.

To the extent desired, the original alkali or alkaline earth, e.g., sodium, cations of the as-synthesized material can be replaced in accordance with techniques well known in the art, at least in part, by ion exchange with other cations. Preferred replacing cations include metal ions, hydrogen ions, 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, IB, IIB, IIIB, IVB and VIII of the Periodic Table of the Elements.

When used as a catalyst, the layered MCM-56 material of the invention may be subjected to treatment, normally calcination, to remove part or all of any organic constituent. The crystalline material can also be used as a catalyst in intimate combination with a hydrogenating component such as tungsten, vanadium, molybdenum, rhenium, nickel, cobalt, chromium, manganese, or a noble metal such as platinum or palladium where a hydrogenation-dehydrogenation function is to be performed. Such component can be in the composition by way of cocrystallization, 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 the silicate 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.

MCM-56 may be thermally treated without affecting its layered structure in that it is still swellable after thermal treatment. Thermal treatment is generally performed by heating 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 925°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. Non-limiting examples of such reactions include those described in U.S. Patents 4,954,325; 4,973,784; 4,992,611; 4,956,514; 4,962,250; 4,982,033; 4,962,257; 4,962,256; 4,992,606; 4,954,663; 4,992,615; 4,983,276; 4,982,040; 4,962,239; 4,968,402; 5,000,839; 5,001,296; 4,986,894; 5,001,295; 5,001,283; 5,012,033; 5,019,670; 5,019,665; 5,019,664; and 5,013,422.

The layered MCM-56 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 200°C to 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 MCM-56 in a vacuum, but a longer time is required to obtain a sufficient amount of dehydration.

The present layered MCM-56 material can be prepared from a reaction mixture containing sources of alkali or alkaline earth metal (M), e.g., sodium or potassium, cation, an oxide of trivalent element X, e.g., aluminum, an oxide of tetravalent element Y, e.g., silicon, directing agent (R), and water, said reaction mixture having a composition, in terms of mole ratios of oxides, within the following ranges:

Reactants	Useful	Preferred
YO_2/X_2O_3	5 to 35	10 to 25
H_2O/YO_2	10 to 70	16 to 40
OH^-/YO_2	0.05 to 0.5	0.06 to 0.3
M/YO_2	0.05 to 3.0	0.06 to 1.0
R/YO_2	0.1 to 1.0	0.3 to 0.5

In the present synthesis method, the source of YO_2 should comprise predominantly solid YO_2, for example at least about 30 wt.% solid YO_2 in order to obtain the crystal product of the invention. Where YO_2 is silica, the use of a silica source containing at least about 30 wt.% solid silica, e.g., Ultrasil (a precipitated, spray dried silica containing about 90 wt.% silica) or HiSil (a precipitated hydrated SiO_2 containing about 87 wt.% silica, about 6 wt.% free H_2O and about 4.5 wt.% bound H_2O of hydration and having a particle size of about 0.02 micron) favors crystalline MCM-56 formation from the above mixture under the synthesis conditions required. Preferably, therefore, the YO_2, e.g., silica, source contains at least about 30 wt.% solid YO_2, e.g., silica, and more preferably at least about 40 wt.% solid YO_2, e.g., silica.

Directing agent R is selected from the group consisting of cycloalkylamine, azacycloalkane, diazacycloalkane, and mixtures thereof, alkyl comprising from 5 to 8 carbon atoms. Non-limiting examples of R include cyclopentylamine, cyclohexylamine, cycloheptylamine, hexamethyleneimine, heptamethyleneimine, homopiperazine, and combinations thereof.

Crystallization of the present layered material can be carried out at either static or stirred conditions in a suitable reactor vessel, such as for example, polypropylene jars or teflon lined or stainless steel autoclaves. Crystallization is preferably carried out at a temperature of 80°C to 225°C. It is critical, however, for synthesis of MCM-56 from the above reaction mixture to stop and quench the reaction prior to the onset of MCM-49 formation at the expense of MCM-56. Thereafter, the MCM-56 is separated from the liquid and recovered. The time required to synthesise MCM-56 without subsequent conversion to MCM-49 will depend on the reaction temperature employed. However, the reaction can conveniently be controlled to allow quenching prior to onset of MCM-49 formation by monitoring the X-ray diffraction pattern in the 9-11 Angstrom d-spacing range as the synthesis proceeds. Thus, as is apparent from Table 1, MCM-56 exhibits a single peak at a d-spacing of 9.9 ± 0.3, whereas MCM-49 exhibits 2 peaks centered at d-spacings of 9.0 and 11.2 Angstrom.

The layered MCM-56 material of this invention may be used as an adsorbent, such as for separating at least one component from a mixture of components in the vapor or liquid phase having differential sorption characteristics with respect to MCM-56. Therefore, at least one component can be partially or substantially totally separated from a mixture of components having differential sorption characteristics with respect to MCM-56 by contacting the mixture with the MCM-56 to selectively sorb the one component.

The layered MCM-56 material of this invention can be used to catalyze a wide variety of chemical conversion processes including many of present commercial/industrial importance. Examples of chemical conversion processes which are effectively catalyzed by MCM-56, 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. Specific examples include:

(1) alkylation of aromatic hydrocarbons, e.g., benzene, with long chain olefins, e.g., C_{14} olefin, with reaction conditions including a temperature of 340°C to 500°C, a pressure of 100 to 20,000 kPa (atmospheric to 200 atmospheres), a weight hourly space velocity of 2 hr^{-1} to 2000 hr^{-1} and an aromatic hydrocarbon/olefin mole ratio of 1/1 to 20/1, to provide long chain alkyl aromatics which can be subsequently sulfonated to provide synthetic detergents;

(2) alkylation of aromatic hydrocarbons with gaseous olefins to provide short chain alkyl aromatic compounds, e.g., the alkylation of benzene with propylene to provide cumene, with reaction conditions including a temperature of 10°C to 125°C, a pressure of 100 to 3,000 kPa (1 to 30 atmospheres), and an aromatic hydrocarbon weight hourly

space velocity (WHSV) of 5 to 50 hr^{-1};

(3) alkylation of reformate containing substantial quantities of benzene and toluene with fuel gas containing C_5 olefins to provide, <u>inter alia</u>, mono- and dialkylates with reaction conditions including a temperature of 315°C to 455°C, a pressure of 2860 to 5620 kPa (400 to 800 psig), a WHSV-olefin of 0.4 hr^{-1} to 0.8 hr^{-1}, a WHSV-reformate of 1 hr^{-1} to 2 hr^{-1} and a gas recycle of 1.5 to 2.5 vol/vol fuel gas feed;

(4) alkylation of aromatic hydrocarbons, e.g., benzene, toluene, xylene and naphthalene, with long chain olefins, e.g., C_{14} olefin, to provide alkylated aromatic lube base stocks with reaction conditions including a temperature of 160°C to 260°C and a pressure of 2510 to 3200 kPa (350 to 450 psig);

(5) alkylation of phenols with olefins or equivalent alcohols to provide long chain alkyl phenols with reaction conditions including a temperature of 200°C to 250°C, a pressure of 1480 to 2170 kPa (200 to 300 psig) and a total WHSV of 2 hr^{-1} to 10 hr^{-1}; and

(6) alkylation of isoalkanes, e.g., isobutane, with olefins, e.g., 2-butene, with reaction conditions including a temperature of -25°C to 400°C, e.g., from 75°C to 200°C, a pressure of from below atmospheric to 35000 kPa (5000 psig), e.g., from 100 to 7000 kPa (1 to 1000 psig), a weight hourly space velocity based on olefin of 0.01 hr^{-1} to 100 hr^{-1}, e.g., from 0.1 hr^{-1} to 20 hr^{-1}, and a mole ratio of total isoalkane to total olefin of 1:2 to 100:1, e.g., from 3:1 to 30:1.

As in the case of many catalysts, it is desired to incorporate MCM-56 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 MCM-56, i.e., combined therewith or present during synthesis of MCM-56, 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.

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 MCM-56 layered material also include inorganic oxides, notably alumina.

In addition to the foregoing materials, the MCM-56 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.

The relative proportions of finely divided MCM-56 material and inorganic oxide matrix may vary widely, with the MCM-56 content ranging from 1 to 90 percent by weight and more usually, particularly when the composite is prepared in the form of beads, in the range 2 to 80 weight percent of the composite.

The invention will now be more particularly described with reference to the Examples and the accompanying drawings, in which:

Figure 1 shows the X-ray diffraction pattern of the dried product MCM-56 of Example 1.

Figure 2 shows the X-ray diffraction pattern of the calcined product MCM-56 of Example 2.

Figure 3 shows the X-ray diffraction pattern of the dried product MCM-56 of Example 9.

Figure 4 shows the X-ray diffraction pattern of the calcined product MCM-56 of Example 10.

Figure 5(a) shows the X-ray diffraction pattern of the Example 2 product.

Figure 5(b) shows the X-ray diffraction pattern of the Example 3 product.

Figure 5(c) shows the X-ray diffraction pattern of the Example 4 product.

Figure 5(d) shows the X-ray diffraction pattern of the Example 5 product.

In the Examples, when Alpha Value is examined, it is noted that the 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. Patent 3,354,078; in the Journal of Catalysis, Vol. 4, p. 527 (1965); Vol. 6, p. 278 (1966); and Vol. 61, p. 395 (1980). 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, Vol. 61, p. 395.

Example 1

A mixture of 258 grams of water, 6 grams of 50% sodium hydroxide solution, 13.4 grams of sodium aluminate solution (25.5% Al_2O_3 and 19.5% Na_2O), 51.4 grams of Ultrasil (VN3), and 27.1 grams of hexamethyleneimine (HMI) was reacted in a 600 ml stirred (400 rpm) autoclave at 143°C.

The reaction mixture had the following composition in mole ratios:

SiO_2/Al_2O_3 = 23
OH^-/SiO_2 = 0.21
Na/SiO_2 = 0.21
HMI/SiO_2 = 0.35
H_2O/SiO_2 = 20

The reaction was stopped at 34 hours. The product was filtered, washed with water to form a wet cake, and a portion was dried in an oven at 110°C.

A portion of the product wet cake and the dried portion were submitted for X-ray analysis and identified as MCM-56. The X-ray diffraction pattern of the dried MCM-56 is presented below in Table IV and shown in Figure 1.

TABLE IV

2 theta	d(A)	I/I_o	Comments[a]
4.1	21.6	10	B
6.94	12.74	34	B, sh
7.15	12.36	100	S
8.9	9.9	32	VVB
12.84	6.89	12	B
13.89	6.38	7	VB, sh
14.32	6.18	15	S
15.92	5.57	8	VVB
19.94	4.45	30	VVB
21.98	4.04	43	B
22.51	3.95	59	VB
23.44	3.80	28	VVB
24.97	3.57	43	S
25.93	3.44	100	S
26.61	3.35	51	B
31.52	2.838	5	S
33.40	2.683	10	VVB
34.71	2.584	3	VVB
36.26	2.477	3	S
37.00	2.429	3	S
37.75	2.383	9	S

[a] S = sharp, B = broad, VB = very broad, VVB = very very broad, sh = shoulder

The chemical composition of the product of Example 1 was, in wt.%,

N = 1.61

Na = 1.1

Al_2O_3 = 6.6

SiO_2 = 70.5

Ash = 78.2

The SiO_2/Al_2O_3 molar ratio of this product was 18.

Example 2

A portion of the product of Example 1 was ammonium exchanged by contacting three times with 1M ammonium nitrate, and then calcined in air for 6 hours at 540°C. The X-ray diffraction pattern of the calcined product of this example proved it to be MCM-56 and is presented below in Table V and shown in Figure 2.

TABLE V

2 theta	d(A)	I/I_o	Comments[a]
4.1	21.6	37	B
7.14	12.38	97	S
8.9	9.9	33	VVB
12.80	6.92	12	B
14.42	6.14	59	S
15.80	5.61	14	VVB
19.76	4.49	27	VVB
22.45	3.96	73	VVB
23.75	3.75	26	VVB
25.10	3.55	37	S
26.05	3.42	100	S
26.79	3.33	35	B
31.75	2.818	6	S
33.52	2.673	10	VVB
34.82	2.576	4	VVB
36.44	2.466	3	S
37.96	2.370	6	S

[a] S = sharp, B = broad, VVB = very very broad

Example 3

For comparison purposes, Example 1 of U.S. Patent 4,954,325 was repeated. The as-synthesized crystalline material of the example, referred to herein as MCM-22 precursor or the precursor form of MCM-22, was examined by X-ray diffraction analysis. Its X-ray diffraction pattern is presented in Table VI and shown in Figure 5(b).

TABLE VI

2 theta	d(A)	I/I_o
3.1	28.5	14
3.9	22.7	<1
6.53	13.53	36
7.14	12.38	100
7.94	11.13	34
9.67	9.15	20
12.85	6.89	6
13.26	6.68	4
14.36	6.17	2
14.70	6.03	5
15.85	5.59	4
19.00	4.67	2
19.85	4.47	22
21.56	4.12	10
21.94	4.05	19
22.53	3.95	21
23.59	3.77	13
24.98	3.56	20
25.98	3.43	55
26.56	3.36	23
29.15	3.06	4
31.58	2.833	3
32.34	2.768	2
33.48	2.676	5
34.87	2.573	1
36.34	2.472	2
37.18	2.418	1
37.82	2.379	5

Example 4

The product of Example 3 was calcined at 538°C for 20 hours. The X-ray diffraction pattern of this calcined product is shown in Table VII below and in Figure 5(c).

TABLE VII

2 theta	d(A)	I/I_o
2.80	31.55	25
4.02	21.98	10
7.10	12.45	96
7.95	11.12	47
10.00	8.85	51
12.90	6.86	11
14.34	6.18	42
14.72	6.02	15
15.90	5.57	20
17.81	4.98	5
19.08	4.65	2
20.20	4.40	20
20.91	4.25	5
21.59	4.12	20
21.92	4.06	13
22.67	3.92	30
23.70	3.75	13
25.01	3.56	20
26.00	3.43	100
26.96	3.31	14
27.75	3.21	15
28.52	3.13	10
29.01	3.08	5
29.71	3.01	5
31.61	2.830	5
32.21	2.779	5
33.35	2.687	5
34.61	2.592	5

Example 5

A 2.24 part quantity of 45% sodium aluminate was added to a solution containing 1.0 part of 50% NaOH solution and 43.0 parts H_2O in an autoclave. An 8.57 part quantity of Ultrasil precipitated silica was added with agitation, followed by 4.51 parts of HMI.

The reaction mixture had the following composition, in mole ratios:

SiO_2/Al_2O_3 = 23
OH^-/SiO_2 = 0.21
Na/SiO_2 = 0.21
HMI/SiO_2 = 0.35
H_2O/SiO_2 = 19.3

The mixture was crystallized at 150°C for 84 hours with stirring. The product was identified as MCM-49 and had the X-ray pattern which appears in Table VIII and Figure 5(d).

The chemical composition of the product was, in wt.%,

N	1.70
Na	0.70
Al_2O_3	7.3
SiO_2	74.5
Ash	84.2

The silica/alumina mole ratio of the product was 17.3.

The sorption capacities, after calcining at 538°C for 9 hours were, in wt.%,

Cyclohexane, 40 Torr	10.0
n-Hexane, 40 Torr	13.1
H_2O, 12 Torr	15.4

A portion of the sample was calcined in air for 3 hours at 538°C. This material exhibited the X-ray diffraction pattern shown in Table IX.

TABLE VIII

2 theta	d(A)	I/I_o
3.1	28.5	18
3.9	22.8	7+
6.81	12.99	61 sh
7.04	12.55	97
7.89	11.21	41
9.80	9.03	40
12.76	6.94	17
13.42	6.60	4*
13.92	6.36	17
14.22	6.23	11
14.63	6.05	2
15.81	5.61	15
17.71	5.01	4
18.86	4.71	4
19.23	4.62	6
20.09	4.42	27
20.93	4.24	8
21.44	4.14	17
21.74	4.09	37
22.16	4.01	17
22.56	3.94	58
23.53	3.78	26
24.83	3.59	22
25.08	3.55	10
25.86	3.45	100
26.80	3.33	28
27.53	3.24	21
28.33	3.15	15
28.98	3.08	4
29.47	3.03	2
31.46	2.843	4
32.08	2.790	6
33.19	2.699	9
34.05	2.633	5
34.77	2.580	4
36.21	2.481	2
36.90	2.436	3
37.68	2.387	8

sh = Shoulder

+ = Non-crystallographic MCM-49 peak

* = Impurity peak

TABLE IX

2-Theta	d(A)	I/I_o
3.2	28.0	9+
3.9	22.8	7+
6.90	12.81	48 sh
7.13	12.39	100
7.98	11.08	46
9.95	8.89	53
12.87	6.88	10
14.32	6.18	36
14.74	6.01	11
15.94	5.56	17
17.87	4.96	2
19.00	4.67	5
19.35	4.59	3
20.24	4.39	14
21.06	4.22	5
21.56	4.12	15
21.87	4.06	25
22.32	3.98	12
22.69	3.92	41
23.69	3.76	23
24.95	3.57	19
25.22	3.53	4
25.99	3.43	90
26.94	3.31	20
27.73	3.22	17
28.55	3.13	11
29.11	3.07	3
29.63	3.01	2
31.59	2.833	6
32.23	2.777	4
33.34	2.687	9
34.35	2.611	4
34.92	2.570	3
36.35	2.471	2
37.07	2.425	2
37.82	2.379	6

sh = Shoulder

\+ = Non-crystallographic MCM-49 peak

Example 6

The product of Example 2 was subjected to the Alpha Test which indicated an Alpha value of 106.

Example 7

To compare microporosity and effective pore openings between MCM-56, MCM-22, and MCM-49, hydrocarbon compounds with increasing molecular dimensions were adsorbed sequentially onto portions of calcined MCM-56, MCM-22, and MCM-49 products of the examples according to the procedure described by E.L. Wu, G.R. Landolt, and A.W. Chester in "New Developments in Zeolite Science and Technology", Studies in Surface Science and Catalysis, 28, 547 (1986). The dynamic sorption results of this investigation are presented in Table X below.

TABLE X

Sorbate	MCM-56		MCM-22		MCM-49	
	μl/g	sec.	μl/g	sec.	μl/g	sec.
n-Hexane	79	17	120	12	114	10
2,2-Dimethylbutane	60	12	72	252	85	233
1,3,5-Trimethylbenzene	41	24	8	550	undetectable	

The sorption results indicate clear distinction between the tested materials. MCM-56 has at least 4 times the capacity of MCM-22 and MCM-49 for 1,3,5-trimethylbenzene, the most hindered hydrocarbon molecule used in this investigation. MCM-56 also demonstrates a much faster initial rate of sorption of 2,2-dimethylbutane (time required to sorb the first 15 mg of 2,2,-dimethylbutane/g of the sorbent at 80 Torr 2,2-dimethylbutane in flowing helium at 373°K) than MCM-22 or MCM-49. The corresponding times for representative MCM-56, MCM-22, and MCM-49 materials were 12, 252, and 233 seconds, respectively. The initial rate of sorption of n-hexane is the time required to sorb the first 40 mg n-hexane/g of sorbent and for 1,3,5-trimethyl- benzene, the time required to sorb the first 7 mg of 1,3,5-tri- methylbenzene/g of sorbent.

Example 8

Example 1 was repeated, except that the reaction was stopped at 40 hours. X-ray analysis proved the product to be MCM-56.

Example 9

A mixture of 258 grams of water, 20.5 grams of sodium aluminate solution (25.5% Al_2O_3 and 19.5% Na_2O), 51.4 grams of Ultrasil (VN3), and 50 grams of hexamethyleneimine (HMI) was reacted in a 600 ml stirred (400 rpm) autoclave at 154°C.

The reaction mixture had the following composition in mole ratios:

SiO_2/Al_2O_3 = 15
OH^-/SiO_2 = 0.17
Na/SiO_2 = 0.17
HMI/SiO_2 = 0.66
H_2O/SiO_2 = 19

The reaction was stopped at 130 hours. The product was filtered, washed with water to form a wet cake, and a portion was dried in an oven for 2 hours at 110°C.

A portion of the product wet cake and the dried portion were submitted for X-ray analysis and identified as MCM-56. The X-ray diffraction pattern of the dried material is presented below in Table XI and shown in Figure 3.

TABLE XI

2 theta	d(A)	I/I_o	Comments[a]
4.1	21.6	30	B
6.67	13.25	23	B, sh[b]
6.96	12.70	24	B
7.16	12.35	80	S
8.9	9.9	21	VVB
12.86	6.88	14	B
13.98	6.33	7	VB, sh
14.33	6.18	15	S
15.85	5.59	7	VVB
19.93	4.45	25	VVB
21.95	4.05	42	VB
22.56	3.94	38	B
23.46	3.79	26	VVB
24.94	3.57	39	S
25.94	3.43	100	S
26.64	3.35	33	B

[a] S = sharp, B = broad, VB = very broad, VVB = very very broad,
sh = shoulder

[b] Possible trace of MCM-22 precursor

The chemical composition of the product of Example 9 was, in wt.%,

N = 1.42
Na = 2.3
Al_2O_3 = 9.3
SiO_2 = 70.7
Ash = 82.3

The SiO_2/Al_2O_3 molar ratio of this product was 13.

Example 10

A portion of the dried sample from Example 9 was subjected to a three-fold exchange with a 1 M ammonium nitrate solution. The solid was then heated in nitrogen at 482°C for 3 hours, cooled to about 130°C, and then calcined in air at 538°C for 5 hours. This material exhibited the X-ray diffraction pattern shown in Table XII and Figure 4.

TABLE XII

2 theta	d(A)	I/I_o	Comments[a]
4.3	20.5	69	B
7.13	12.40	100	S
8.1	10.9	33	VVB
9.8	9.0	37	VVB
12.79	6.92	12	B
14.38	6.16	48	S
15.78	5.62	17	VVB
19.74	4.50	24	VVB
22.45	3.96	69	VVB
23.70	3.75	23	VVB
25.10	3.55	36	S
26.05	3.42	88	S
26.86	3.32	27	B
31.71	2.822	5	S
33.34	2.687	9	B
34.30	2.614	6	VVB
36.40	2.468	5	S
37.92	2.373	5	S

[a] S = sharp, B = broad, VVB = very very broad

The X-ray diffraction patterns of the product materials from Examples 2-5 are presented in Figure 5. Figure 5(a) shows the pattern of the MCM-56 product from Example 2; Figure 5(b), the pattern of the product from Example 3. The pattern of the MCM-22 product from Example 4 is shown in Figure 5(c), and the pattern shown in Figure 5(d) is from the MCM-49 product of Example 5. These patterns are presented in this Figure in a manner by which comparison is facilitated. Figures 5(b) and (c) are from the as-synthesized layered material which transforms into crystalline MCM-22 upon calcination, and the crystalline MCM-22, respectively.

CLAIMS:

1. A synthetic layered material having a composition comprising the molar relationship

$$X_2O_3:(n)YO_2,$$

wherein n is less than about 35, X is a trivalent element, and Y is a tetravalent element, said material further characterized by a sorption capacity for 1,3,5-trimethylbenzene of at least about 35 μl/gram of calcined synthetic material, an initial uptake of 15 mg of 2,2-dimethylbutane/gram of calcined synthetic material of less than about 20 seconds, and an X-ray diffraction pattern for the calcined synthetic material having d-spacing maxima at 12.4 ± 0.2, 9.9 ± 0.3, 6.9 ± 0.1, 6.2 ± 0.1, 3.55 ± 0.07, and 3.42 ± 0.07 Angstroms.

2. The synthetic material of Claim 1 wherein X is selected from aluminum, boron, iron and gallium and Y is selected from silicon and germanium.

3. The material of Claim 1 wherein X comprises aluminum and Y comprises silicon.

4. The material of Claim 1 wherein n is 5 to less than 25.

5. The material of Claim 6 wherein n is 10 to 20.

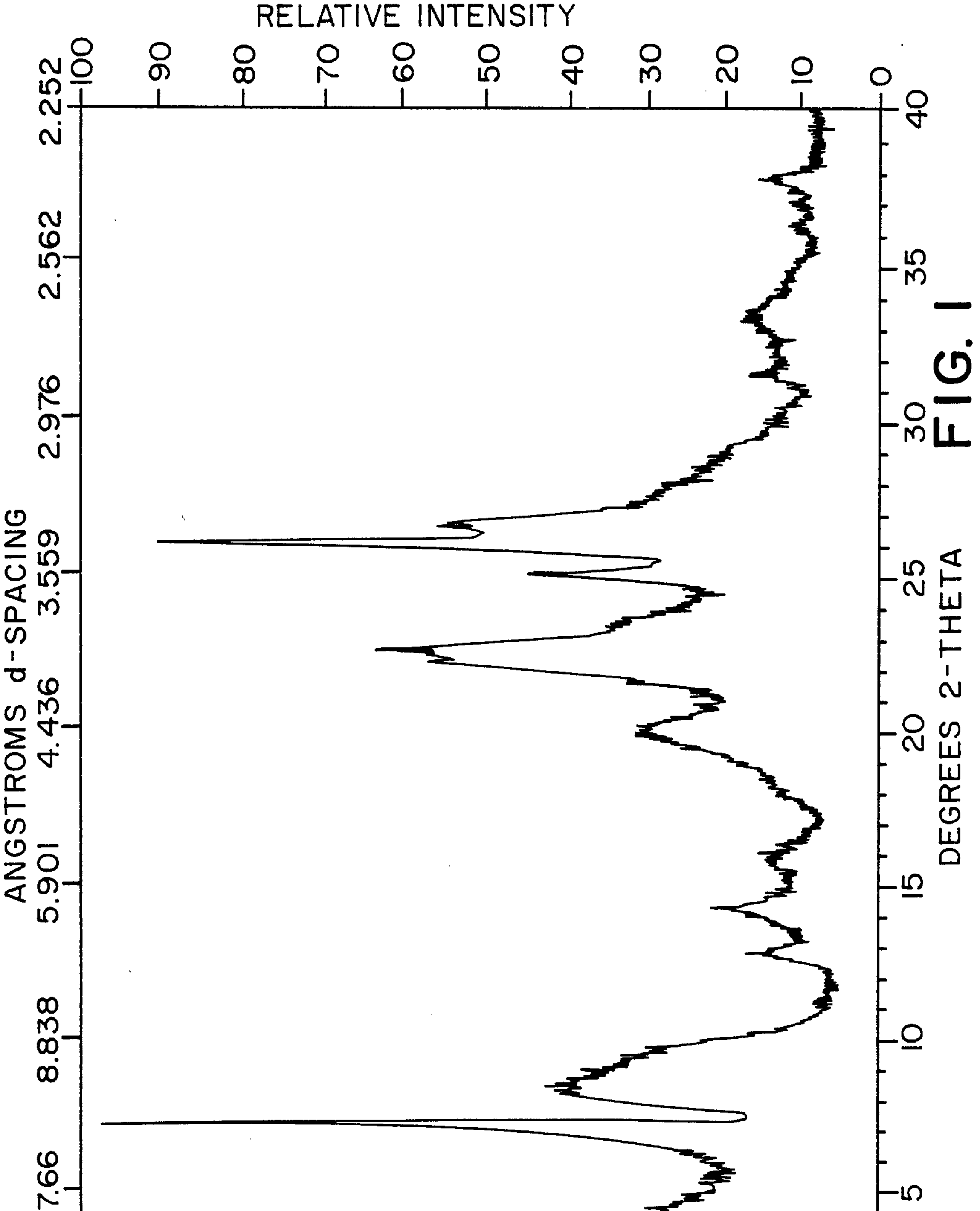
6. The material of Claim 1 having a composition, on an as-synthesised, anhydrous basis and in terms of moles of oxides per n moles of YO_2, expressed by the formula:

$$(0\text{-}2)M_2O:(1\text{-}2)R:X_2O_3:(n)YO_2$$

wherein M is alkali or alkaline earth metal and R is an organic moiety.

7. The material of Claim 6 wherein said R is selected from the group consisting of cycloalkylamine, azacycloalkane, diazacycloalkane, and mixtures thereof, alkyl comprising from 5 to 8 carbon atoms.

8. A process for converting a feedstock comprising organic compounds to conversion product which comprises contacting said feedstock with a catalyst comprising an active form of the synthetic layered material of Claim 1.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2.976
3.559
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DEGREES 2-THETA
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FIG. 1

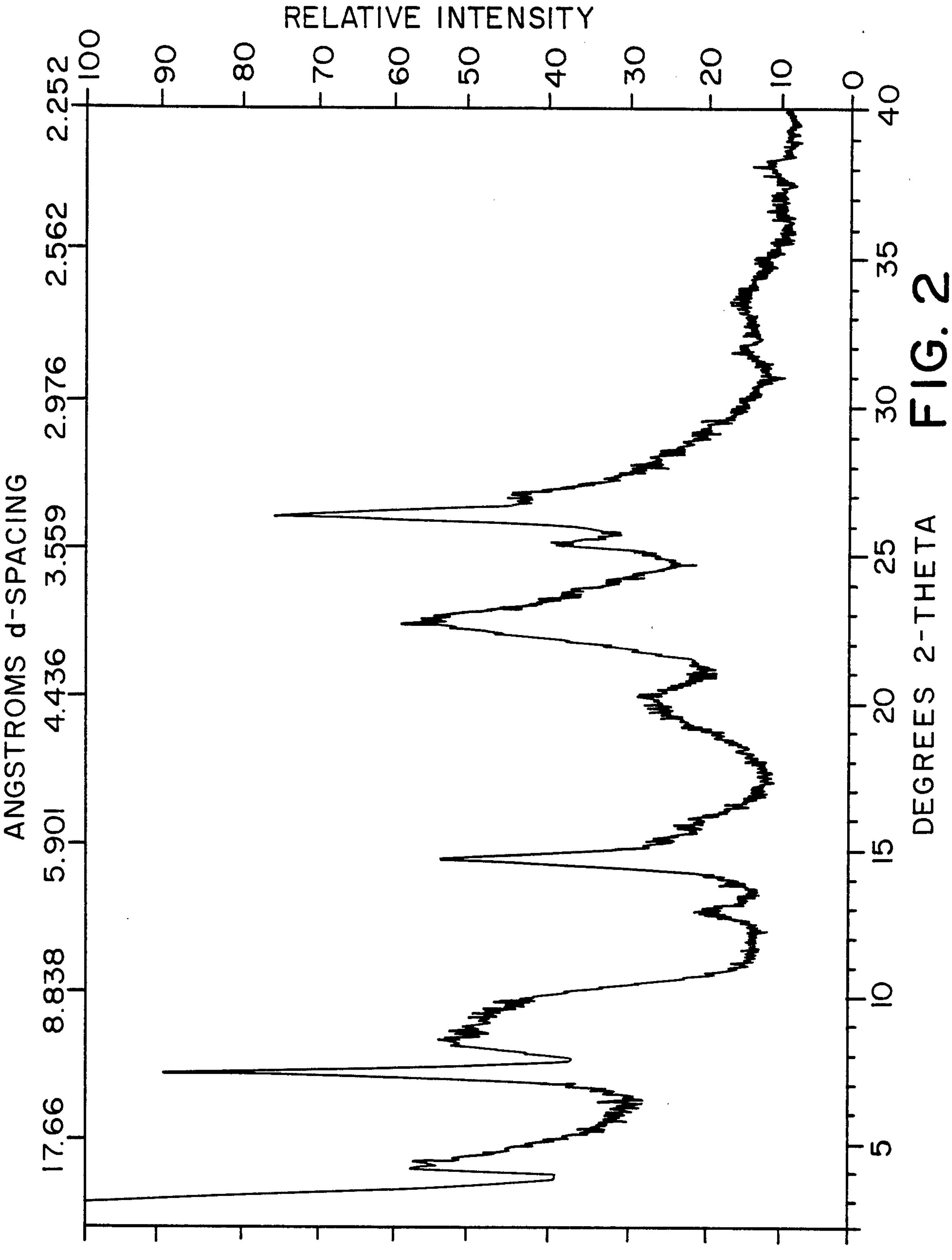
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FIG. 2

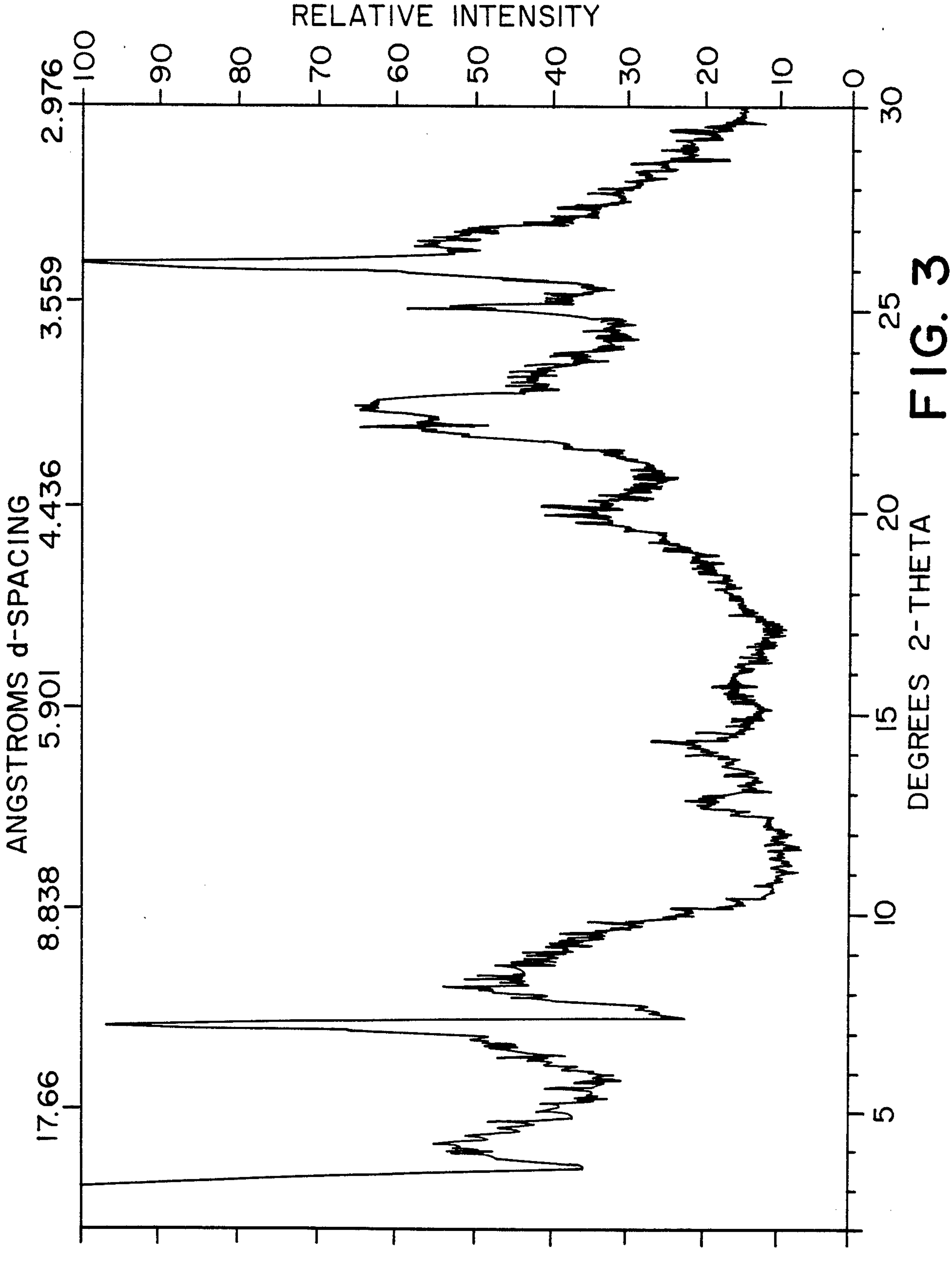
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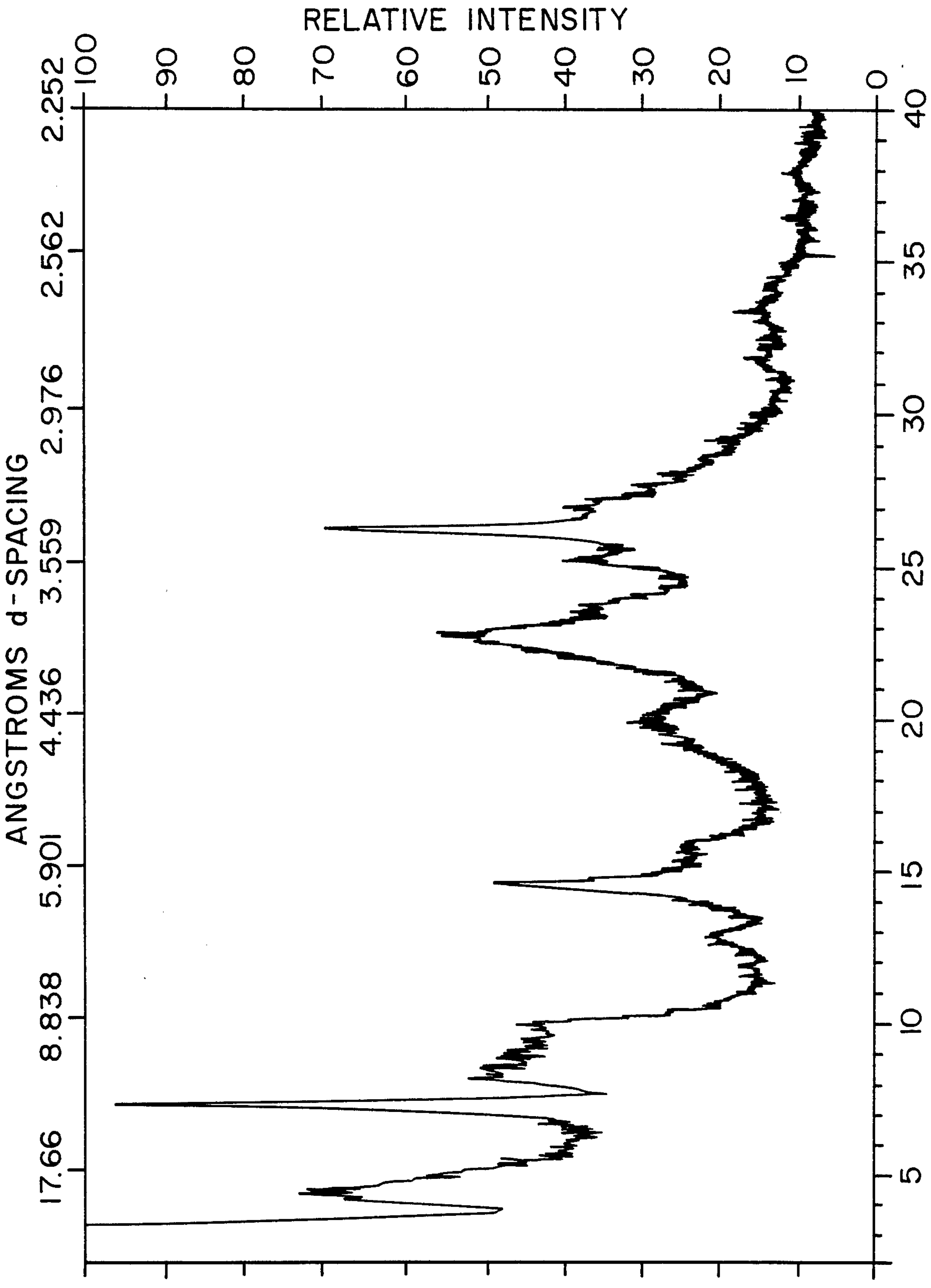
FIG. 3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DEGREES 2-THETA
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FIG. 4

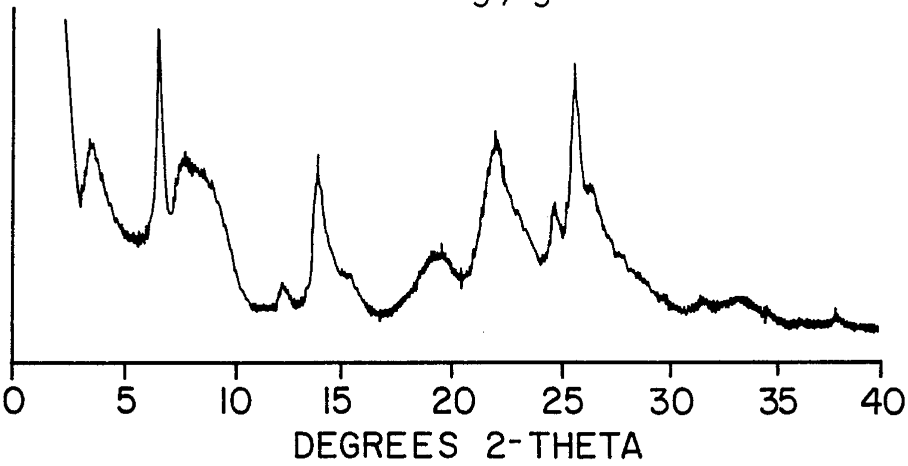

FIG. 5a

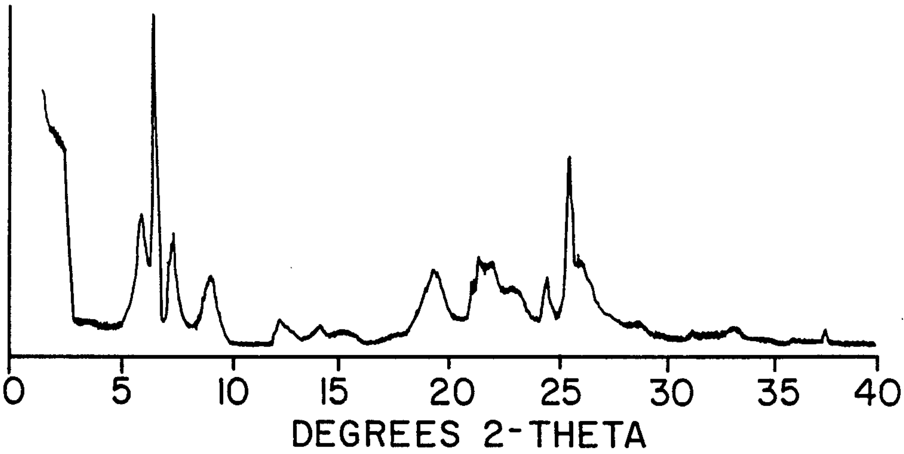

FIG. 5b

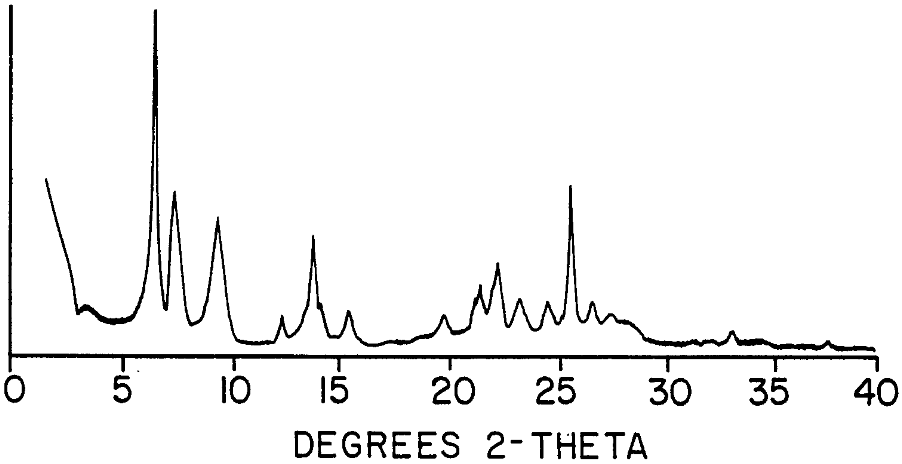

FIG. 5c

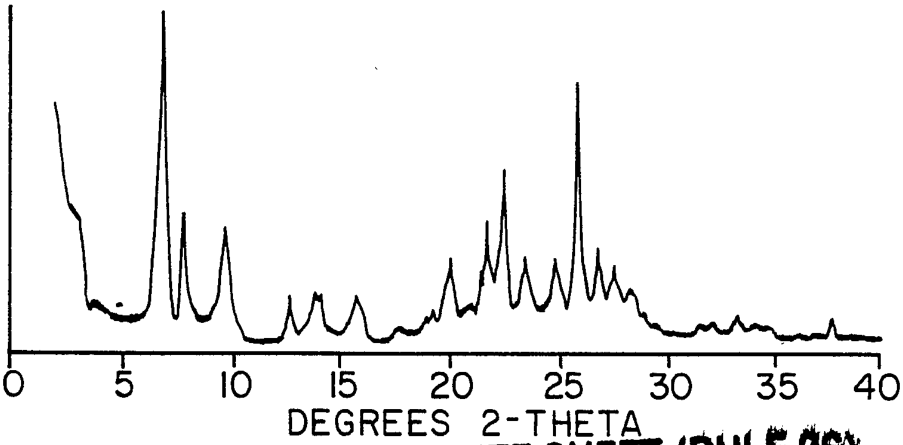

FIG. 5d

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/04284

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) : C10G 35/095; B01J 29/28; C01B 33/34
US CL : 208/46; 423/718; 502/62
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 208/46, 135; 423/328, 706,718; 502/62, 71, 77

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	US,A, 5,236,575 (Bennett et al) 17 August 1993 (see Example 1)	1-8

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search
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