

**INSTRUCTIONS**

(a) If Convention application insert "Convention"

(a) CONVENTION

AUSTRALIA

Patents Act

609237

**APPLICATION FOR A (b) STANDARD ~~XXXX~~ PATENT**

(b) Delete one

(c) Insert FULL name(s) of applicant(s)

~~XX~~/We (c) MOBIL OIL CORPORATION

(d) Insert FULL address(es) of applicant(s)

Of (d) 150 East 42nd Street,  
New York, New York,  
United States of America

(e) Delete one

hereby apply for the grant of a (e) Standard ~~XXXX~~ Patent for an invention entitled

(f) Insert TITLE of invention

(f) PROCESS FOR THE CATALYTIC HYDRATION OF OLEFINS

(g) Insert "complete" or "provisional" or "petty patent"

which is described in the accompanying (g) complete specification.

(Note: The following applies only to Convention applications)

Details of basic application ~~is~~

(h) Insert number, country and filing date for the/or each basic application

|     | Application No. | Country                  | Filing Date      |
|-----|-----------------|--------------------------|------------------|
| (h) | 139,570         | United States of America | 30 December 1987 |

APPLICATION ACCEPTED AND AMENDMENTS

ALLOWED 31.1.91.

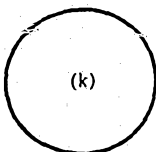
Address for Service:

PHILLIPS ORMONDE AND FITZPATRICK  
Patent and Trade Mark Attorneys  
367 Collins Street  
Melbourne, Australia 3000

(i) Insert date of signing

Dated (i) 30 December 1988

(j) Signature of applicant(s) (For body corporate see headnote\*)



(k) Corporate seal if any

(j) PHILLIPS ORMONDE & FITZPATRICK  
Attorneys for:  
MOBIL OIL CORPORATION

*David B. Fitzpatrick*

Note: No legalization or other witness required

PHILLIPS ORMONDE AND FITZPATRICK  
Patent and Trade Mark Attorneys  
367 Collins Street  
Melbourne, Australia

## DECLARATION FOR A PATENT APPLICATION

## ▼ INSTRUCTIONS

- (a) Insert "Convention" if applicable  
(b) Insert FULL name(s) of applicant(s)

In support of the (a) Convention application made by (b)

MOBIL OIL CORPORATION

- (c) Insert "of addition" if applicable  
(d) Insert TITLE of invention

(hereinafter called "applicant(s)" for a patent (c) for an invention entitled (d)

PROCESS FOR THE CATALYTIC HYDRATION OF OLEFINS

- (e) Insert FULL name(s) AND address(es) of declarant(s) (See headnote\*)

I/~~we~~ (e) EDWARD H. VALANCE of Mobil Oil Corporation of 150 East 42nd Street, New York, New York 10017, UNITED STATES OF AMERICA

do solemnly and sincerely declare as follows:

1. ~~I am/we are the applicant(s)~~

(or, in the case of an application by a body corporate)

1. I am/~~we~~ are authorized to make this declaration on behalf of the applicant(s).

2. ~~I am/we are the actual inventor(s)~~

(or, where the applicant(s) is/are not the actual inventor(s))

- (f) Insert FULL name(s) AND address(es) of actual inventor(s)

2. (i) WELDON KAY BELL, 428 Burd Street, Mercer County, Pennington, New Jersey 08534; WERNER OTTO HAAG, 38 Pine Knoll Drive, Mercer County, Lawrenceville, New Jersey 08648; TRACH JAU-HUA HUANG, 9 Woodfield Lane, Mercer County, Lawrenceville, New Jersey 08648; PHILIP VARGHESE, 8 Chadwick Drive, Camden County, Voorhees, New Jersey 08043; ALL of the United States of America,

- (g) Recite how applicant(s) derive(s) title from actual inventor(s) (See headnote\*\*)

~~is/are~~ are the actual inventor(s) of the invention and the facts upon which the applicant(s) is/~~are~~ entitled to make the application are as follows:

(g)

The Applicant is the assignee of the invention from the actual inventor(s).

(Note: Paragraphs 3 and 4 apply only to Convention applications)

- (h) Insert country, filing date, and basic applicant(s) for the/or EACH basic application

3. The basic application(s) for patent or similar protection on which the application is based is/~~are~~ identified by country, filing date, and basic applicant(s) as follows:

- (h) United States of America, U.S. Serial No. 139,570 filed December 30, 1987, Weldon Kay Bell, Werner Otto Haag, Tracy Jau-Hau Huang and Philip Varghese

4. The basic application(s) referred to in paragraph 3 hereof was/~~were~~ the first application(s) made in a Convention country in respect of the invention the subject of the application.

- (k) Insert PLACE of signing

Declared at (k) Fairfax, Virginia, U.S.A.

- (l) Insert DATE of signing

Dated (l) January 11, 1989

- (m) Signature(s) of declarant(s)

(m) MOBIL OIL CORPORATION

BY: Edward H. Valance  
Edward H. Valance

Associate General Patent Counsel  
Authorized Attorney in Fact

To: The Commissioner of Patents

- Note: No legalization or other witness required

PIR/7/78

PHILLIPS ORMONDE & FITZPATRICK  
Patent and Trade Mark Attorneys  
367 Collins Street  
Melbourne, Australia

---

**(12) PATENT ABRIDGMENT      (11) Document No. AU-B-27657/88**  
**(19) AUSTRALIAN PATENT OFFICE      (10) Acceptance No. 609237**

---

(54) Title  
**PROCESS FOR THE CATALYTIC HYDRATION OF OLEFINS**

International Patent Classification(s)  
(51)<sup>4</sup> **C07C 027/16      C07C 029/03      C07C 041/05**

(21) Application No. : **27657/88**      (22) Application Date : **30.12.88**

(30) Priority Data

(31) Number      (32) Date      (33) Country  
**139570      30.12.87      US UNITED STATES OF AMERICA**

(43) Publication Date : **06.07.89**

(44) Publication Date of Accepted Application : **26.04.91**

(71) Applicant(s)  
**MOBIL OIL CORPORATION**

(72) Inventor(s)  
**PHILIP VARGHESE; TRACH JAU-HUA HUANG; WERNER OTTO HAAG; WELDON KAY BELL**

(74) Attorney or Agent  
**PHILLIPS ORMONDE & FITZPATRICK, 367 Collins Street, MELBOURNE VIC 3000**

(56) Prior Art Documents  
**AU 27654/88**  
**AU 27656/88**

(57)      This invention relates to a process for the catalytic hydration of olefins to provide alcohols, ethers and their mixtures. More particularly, the invention relates to a process for the hydration of light olefins such as ethylene, propylene, butenes, pentenes, hexenes, heptenes, etc., and their mixtures to provide a mixture of alcohol(s) and ether(s) employing acidic zeolite Beta as catalyst. The co-produced alcohols and ethers are useful, inter alia, as high octane blending stocks for gasolines.

#### **CLAIM**

1. A process for converting light olefins to alcohols and/or ethers which comprises contacting a feed containing at least one light olefin with water in the vapour and/or liquid phase under olefin hydration conditions in the presence of a catalyst comprising zeolite Beta.

AUSTRALIA

609237

Patents Act

COMPLETE SPECIFICATION  
(ORIGINAL)

Application Number:  
Lodged:

Class

Int. Class

Complete Specification Lodged:  
Accepted:  
Published:

Priority

This document contains the  
amendment made under  
Section 49 and is correct for  
printing.

Related Art:

---

APPLICANT'S REFERENCE: F-4639

Name(s) of Applicant(s):

Mobil Oil Corporation

Address(es) of Applicant(s):

150 East 42nd Street,  
New York,  
New York,  
UNITED STATES OF AMERICA.

Address for Service is:

PHILLIPS ORMONDE & FITZPATRICK  
Patent and Trade Mark Attorneys  
367 Collins Street  
Melbourne 3000 AUSTRALIA

Complete Specification for the invention entitled:

PROCESS FOR THE CATALYTIC HYDRATION OF OLEFINS

Our Ref : 119630  
POF Code: 1462/1462

The following statement is a full description of this invention, including  
the best method of performing it known to applicant(s):

F-4639

PROCESS FOR THE CATALYTIC HYDRATION OF OLEFINS

This invention relates to a process for the catalytic hydration of olefins to provide alcohols, ethers and their mixtures. More particularly, the invention relates to a process for the hydration of light olefins such as ethylene, propylene, butenes, pentenes, hexenes, heptenes, etc., and their mixtures to provide a mixture of alcohol(s) and ether(s) employing acidic zeolite Beta as catalyst. The co-produced alcohols and ethers are useful, inter alia, as high octane blending stocks for gasolines.

There is a need for an efficient catalytic process to manufacture alcohols and ethers from light olefins thereby augmenting the supply of high octane blending stocks for gasoline. Lower molecular weight alcohols and ethers such as isopropyl alcohol (IPA) and diisopropyl ether (DIPE) are in the gasoline boiling range and are known to have a high blending octane number. In addition, by-product propylene from which IPA and DIPE can be made is usually available in a fuels refinery. The petrochemicals industry also produces mixtures of light olefin streams in the C<sub>2</sub> to C<sub>7</sub> molecular weight range and the conversion of such streams or fractions thereof to alcohols and/or ethers can also provide products useful as solvents and as blending stocks for gasoline.

The catalytic hydration of olefins to provide alcohols and ethers is a well-established art and is of significant commercial importance. US-A-4,214,107 discloses catalytic hydration of propylene over a crystalline aluminosilicate zeolite catalyst having a

silica to alumina ratio of at least 12 and a Constraint Index of from 1 to 12, e.g. HZSM-5 type zeolite, to provide the corresponding alcohol, essentially free of ether and hydrocarbon by-product.

According to US-A-4,499,313 an olefin is hydrated to the corresponding alcohol in the presence of H-mordenite or H-Y each having a silica-alumina molar ratio of 20 to 500. The use of such a catalyst is said to result in higher yields of alcohol than olefin hydration processes which employ conventional solid acid catalysts. Use of the catalyst is said to offer the advantage over ion-exchange type olefin hydration catalysts of not being restricted by the hydration temperature. Reaction conditions employed in the process include a temperature of from 50-300°C, preferably 100-250°C, a pressure of 5 to 200 kg/cm<sup>2</sup> to maintain liquid phase or gas-liquid multi-phase conditions and a mole ratio of water to olefin of from 1 to 20. The reaction time can be 20 minutes to 20 hours when operating batchwise and the liquid hourly space velocity (LHSV) is usually 0.1 to 10 in the case of continuous operation.

EP-A-210,793 describes an olefin hydration process employing a medium pore zeolite as hydration catalyst. Specific catalysts mentioned are Theta-1, said to be preferred, ferrierite, ZSM-22, ZSM-23 and NU-10.

According to the present invention a process for converting light olefin(s) to alcohol(s), ether(s) or a mixture of alcohol(s) and ether(s) is provided which comprises contacting a feed containing at least one light olefin with water in the vapour and/or liquid phase under olefin hydration conditions in the presence of zeolite Beta as catalyst to produce alcohol(s), ether(s) or mixture thereof.

The alcohol(s), ether(s) and alcohol/ether

mixtures resulting from the foregoing olefin hydration process are advantageously employed as blending components for gasoline, as cosolvents for methanol to be incorporated into gasoline, and many other applications.

The zeolite is preferably employed in the hydrogen form, and the catalyst may further comprise a co-catalyst effective for light olefin hydration. The light olefins particularly contemplated are those of 2 to 7 carbon atoms, including ethylene, propylene, butenes, pentenes, hexenes, heptenes and mixtures of these with each other or with other olefins.

Accordingly, the invention is applicable to the hydration of olefins contained in refinery streams such as gas plant off-gas containing ethylene and propylene, naphtha cracker off-gas containing light olefins, fluidized catalytic cracked (FCC) light gasoline containing pentenes, hexenes and heptenes, refinery FCC propane/propylene streams, etc. For example, a typical FCC light olefin stream possesses the following composition:

Typical Refinery FCC Light Olefin Composition

|           | <u>Wt. %</u> | <u>Moles %</u> |
|-----------|--------------|----------------|
| Ethane    | 3.3          | 5.1            |
| Ethylene  | 0.7          | 1.2            |
| Propane   | 14.5         | 15.3           |
| Propylene | 42.5         | 46.8           |
| Isobutane | 12.9         | 10.3           |
| n-Butane  | 3.3          | 2.6            |
| Butenes   | 22.1         | 18.3           |
| Pentanes  | 0.7          | 0.4            |

The process of the invention is especially applicable to the conversion of propylene and propylene-

containing streams to mixtures of IPA and DIPE, which may be employed as an octane improver for gasoline.

The operating conditions of the olefin hydration process herein are not especially critical. They include a temperature ranging from ambient up to about 300°C, preferably from about 50 to about 220°C and more preferably from about 90 to about 200°C, a total system pressure of at least about 5 atm, preferably at least about 20 atm and more preferably at least about 40 atm, a water to total olefin mole ratio of from about 0.1 to about 30, preferably from about 0.2 to about 15 and most preferably from about 0.3 to about 5. It may be desirable to operate at low water to total olefin mole ratios, e.g. at water to total olefin mole ratios of less than about 1. Those skilled in the art will recognize that selection of specific operating conditions for a particular feed will influence product distribution. It will also be appreciated that the precise conditions selected should, to some extent, reflect the nature of the olefin feed, isoolefins generally requiring milder process conditions than straight chain olefins.

The olefin hydration process of this invention can be carried out under liquid phase, vapour phase or mixed vapour-liquid phase conditions in batch or continuous manner using a stirred tank reactor or fixed bed flow reactor, e.g., trickle-bed, liquid-up-flow, liquid-down-flow, counter-current, co-current, etc. Reaction times of from about 20 minutes to about 20 hours when operating in batch and an LHSV of from about 0.1 to about 10 when operating continuously are suitable. It is generally preferable to recover any unreacted olefin and recycle it to the reactor.

When seeking to maximise the production of ether by the hydration of olefin, the aqueous product effluent

from the olefin hydration reactor containing both alcohol and ether olefin hydration products can be introduced into a separator, e.g., a distillation column, for recovery of ether. The dilute aqueous solution of alcohol may be then introduced into a second separator, e.g., another distillation column, where a water/alcohol azeotrope is recovered. A fraction of the azeotrope may be fed into a dehydration reactor of conventional or otherwise known type and operation to provide a further quantity of ether which can be combined with the ether previously recovered from the olefin hydration reactor. By blending various product streams, almost any ratio of alcohol/ether can be obtained. When alcohol/ether mixtures are to be used as gasoline blending stocks, this capability for adjusting the ratios of alcohol to ether offers great flexibility in meeting the octane requirements for given gasoline compositions. Regulatory considerations aside, alcohol/ether mixtures, e.g., IPA/DIPE mixtures, can constitute up to about 20 weight percent or so of the gasoline to which they are added.

A particularly advantageous procedure for producing mixtures of alcohol and ether, and in particular IPA and DIPE, from the hydration of an olefin-containing feed (a propylene-containing feed in the case of IPA/DIPE mixtures) comprises co-feeding a fresh propane/propylene-containing feed (readily available in many petroleum refineries) and fresh water, together with recycled unreacted propylene and recycled water from a decanter, into a hydration reactor. The reactor effluent is passed to a separator unit with propane and unconverted propylene being recycled to the reactor, part of the gaseous mixture being purged in order to avoid build-up of propane in the recycle loop. The liquid products from the separator unit are introduced to a distillation unit where an azeotropic

10 mixture of IPA, DIPE, water and propylene oligomers (mostly C<sub>6</sub> olefin) is distilled off and, following cooling, is introduced into a decanter in which phase separation takes place. The upper layer contains mostly DIPE, e.g., 90 weight percent or more, and relatively little water, e.g., 1 weight percent or so. The lower layer is largely water containing negligible quantities of IPA and DIPE. The quantity of the decanter overhead which is recycled can be regulated so as to control the water content in the final product. The bottom fraction from the distillation unit, mainly IPA, is combined with DIPE in the decanter overhead to provide the final IPA/DIPE mixture.

20 Where it is desired to separate out the alcohol from an alcohol/ether mixture and thus provide essentially pure ether, one can advantageously pass the effluent from the hydration reactor to a separator operating below the olefin hydration reaction temperature, where two liquid phases form, the aqueous phase being removed and recycled to the hydration reactor. The hydrocarbon-rich phase is flashed to a lower pressure to effect separation of the unreacted C<sub>3</sub> components. The flashed product, now containing a substantial amount of IPA product, is introduced to a distillation unit operated at or below atmospheric pressure to effect further purification of the DIPE. The azeotropic IPA, DIPE and water overhead product containing a small amount of propylene oligomer is condensed and thereafter contacted with reactor feed water. The resulting phase separation provides a DIPE product containing at most negligible amounts of IPA and water, e.g., 1.0 weight percent and 0.5 weight percent of these materials, respectively. The remaining aqueous phase can be recycled to the reactor.

30 The catalyst employed in the olefin hydration

process of this invention, acidic zeolite Beta, is a large pore aluminosilicate zeolite which, like other large pore zeolites, possesses a Constraint Index of no greater than about 2 but in several respects does not behave like other large pore zeolites. Zeolite Beta is described in US-A-3,308,069, to which reference is made for further details. In general, the zeolite employed herein will possess a silica to alumina ratio of greater than about 10 and usually greater than about 20. In addition to aluminium present in the framework structure of zeolite Beta, other metals can be present such as gallium, iron, boron, etc.

The zeolite Beta catalyst used herein will generally possess an alpha value of at least about 1, preferably at least about 10 and more preferably at least about 100. (The alpha test is described in J. Catalysis, 6, pp. 278-287 (1966).) Zeolite Beta of low acidity (alpha values of less than about 200) can be achieved by a variety of techniques including (a) synthesising the zeolite with a high silica/alumina ratio, (b) steaming, (c) steaming followed by dealumination and (d) substituting aluminium with one or more other species. For example, in the case of steaming, the zeolite can be exposed to steam at elevated temperatures ranging from about 500 to about 1200°F (260 to 649°C) and preferably from about 750 to about 1000°F (339 to 538°C). This treatment can be accomplished in an atmosphere of 100% steam or an atmosphere consisting of steam and a gas which is substantially inert to the zeolite. A similar treatment can be accomplished at lower temperatures employing elevated pressure, e.g., at from about 350 to about 700°F (177 to 371°C) with from about 10 to 200 atmospheres (10.14 to 202.76 bar). Specific details of several steaming procedures may be gained from the disclosures of US-A-4,325,994, 4,347,296, and 4,418,235.

Aside from or in addition to any of the foregoing procedures, the surface acidity of the zeolite can be eliminated or reduced by treatment with bulky reagents as described in US-A-4,520,221.

Zeolite Beta catalysts having an alpha of from about 100 to about 600 may be especially preferred for converting propylene feeds.

In practising the olefin hydration process of the present invention, it can be advantageous to composite the zeolite Beta within a matrix, or binder, material which is resistant to the temperature and other conditions employed in the process. Useful matrix materials include both synthetic and naturally-occurring substances, e.g., inorganic materials such as clay, silica and/or metal oxides such as alumina. The latter can be either naturally-occurring or can be provided in the form of gelatinous precipitates or gels including mixtures of silica and metal oxides. Naturally-occurring clays which can be composited with the zeolite include those of the montmorillonite and kaolin families, which families include the sub-bentonites 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.

In addition to the foregoing materials, zeolite Beta can be composited with a porous matrix material such as carbon, alumina, silica, titania, zirconia, silica-alumina, silica-magnesia, silica-zirconia, silica-thoria, silica-beryllia and silica-titania, etc, as well as ternary oxide compositions such as silica-alumina-thoria, silica-alumina-zirconia, silica-alumina-magnesia and

silica-magnesia-zirconia. The matrix can be in the form of a cogel. The relative proportions of zeolite Beta and matrix material, on an anhydrous basis, can vary widely with the zeolite content ranging from between about 1 to about 99 wt%, and more usually in the range of about 5 to about 90 wt%, of the dry composite.

In some cases, it may be advantageous to provide the zeolite Beta hydration catalyst as an extrudate bound with a low acidity refractory oxide binder. In a preferred preparative technique a homogeneous mixture of zeolite Beta, water and a low acidity refractory oxide binder, e.g., silica, which contains at least an extrusion-facilitating amount of the binder in a colloidal state and which is substantially free of added alkali metal base and/or base salt, is formed into an extrudable mass. The mass is extruded and the resulting extrudate is dried and calcined.

The original cations associated with zeolite Beta utilized herein can be replaced by a wide variety of other cations according to techniques well known in the art, e.g., by ion-exchange. Typical replacing cations include hydrogen, ammonium, alkyl ammonium and metal cations, and their mixtures. Metal cations can also be introduced into the zeolite. In the case of replacing metallic cations, particular preference is given to metals of Groups IB to VIII of the Periodic Table, including, by way of example, iron, nickel, cobalt, copper, zinc, palladium, calcium, chromium, tungsten, molybdenum, rare earth metals, etc. These metals can also be present in the form of their oxides.

The following examples are illustrative of the olefin hydration process of the present invention.

### EXAMPLE 1

Zeolite Beta (hydrogen form; binder free) was employed in a number of hydration runs carried out at water:olefin mole ratios both at and below those disclosed for other large pore zeolites.

The conditions of the hydration runs and the results thereof are set forth in Table 1 as follows:

Table 1: Propylene Hydration Under Varying Conditions

| Hydration Conditions                  | RUN        |        |       |       |       |       |
|---------------------------------------|------------|--------|-------|-------|-------|-------|
|                                       | 1          | 2      | 3     | 4     | 5     | 6     |
| Temp., °C                             | 201        | 202    | 202   | 200   | 202   | 202   |
| Pressure, psi (bar)                   | 255 (17.6) | 255    | 255   | 255   | 255   | 255   |
| Water:Propylene Mole Ratio            | 0.99       | 0.93   | 0.99  | 4.74  | 1.00  | 1.17  |
| LHSV, total cat.                      | 18.21      | 9.28   | 5.04  | 4.26  | 2.51  | 0.35  |
| WHSV, total cat.                      | 20.144     | 10.197 | 5.574 | 5.956 | 2.783 | 0.393 |
| CONVERSION, %                         |            |        |       |       |       |       |
| Propylene                             | 3.98       | 6.58   | 7.79  | 10.37 | 9.13  | 9.06  |
| Water                                 | 4.27       | 7.46   | 7.84  | 2.58  | 8.78  | 11.08 |
| IPA                                   | 3.7        | 6.5    | 6.7   | 10.1  | 7.5   | 8.3   |
| DIPE                                  | 0.2        | 0.0    | 0.0   | 0.1   | 0.0   | 0.2   |
| Hydrocarbon (HC) (propylene oligomer) | 0.1        | 0.1    | 1.0   | 0.1   | 1.7   | 0.6   |
| IPA g/hr/l cat.                       | 445.7      | 380.0  | 219.0 | 179.5 | 122.0 | 20.5  |
| HC g/hr/l cat.                        | 9.4        | 4.4    | 23.6  | 1.5   | 18.9  | 1.0   |
| DIPE g/hr/l cat.                      | 16.8       | 0.5    | 0.1   | 2.0   | 0.1   | 0.4   |
| IPA/HC+DIPE                           | 0.944      | 0.987  | 0.902 | 0.981 | 0.865 | 0.935 |

As these data show, by operating at a high space velocity at near equilibrium conversion, hydrocarbon coproduction is minimised at about 5%.

### EXAMPLE 2

This example illustrates the effect of the feed water:propylene mole ratio on the coproduction of hydrocarbon employing zeolite Beta (bound with 35 weight percent alumina). The hydration conditions and results are set forth in Table 2 as follows:

Table 2: Effect of Water:Propylene Mole Ratio

| Hydration Conditions       | 1         | 2     | 3     | 4     | 5     | 6     | 7          | 8      |
|----------------------------|-----------|-------|-------|-------|-------|-------|------------|--------|
| Temp., °C                  | 162       | 161   | 161   | 162   | 162   | 162   | 205        | 214    |
| Pressure, psi (bar)        | 1000 (70) | 1000  | 1000  | 1000  | 1000  | 1000  | 255 (17.6) | 255    |
| Water:Propylene Mole Ratio | 0.48      | 2.28  | 3.57  | 0.74  | 0.57  | 1.76  | 1.00       | 0.98   |
| LHSV, total cat.           | 0.48      | 0.66  | 0.35  | 0.13  | 0.45  | 0.61  | 14.35      | 19.77  |
| WHSV, total cat.           | 0.495     | 0.823 | 0.469 | 0.141 | 0.514 | 0.728 | 13.601     | 21.822 |
| <b>CONVERSION, %</b>       |           |       |       |       |       |       |            |        |
| Propylene                  | 30.91     | 31.41 | 60.30 | 62.63 | 25.52 | 24.52 | 23.39      | 4.79   |
| Water                      | 62.19     | 11.36 | 14.48 | 54.21 | 33.67 | 12.10 | 0.00       | 2.56   |
| IPA                        | 11.8      | 17.8  | 31.1  | 21.9  | 11.8  | 17.6  | 0.0        | 2.2    |
| DIPE                       | 17.6      | 12.4  | 24.1  | 36.7  | 12.8  | 6.9   | 0.0        | 0.0    |
| Hydrocarbon (HC)           | 1.5       | 1.2   | 5.0   | 4.0   | 1.0   | 0.0   | 23.4       | 2.6    |
| IPA g/hr/l cat.            | 38.3      | 56.3  | 44.4  | 17.1  | 36.6  | 55.7  | 0.0        | 277.9  |
| HC g/hr/l cat.             | 3.4       | 2.7   | 5.0   | 2.2   | 2.1   | 0.0   | 1971.5     | 232.1  |
| DIPE g/hr/l cat.           | 48.4      | 33.1  | 29.3  | 44.4  | 33.8  | 18.5  | 0.0        | 0.0    |
| IPA/IPA+HC+DIPE            | 0.425     | 0.611 | 0.565 | 0.392 | 0.503 | 0.750 | 0.000      | 0.545  |

As these data show, water strongly inhibits polymerisation. For a pure propylene feed, hydrocarbon production was 14 times that for an equimolar water:propylene feed (Runs 7 and 8). It is unnecessary to employ a large excess of water (e.g., 10:1 mole ratios as shown in US-A-4,499,313, *supra*) as the latter does not exert a proportional suppression of hydrocarbon coproduction but has the disadvantage of requiring greater water recycle capability.

EXAMPLE 3

Data set forth below in Table 3 below show the oxygenate selectivities for a mixed propylene/butene feed hydrated in the presence of zeolite Beta extrudate bound with 17 weight percent colloidal silica. The feed consisted of the following components: water/propane/propylene/1-butene/n-butane in the respective weight ratios of 11:9:24:32:23. Reaction conditions were: 330°F (166°C), 1750 psi (121.7 bar) and 0.5 olefin WHSV.

Table 3: Conversion of Propylene/Butene  
Mixtures to Alcohols and Ethers

| <u>Alcohol/ether Product</u> | <u>% Selectivity</u> |
|------------------------------|----------------------|
| 2-propanol                   | 41                   |
| 2-butanol                    | 29                   |
| C <sub>8</sub> ethers        | 2                    |
| diisopropyl ether            | 12                   |
| isopropyl, 2-butyl ether     | 10                   |

#### EXAMPLE 4

This example demonstrates the superior activity of zeolite Beta (hydrogen form, binder free) compared to typical acid ion exchange resin catalysts for the hydration of propylene under fairly severe process conditions including high water to propylene mole ratios. The zeolite Beta possesses a silica to alumina ratio of 41.

The conditions of hydration and the results thereof are set forth in Table 4 as follows:

Table 4: Comparison of Zeolite Beta with Acid Ion Exchange Catalysts at High Water: Propylene Mole Ratios-----

| Hydration Conditions       | Ion Exchange Resin  |                      |                     |
|----------------------------|---------------------|----------------------|---------------------|
|                            | <u>Zeolite Beta</u> | <u>Amberlite 250</u> | <u>Amberlyst 15</u> |
| Temp, °C                   | 150                 | 150                  | 149                 |
| Pressure, psig (bar)       | 1000 (70)           | 1200 (83.8)          | 1000                |
| Water:Propylene Mole Ratio | 10                  | 14                   | 7                   |
| % Propylene Conversion     | 49                  | 45                   | 36                  |
| IPA/IPA+DIPE+HC            | 0.9                 | ~1                   | ~1                  |
| SPACE TIME YIELDS          |                     |                      |                     |
| g-IPA/L-cat hr             | 188                 | 108                  | 105                 |
| g-DIPE/L-cat hr            | 19                  | 4                    | 2                   |
| g-HC/L-cat hr              | -                   | -                    | -                   |
|                            | ----                | ----                 | ----                |
| g-Total/L-cat hr           | 207                 | 112                  | 107                 |

As these data show, under relatively severe conditions, zeolite Beta is nearly twice as active as the acid ion exchange resins.

EXAMPLE 5

Three grams of unbound zeolite Beta (in the hydrogen form) having a silica to alumina ratio of 40 and an alpha value of 424 were placed in a stainless steel reactor. The reactor was purged with helium and brought to 150°C and 1000 psig (70 bar). Propylene and water were separately fed into the reactor. The weight hourly space velocity of liquid propylene was maintained at 0.5 and the mole ratio of water:propylene in the feed was varied from 10:1 to 1:1. Gas and liquid products were collected and analysed chromatographically. The results are set forth in Table 5 as follows:

Table 5: Propylene Hydration Over Zeolite Beta

|                            |      |     |     |     |
|----------------------------|------|-----|-----|-----|
| Water:Propylene Mole Ratio | 10/1 | 5/1 | 2/1 | 1/1 |
| % Propylene Conversion     | 49   | 40  | 37  | 30  |
| Product Selectivity, wt%   |      |     |     |     |
| IPA                        | 91   | 79  | 59  | 57  |
| DIPE                       | 9    | 20  | 39  | 41  |
| Others                     | 0    | 1   | 2   | 2   |

As the data in Table 5 show, once-through propylene conversion of 49% (63% of equilibrium conversion) was obtained with 100% selectivity to IPA and DIPE (91% and 9% by weight, respectively). The results are striking in terms of activity, selectivity, and the quantity of DIPE produced at such a high ratio of water:propylene. DIPE selectivity increased sharply with decreasing water:propylene ratio (from 9% at 10:1 to 41 wt% at 1:1 ratio).

### EXAMPLE 6

This example demonstrates the superior performance of zeolite Beta catalyst bound with 35 weight percent alumina compared to several other known olefin hydration catalysts when used in the hydration of propylene at relatively high temperatures. The reaction conditions and results are set forth in Table 6 as follows:

Table 6: High Temperature Propylene Hydration Processes

| Hydration Conditions             | Zeolite Beta | SiO <sub>2</sub> /Al <sub>2</sub> O <sub>3</sub> (Solid) | W/Al (Solid) | Na <sub>2</sub> HSW <sup>a</sup> (Liquid) | H <sub>3</sub> PO <sub>4</sub> (Supported Liquid) | 60% H <sub>3</sub> PO <sub>4</sub> (Supported Liquid) |
|----------------------------------|--------------|----------------------------------------------------------|--------------|-------------------------------------------|---------------------------------------------------|-------------------------------------------------------|
| Temp., °C                        | 206          | 270                                                      | 270          | 260                                       | 218                                               | 171                                                   |
| Pressure, psig (bar)             | 1400 (97.6)  | 3700 (256.2)                                             | 3700         | 3000 (207.9)                              | 590 (41.7)                                        | 428 (30.5)                                            |
| Water:Propylene Mole Ratio       | 1            | 15                                                       | 16           | 28                                        | 1                                                 | 0.24                                                  |
| % Propylene Conversion           | 17           | 45                                                       | 18           | 64                                        | 6                                                 | 8                                                     |
| IPA/IPA+DIPE+HC                  | 0.9          | 1                                                        | 1            | 1                                         | 1                                                 | 1                                                     |
| SPACE TIME YIELDS g-IPA/L-cat hr | 1660         | 522                                                      | 1020         | 260                                       | 103                                               | 630                                                   |

The comparison indicates that zeolite Beta showed higher IPA space time yield than the other catalysts, particularly those operating at comparable or lower conversion. In particular, zeolite Beta showed 60% higher space time yield than the tungsten catalyst operating at the same conversion but at twice the pressure and 60°C higher temperature. The space time yield for zeolite Beta was much higher than the remaining catalysts (HSW, SiO<sub>2</sub>/Al<sub>2</sub>O<sub>3</sub>) although the latter were operated at higher temperatures, pressure and water co-feed.

\* Na<sub>3</sub>H[Si(W<sub>3</sub>O<sub>10</sub>)<sub>4</sub>] in water, 0.001 M

EXAMPLE 7

The performance of zeolite Beta (unbound) for the hydration of propylene at a water:propylene mole ratio of 10:1, compared with other large pore zeolites is set forth in Table 7 as follows:

Table 7: Comparison of Propylene Hydration With Zeolite Beta and Other Large Pore Zeolites

| Zeolite                              | Zeolite Beta | UltraStable Zeolite Y | Zeolite Y | Mordenite |
|--------------------------------------|--------------|-----------------------|-----------|-----------|
| $\text{SiO}_2/\text{Al}_2\text{O}_3$ | 40           | 10                    | 150       | 64        |
| Propylene Conversion, %              | 49           | <1                    | 16        | 44        |
| Product Selectivity, wt%             |              |                       |           |           |
| IPA                                  | 91           | 100                   | 98        | 91        |
| DIPE                                 | 9            | 0                     | 2         | 6         |
| Propylene Oligomers                  | 0            | 0                     | 0         | 3         |

As these data show, the percentage of conversion of propylene was significantly higher under the stated conditions than the next most active large pore zeolite, mordenite; and, unlike the latter, no appreciable amounts of propylene oligomers were present in the mixture of product IPA and DIPE.

### EXAMPLE 8

The performance of unbound zeolite Beta for the hydration of propylene at water:propylene mole ratios of 2:1 and 0.5:1 compared with other large pore zeolites at 1000 psig (70 bar), 330°F (166°C) and 0.6 WHSV propylene is set forth in Table 8 as follows:

Table 8: Comparison of Propylene Hydration With Zeolite Beta and Other Large Pore Zeolites at Water:Propylene Mole Ratios of 2:1 and 0.5:1

| Zeolite   | SiO <sub>2</sub> /Al <sub>2</sub> O <sub>3</sub> | Alpha | Propylene Conversion, %                               |                                                         | IPA                                                   |                                                         | Selectivities<br>DIPE                                 |                                                         | Oligomers                                             |                                                         |
|-----------|--------------------------------------------------|-------|-------------------------------------------------------|---------------------------------------------------------|-------------------------------------------------------|---------------------------------------------------------|-------------------------------------------------------|---------------------------------------------------------|-------------------------------------------------------|---------------------------------------------------------|
|           |                                                  |       |                                                       |                                                         |                                                       |                                                         |                                                       |                                                         |                                                       |                                                         |
|           |                                                  |       | 2:1<br>H <sub>2</sub> O:C <sub>3</sub> H <sub>6</sub> | 0.5:1<br>H <sub>2</sub> O:C <sub>3</sub> H <sub>6</sub> | 2:1<br>H <sub>2</sub> O:C <sub>3</sub> H <sub>6</sub> | 0.5:1<br>H <sub>2</sub> O:C <sub>3</sub> H <sub>6</sub> | 2:1<br>H <sub>2</sub> O:C <sub>3</sub> H <sub>6</sub> | 0.5:1<br>H <sub>2</sub> O:C <sub>3</sub> H <sub>6</sub> | 2:1<br>H <sub>2</sub> O:C <sub>3</sub> H <sub>6</sub> | 0.5:1<br>H <sub>2</sub> O:C <sub>3</sub> H <sub>6</sub> |
| Beta      | 35                                               | 289   | 51.0                                                  | 44.9                                                    | 48.7                                                  | 39.8                                                    | 48.2                                                  | 57.3                                                    | 3.1                                                   | 3.1                                                     |
| Mordenite | 25                                               | 62    | 5.7                                                   | 5.2                                                     | 96.5                                                  | 0.0                                                     | 3.5                                                   | 0.0                                                     | 0.0                                                   | 100.0                                                   |
| USY       | 5                                                | 144   | 1.8                                                   | 1.6                                                     | 100.0                                                 | 100.0                                                   | 0.0                                                   | 0.0                                                     | 0.0                                                   | 0.0                                                     |

As these data show, when the mole ratio of olefin and propylene are reduced to well under the 10:1 level of Example 7, the advantages of zeolite Beta over the other large pore zeolites becomes more pronounced. Thus, propylene conversion where zeolite Beta is employed is much higher and selectivity to oxygenates is maintained.

EXAMPLE 9

This example compares the performance of zeolite Beta for the hydration of propylene at a water:propylene mole ratio of 10:1 with that of a medium pore zeolite, ZSM-5. The other conditions of the hydrations were: 330°F (166°C), 1000 psig (70 bar) and 0.5 WHSV propylene. The results are set forth in Table 10 as follows:

Table 9: Comparison of Propylene Hydration  
With Zeolite Beta and ZSM-5 at 10:1  
Propylene:Water Mole Ratio-----

| <u>Zeolite</u>                                   | <u>Zeolite Beta</u> | <u>ZSM-5</u> |
|--------------------------------------------------|---------------------|--------------|
| SiO <sub>2</sub> /Al <sub>2</sub> O <sub>3</sub> | 40                  | 70           |
| Alpha                                            | 424                 | 310          |
| Propylene Conversion, %                          | 49                  | 22           |
| Product Selectivity, %                           |                     |              |
| IPA                                              | 91                  | 98           |
| DIPE                                             | 9                   | 2            |
| Propylene Oligomers                              | 0                   | 0            |

As these data show, the percentage of propylene conversion was dramatically higher in the case of zeolite Beta and, in addition, substantially more DIPE was produced employing the zeolite Beta catalyst.

EXAMPLE 10

This comparison resembles that of Example 9 except that the water:propylene mole ratio is 0.5:1 and the characteristics of the zeolite Beta and ZSM-5 differ somewhat. The results are set forth in Table 10 as follows:

Table 10: Comparison of Propylene Hydration  
With Zeolite Beta and ZSM-5 at  
0.5:1 Propylene:Water Mole Ratio

| <u>Zeolite</u>                                   | <u>Zeolite Beta</u> | <u>ZSM-5</u> |
|--------------------------------------------------|---------------------|--------------|
| SiO <sub>2</sub> /Al <sub>2</sub> O <sub>3</sub> | 35                  | 52           |
| Alpha                                            | 289                 | 306          |
| Propylene Conversion, %                          | 45                  | 3            |
| Product Selectivity, %                           |                     |              |
| IPA                                              | 40                  | 100          |
| DIPE                                             | 57                  | 0            |
| Propylene Oligomers                              | 3                   | 0            |

Again, as in Example 9, the percentage of propylene conversion was much higher in the case of zeolite Beta and while use of the latter catalyst led to even greater ether co-production at the reduced water:propylene mole ratio of this example, use of the ZSM-5 catalyst failed to provide any appreciable amount of ether under such low water:propylene mole ratios.

EXAMPLE 11

This example compares the results obtained with unbound zeolite Beta and zeolite Beta bound with varying amounts of two different binders, silica and alumina. The alpha values of the different catalysts are set forth in Table 11 as follows:

Table 11: Alpha Values of Unbound and Bound  
Zeolite Beta-----

| <u>Catalyst</u> | <u>Composition (Wt%)</u>                                | <u>Alpha Value<br/>(of the Un-<br/>bound zeolite)</u> | <u>Unsteamed<br/>or Steamed</u> |
|-----------------|---------------------------------------------------------|-------------------------------------------------------|---------------------------------|
| A               | Unbound Zeolite Beta                                    | 438                                                   | Unsteamed                       |
| B               | 65% Zeolite Beta/<br>35% SiO <sub>2</sub>               | 359                                                   | Unsteamed                       |
| C               | 65% Zeolite Beta/<br>35% Al <sub>2</sub> O <sub>3</sub> | 281                                                   | Unsteamed                       |

The hydration runs were conducted in a 3/8" (0.95 cm) stainless steel reactor at 1000 psig (70 bar) in a downflow operation (propylene in gas phase and water in liquid phase). In each run, 5 grams of each of Catalysts A, B and C (based on zeolite component) (12-20 mesh) (1.68-0.84 mm) were loaded into the reactor and the unit was pressurised with helium to 1000 psig. Propylene and water were fed separately into the top of the reactor at a rate ten times that of the desired space velocity. The reactor was then gradually brought up to the desired operating temperature at which point the rates of introduction of propylene and water were reduced to the desired space velocities. The temperature profile was quite uniform ( $\pm 1.5^{\circ}\text{F}$  ( $0.83^{\circ}\text{C}$ ) variation). After lineout, gas and liquid samples were collected periodically

(generally over a period of 17 hours for each sample) and were analysed by gas chromatography. The results of the hydration runs are set forth in Table 12 as follows:

Table 12: Propylene Hydration over Unbound and Bound Zeolite Beta

|                                    | Catalyst A |       |              | Catalyst B |       |              | Catalyst C |       |              |
|------------------------------------|------------|-------|--------------|------------|-------|--------------|------------|-------|--------------|
| Temp., C                           | 150        | 150   |              | 150        | 150   |              | 150        | 150   |              |
| Mole Ratio of Water:Propylene      | 1:1        | 1:1   |              | 1:1        | 1:1   |              | 1:1        | 1:1   |              |
| Propylene WHSV (based on catalyst) | .72        | .72   |              | .5         | .5    |              | .5         | .5    |              |
| Propylene WHSV (based on zeolite)  | .72        | .72   |              | .77        | .77   |              | .77        | .77   |              |
| Time on Stream, hrs.               | 5-25       | 29-42 |              | 5-22       | 29-52 |              | 6-24       | 30-48 |              |
| Propylene Conversion, %            | 28.2       | 38.0  | Ave.<br>38.1 | 30.6       | 31.5  | Ave.<br>31.1 | 25.2       | 14.5  | Ave.<br>14.9 |
| Product Distribution, wt%          |            |       |              |            |       |              |            |       |              |
| IPA                                | 40.9       | 42.1  | 41.5         | 45.3       | 48.5  | 44.9         | 55.0       | 59.6  | 57.3         |
| DIPE                               | 57.3       | 56.2  | 56.7         | 53.1       | 54.0  | 53.5         | 43.5       | 38.6  | 41.0         |
| Propylene Oligomers                | 1.8        | 1.7   | 1.8          | 1.6        | 1.5   | 1.6          | 1.5        | 1.8   | 1.7          |

**EXAMPLE 12**

Example 11 was repeated under somewhat more severe conditions with Catalysts A and B. At 324°F (162°C), 1000 psig (70 bar), 0.5 propylene WHSV (based on zeolite) and a 0.5 mole ratio of water:propylene, Catalyst A resulted in 64% propylene conversion with 55 wt% DIPE selectivity while Catalyst B resulted in 56% propylene conversion with 54 wt% DIPE selectivity.

8

### EXAMPLE 13

This example explores the relationship between catalyst acidity (expressed in terms of alpha value) and catalyst performance. At 302°F (150°C), 1000 psig (70 bar), 0.77 propylene WHSV (based on zeolite) and 1:1 mole ratio of water: propylene, using Catalyst B (alpha value of 359), Catalyst D (steamed 65% zeolite Beta/35% SiO<sub>2</sub>, alpha value of 272) and Catalyst E (steamed 65% zeolite Beta/35% SiO<sub>2</sub>, alpha value of 35), propylene conversions of 31%, 26% and 12%, respectively, were obtained. A favourable relationship between increased alpha values and percentage of propylene conversion were also noted with alumina-bound zeolite Beta. Thus, under substantially similar olefin hydration conditions, Catalyst C (alpha value of 281) provided 15% propylene conversion whereas Catalyst F (steamed 65% zeolite Beta/35 wt% Al<sub>2</sub>O<sub>3</sub>) provided only 7% conversion.

# EXAMPLE 14

Unsteamed, unbound zeolite Beta (Catalyst 1) was evaluated for the hydration of propylene under the conditions, and with the results, set forth in Table 13 as follows:

Table 13: Effect of Process Variables on Performance of Catalyst A-----

|                                      |           |           |      |
|--------------------------------------|-----------|-----------|------|
| Temp., °F (°C)                       | 302 (150) | 324 (162) | 324  |
| Pressure, psig (bar)                 | 1000 (70) | 1000      | 1000 |
| Mole Ratio                           |           |           |      |
| Water/Propylene                      | 1:1       | 1:1       | 0:5  |
| Propylene WHSV<br>(based on zeolite) | 0.5       | 0.5       | 0.5  |
| Propylene Conversion, %              | 49.2      | 61.8      | 64.0 |
| Product Distribution, wt%            |           |           |      |
| IPA                                  | 40.5      | 42.9      | 42.6 |
| DIPE                                 | 57.6      | 54.8      | 54.8 |
| Propylene Oligomers                  | 1.9       | 2.3       | 2.6  |

As these data show, at a mole ratio of water:propylene of 1:1 and a propylene WHSV of 0.5, an increase in temperature of from 302°F to 324°F increased the percentage propylene conversion from 49 to 62%. However, an increase in the temperature to 324°F resulted in a small decrease in propylene conversion possibly resulting from unfavourable thermodynamic equilibrium at the higher temperature. At the same operating temperature of 324°F, a reduction in the mole ratio of water:propylene from 1:1 to 0.5:1 increased the percentage propylene conversion somewhat. Further reduction in the water:propylene mole ratio showed a small decrease in propylene conversion, perhaps as a result of the decreased partial pressure of water (see following Example 15 and Table 14).

EXAMPLE 15

An extrudate of zeolite Beta (83 wt%) bound with colloidal silica (17 wt%) was employed in several propylene hydration runs. The extrudate was prepared by thoroughly mixing the stated amounts of zeolite and colloidal silica together with a sufficient amount of water to provide an extrudable mass in the absence of any added alkali metal base and/or basic salt. Extrusion of the mass into 1/16" (1.59 mm) average diameter extrudate was followed by drying, calcining, ammonium-exchange and calcining in the conventional manner to provide an activated catalyst.

The results of the hydration runs are set forth in Table 14 as follows:

Table 14: Olefin Hydration With Silica-Bound Zeolite Beta

| Temp., °F (°C)                       | 324 (162) | 324     | 324     |
|--------------------------------------|-----------|---------|---------|
| Mole Ratio                           |           |         |         |
| Water/Propylene                      | 0.5:1.0   | 0.5:1.0 | 0.4:1.0 |
| Propylene WHSV<br>(based on zeolite) | 0.5       | 0.5     | 0.5     |
| Time on Stream, days                 | 5         | 12      | 13      |
| Propylene Conversion, %              | 61.9      | 59.1    | 59.1    |
| Water Conversion, %                  | 78.4      | -       | 87.7    |
| Product Distribution, wt%            |           |         |         |
| IPA                                  | 34.2      | 33.3    | 42.6    |
| DIPE                                 | 63.4      | 64.3    | 69.6    |
| Propylene Oligomers                  | 2.4       | 2.4     | 4.1     |

While the activity of Catalyst G was comparable to its unbound counterpart, Catalyst A (61.9% propylene

conversion for Catalyst G as compared with 64.0% propylene conversion for Catalyst A as reported in Table 13 of Example 14), Catalyst G resulted in greater selectivity for DIPE than Catalyst A. At a mole ratio of water:propylene of 0.40, percentage propylene conversion was reduced to 59.1% while both the DIPE and propylene oligomer selectivities were increased at the expense of IPA.

EXAMPLE 16

This example demonstrates the octane-enhancing effect of mixtures of IPA and DIPE when added to gasoline.

Propylene and water were reacted over silica-bound zeolite Beta hydration catalyst under the following conditions: 0.5:1 water:propylene mole ratio, 330°F (166°C), 1000 psig (70 bar) and 0.5 WHSV propylene. Propylene conversion was 62%. The ether-rich liquid product\* was blended directly with 9 volumes of gasoline base stock. After separation and removal of a by-product aqueous phase, a blended gasoline product containing 4.0 wt% DIPE and 4.2 wt% IPA was obtained. Comparison of octane and Reid vapour pressure for the base gasoline and the blended product is shown below in Table 15. The blending (R+M)/2 octane of the hydration product is 108.

Table 15: Direct Blending of IPA/DIPE Mixture  
With Gasoline

|                 | Gasoline Base | Blend |
|-----------------|---------------|-------|
| Research octane | 91.9          | 94.6  |
| Motor Octane    | 82.5          | 83.8  |
| (R+M)/2         | 87.2          | 89.2  |
| RVP (psi)       | 5.1           | 5.2   |

\* The composition (wt%) of the ether-rich product was as follows:

|           |       |
|-----------|-------|
| Water     | 6.36  |
| Propylene | 3.52  |
| IPA       | 34.40 |
| DIPE      | 51.89 |
| Oligomer  | 4.27  |

~~CLAIMS~~ THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A process for converting light olefins to alcohols and/or ethers which comprises contacting a feed containing at least one light olefin with water in the vapour and/or liquid phase under olefin hydration conditions in the presence of a catalyst comprising zeolite Beta.
2. A process according to claim 1 wherein the feed contains a mixture of light olefins.
3. A process according to claim 1 or claim 2 wherein the olefins contain from two to seven carbon atoms.
4. A process according to any preceding claim wherein the feed contains ethylene, propylene, a butene, a pentene, a hexane and/or a heptene.
5. A process according to any preceding claim wherein the feed comprises naphtha cracker off-gas.
6. A process according to any preceding claim wherein the feed is catalytically cracked light gasoline containing pentenes, hexenes and heptenes.
7. A process according to any preceding claim wherein the conditions include a temperature of 50° to 300°C.
8. A process according to claim 7 wherein the temperature is 50° to 220°C.

9. A process according to claim 8 wherein the temperature is 90° to 200°C.

10. A process according to any preceding claim wherein the conditions include a total system pressure of at least 5 atm (bar).

11. A process according to claim 10 wherein the total system pressure is at least 20 atm (bar).

12. A process according to claim 11 wherein the total system pressure is at least 40 atm (bar).

13. A process according to any preceding claim wherein the mole ratio of water to total olefin is from 0.1 to 30.

14. A process according to claim 13 wherein the mole ratio of water to total olefin is from 0.2 to 15.

15. A process according to claim 14 wherein the mole ratio of water to total olefin is from 0.3 to 5.

16. A process according to any preceding claim wherein the zeolite Beta is composited with a binder.

17. A process according to claim 16 wherein the binder comprises silica and/or alumina.

18. A process according to any preceding claim wherein the catalyst is an extrudate containing an extrusion facilitating amount of a low acidity refractory oxide binder in the colloidal state which is substantially free of added alkali metal base or basic salt.

19. A process according to any preceding claim wherein the alpha value of the zeolite Beta is at least 1.

20. A process according to any preceding claim wherein the alpha value of the zeolite Beta is at least 10.

21. A process according to any preceding claim wherein the alpha value of the zeolite Beta is at least 100.

22. A process according to any preceding claim wherein the zeolite is in the hydrogen form.

23. A process according to any preceding claim wherein the catalyst further comprises a co-catalyst effective for the hydration of light olefin.

~~DATED: 30 December 1988~~

PHILLIPS ORMONDE & FITZPATRICK  
Attorneys for:  
MOBIL OIL CORPORATION

*David B. Fitzpatrick*



24. A process substantially as hereinbefore described with reference to any one of the Examples.

DATED: 17 January 1991

PHILLIPS ORMONDE & FITZPATRICK

Attorneys for:

MOBIL OIL CORPORATION

*David B Fitzpatrick*

