

TECHNICAL FIELD

This application is directed to high quality alkylate gasoline and processes to produce high quality alkylate gasoline from olefin feeds comprising pentenes, while producing very low (or even no) isopentane from the olefin feed.

BACKGROUND

It is desired to have a process to increase gasoline production by consuming low value isobutane and pentenes and producing a high quality alkylate gasoline. Others have tried alkylating isobutane with pentenes to improve gasoline production and reduce evaporative hydrocarbon emissions, but the processes using either hydrofluoric or sulfuric acid alkylation catalysts have had significant shortcomings. Hydrofluoric (HF) and sulfuric acid (H₂SO₄) alkylation catalysts produce significant amounts of isopentane and/or n-pentane during the alkylation of pentenes, and both isopentane and n-pentane have undesirably high Reid Vapor Pressures.

Alkylate gasoline is a highly desirable blending component for motor gasoline with its high octane, low sulfur level and no aromatics. As the gasoline specifications have become tightened worldwide due to heightened environmental concerns, the demand for increased use of alkylate gasoline has been increasing steadily over the years. Most of the refineries in United States already have isoparaffin alkylation units that alkylate isobutane with C₃ and C₄ olefins from fluid catalytic cracker (FCC) units to produce alkylate gasoline. The FCC units also produce a light gasoline fraction, containing substantial amount of C₅ – C₆ olefins, and due to the difficulties in performing alkylations with them, they are currently blended into the gasoline pool.

Alkylation of C₅ olefins has been practiced to only a limited extent in the industry so far. There is a trend suggesting that it would be desired to have more of the C₅ olefins be alkylated in the future to help meet tighter environmental regulations. There remains a substantial need to develop an efficient alkylation process for C₅ olefins.

Conventional alkylation processes using HF catalyst are not effective in alkylating C₅ olefins. During the pentenes alkylation with isobutane, the HF alkylation process generates substantial amounts of isopentane through a hydrogen transfer reaction. This is highly undesirable due to the high Reid Vapor Pressure (RVP) of isopentane (21 RVP for isopentane

5 vs. 6-7 maximum RVP specification for gasoline). An example of the high RVP issue with
the HF alkylation process is shown in US patent 5,382,744 by Abbott et al., which showed
that alkylation of 2-methyl-2-butene converts about 70 mol% of the pentene to isopentane via
hydrogen transfer. In the patent, Abbott et al. found that recycling of isopentane to the
10 reactor reduces the isopentane formation somewhat. However, the recycling of isopentane
would make the overall process complicated and raise the cost.

Conventional alkylation processes using H₂SO₄ catalysts are less susceptible to the
hydrogen transfer than processes using HF catalyst, but still from about 0 % up to 20 % of C₅
olefins are converted to isopentane during the alkylation process using H₂SO₄ catalyst
(Stratco report, published in 1999 by Randall Peterson, David Graves, Ken Kranz and David
15 Buckler). The H₂SO₄ alkylation process for alkylating C₅ olefins also increases the acid
consumption. The H₂SO₄ alkylation processes are highly susceptible to cyclopentene and
diene contaminants. The cyclopentene, dienes and other contaminants further increase the
acid consumption to an even higher level. To control the acid consumption, a very low
reaction temperature of less than 10 °C may need to be used for the processes using H₂SO₄
20 catalyst, which requires additional equipment and higher cost.

SUMMARY

This application provides a process to make an alkylate gasoline, comprising:

- a. providing an olefin feed, comprising at least 8 wt% pentenes, a butene, and less than
25 60 wt% isopentane;
- b. providing an isoparaffin feed comprising an isobutane; and
- c. alkylating the olefin feed with the isoparaffin feed using an acidic ionic liquid
alkylation catalyst under alkylation conditions to make the alkylate gasoline;

wherein a yield of the isopentane in the alkylate gasoline corresponds to less than 15
30 mol% of C₅ olefins in the olefin feed and wherein the alkylate gasoline has a final boiling
point from 370 °F (187.8 degree Celsius) to 400 °F (204.4 degree Celsius) and a RON of 85
or greater.

This application also provides an alkylation process comprising:

- alkylating an olefin feed with an isoparaffin feed comprising an isobutane using an acidic
35 ionic liquid alkylation catalyst under alkylation conditions to produce an alkylate gasoline,
wherein the olefin feed comprises at least 8 wt% pentenes and less than 60 wt% isopentane;

5 wherein a yield of the isopentane in the alkylate gasoline corresponds to less than 15 mol% of C5 olefins in the olefin feed, wherein the alkylate gasoline has a final boiling point from 370 °F (187.8 degree Celsius) to 400 °F (204.4 degree Celsius) and a RON of 85 or higher; and

10 wherein an n-pentane product yield relative to a total olefin content in the olefin feed is from zero to less than 0.2 mol/mol.

Additionally, this application provides an alkylate gasoline, comprising less than 0.1 wt% olefins, less than 0.1 wt% aromatics, less than 1.8 wt% C₁₂₊ hydrocarbons, and greater than 60 wt% C₈ hydrocarbons and C₉ hydrocarbons, wherein an amount of a trimethylpentane in the C₈ hydrocarbons is from 70 to 80 wt% and a second amount of a trimethylhexane in the
15 C₉ hydrocarbons is from 80 to 90 wt%.

The present invention may suitably comprise, consist of, or consist essentially of, the elements in the claims, as described herein.

GLOSSARY

20 “Olefin” refers to a class of unsaturated aliphatic hydrocarbons having one or more double bonds

“Pentenenes” are alkenes with the chemical formula C₅H₁₀. Each pentene molecule contains one double bond within its molecular structure. There are a total of six different pentene compounds, differing from each other by whether the carbon atoms are attached
25 linearly or in a branched structure, and whether the double bond has a cis- or trans- form.

“Isoparaffin” refers to a branched isomer of a straight-chain paraffin molecule.

“Alkylate gasoline” refers to hydrocarbons that are composed of a mixture of high-octane, branched-chain paraffinic hydrocarbons (e.g., isoheptane and isooctane). Alkylate gasoline is a premium gasoline blending stock because it has exceptional antiknock properties
30 and is clean burning.

“Fluid catalytic cracker” (FCC) is a unit that performs a conversion process employed in petroleum refineries to convert the high-boiling, high-molecular weight hydrocarbon fractions of petroleum crude oils to more valuable FCC gasoline, olefinic gases, and other hydrocarbon products.

35 “Essentially” refers to from 90 wt% to 100 wt% in the context of this disclosure.

“Periodic Table” refers to the version of the IUPAC Periodic Table of the Elements dated June 22, 2007, and the numbering scheme for the Periodic Table Groups is as described in Chemical And Engineering News, 63(5), 27 (1985).

“Acidic ionic liquid” refers to materials consisting entirely of ions, that can donate a proton or accept an electron pair in reactions, and that are liquid below 100°C.

DETAILED DESCRIPTION

We have discovered that an acidic ionic liquid alkylation catalyst is effective in alkylating a C₅ olefin feed with isobutane to make excellent quality alkylate gasoline. Our processes can operate in a wide range of feed variation with both excellent operability and product selectivity. For alkylation of a mixed C₄ and C₅ olefin feed with isobutane, our process with an acidic ionic liquid alkylation catalyst can selectively convert the C₅ olefins to alkylate gasoline with a minor (or no) incremental production of isopentane. In one embodiment, for olefin feeds comprising high C₅ olefin and isopentane, our processes are able to convert both isopentane and C₅ olefins in the feed to alkylate gasoline and thus, effectively lower the isopentane content in the alkylate gasoline product.

Alkylation of C₅ olefins (pentenes or amylenes) with isoparaffins comprising isobutane would provide many benefits to a refinery. A refinery would be able to increase the alkylate gasoline production volume by alkylating the C₅ olefins with isobutane and the alkylate gasoline has a significantly higher value than the isobutane and the mixed pentene starting materials.

In one embodiment, by converting the high RVP (Reid Vapor Pressure) and olefinic pentenes from a Fluid Catalytic Cracker (FCC) gasoline to generate low RVP alkylate gasoline by the processes of our invention, the overall gasoline pool RVP and olefin content are significantly reduced. The production of additional clean, low RVP alkylate gasoline gives the refinery more flexibility in gasoline blending.

The olefin feed that is useful in the processes herein comprise at least 8 wt% of pentenes and less than 60 wt% isopentane. In one embodiment, the olefin feed comprises greater than 20 wt% of pentenes. In one embodiment, the olefin feed comprises from at least 8 wt% to 100 wt% pentenes. The amount of the pentenes in the olefin feed can range broadly, for example the amount of the pentenes in the olefin feed can be from 10 to 100 mol%, from 10 to 99.9 mol%, or 35 to 100 mol% of a total olefins in the olefin feed.

In one embodiment, the olefin feed additionally comprises a butene, such as from 1 to 80 wt% butene. In one embodiment, the olefin feed comprises C₃, C₄, and C₅ olefins.

5 The olefin feed can come from any source, not just from a refinery. Examples of
suitable olefin feeds include hydrocarbons comprising pentenes which could come, for
example, from FCC, from a coker unit, naphtha cracking, gas-to-liquid (GTL) processes, or
derived via dehydrogenation of pentane, such as from natural gas liquid dehydrogenation or
bio-material dehydrogenation. The feeds may come directly from different sources, or can
10 be blended. In one embodiment the olefin feed is from a FCC unit in a refinery. The
processes may additionally comprise isolating a C₅ olefin stream from a FCC unit to provide
the olefin feed and the alkylating converts the C₅ olefin stream to the alkylate gasoline
without needing to increase a throughput from the FCC unit.

 In one embodiment, the olefin feed comprises 1-pentene, such as from greater than 2
15 wt% to 10 wt% 1-pentene.

 The olefin feed may comprise varying levels of *n*-pentane. In one embodiment, the
olefin feed comprises from zero to 10 wt% *n*-pentane, such as 4 wt% or less, or from 0.1 wt%
to 8 wt% *n*-pentane.

 In one embodiment, the olefin feed comprises greater than 5 wt% isopentane, such as
20 from greater than 12.7 wt% to 55 wt% of the isopentane. In one embodiment, the olefin feed
comprises greater than 12.7 wt% of the isopentane and the alkylating lowers a content of the
isopentane in the alkylate gasoline.

 In one embodiment, the processes may comprise selectively hydrogenating a refinery
olefin stream to make the olefin feed. The selectively hydrogenating can reduce the dienes in
25 the olefin feed. For example, after the selective hydrogenation the olefin feed can comprise
less than 1 wt% dienes, or from zero to 0.5 wt% dienes. Reducing the level of dienes and
cyclopentene in the olefin feed can reduce the rate of conjunct polymer formation during the
alkylating and/or improve the alkylate gasoline product quality, e.g., by reducing formation
of gum or heavy hydrocarbons with high boiling point. Depending on the severity of the
30 selective hydrogenation (e.g., temperature, hydrogen flow, hydrogen partial pressure,
residence time, and choice of the hydrogenation catalyst), different extents of diene removal
and isomerization of the olefins in the olefin feed will occur. In one embodiment, the
conditions for selectively hydrogenating are selected to be mild, and the mild conditions
remove only a portion of the dienes. In one embodiment, the conditions for selectively
35 hydrogenating are chosen to also perform olefin isomerization, and the olefin isomerization
can be limited to shifting of double bonds in molecules in the olefin feed, such as converting
1-pentene to 2-pentene or converting methyl-1-butenes to methyl-2-butenes. Conversion of

5 1-pentene to 2-pentene, thereby increasing the relative amount of 2-pentene in the olefin feed, can increase the RON and MON of the alkylate gasoline produced via alkylation with an ionic liquid catalyst.

In one embodiment, the processes may additionally comprise hydroisomerizing a refinery olefin stream to make an olefin feed that has a reduced amount of 1-butene and an
10 increased amount of 2-butene. Increasing the amount of 2-butene in the olefin feed can increase the RON and/or a MON of the alkylate gasoline.

In one embodiment, the processes may comprise selectively hydrogenating the olefin feed to increase the RON and/or a MON of the alkylate gasoline by at least about 0.5. In a sub-embodiment, the RON is increased by 0.5 to 4.0.

15 In one embodiment, the alkylating can convert essentially all of the olefins in the olefin feed. In one embodiment, the alkylating converts greater than 98 wt%, or even 100 wt%, of the olefins in the olefin feed.

Alkylate Gasoline

20 In one embodiment, the alkylate gasoline made by the processes disclosed herein has one or more of a high Research Octane Number (RON), a high Motor Octane Number (MON), a low final boiling point, and low Reid Vapor Pressure (RVP). The alkylate gasoline produced by the processes of this invention can have one or more desired properties, including a low final boiling point, a high RON, high MON, low RVP, low aromatics, low
25 olefins, and low sulfur. In one or more embodiments, the alkylate gasoline has a final boiling point from 370 °F (187.8 degree Celsius) to 400 °F (204.4 degree Celsius).

Research Octane Number (RON) is determined using ASTM D2699-15 (REV A), Standard Test Method for Research Octane Number of Spark-Ignition Engine Fuel. Additionally, the RON (GC) can be calculated from gas chromatography boiling range
30 distribution data. The RON (GC) calculation is described in the publication, Anderson, P. C., Sharkey, J. M., and Walsh, R. P., "Journal Institute of Petroleum", 58 (560), 83 (1972). Another measure of the octane number of a fuel is the Motor Octane Number (MON). MON correlates with commercial automotive spark-ignition engine antiknock performance under severe conditions of operation. MON can be determined by ASTM D2700-16.

35 In one or more embodiments, the alkylate gasoline has a high RON, such as 85 or higher, from 90.0 or higher, from 85.0 to 96.0, or from 90.0 to 94.5.

5 The alkylate gasoline contains from zero to less than 0.1 wt% aromatics, from zero to less than 0.1 wt% olefins, and can also have low sulfur.

 In one embodiment, the alkylate gasoline has an amount of a trimethylpentane in C₈ hydrocarbons in the alkylate gasoline that is greater than 50 wt%, such as from 70 to 95 wt%.

 In one embodiment, the alkylate gasoline has an amount of trimethylhexane in C₉ hydrocarbons in the alkylate gasoline that is greater than 70 wt%, such as from 85 to 95 wt%.

 In some embodiments, the alkylate gasoline comprises a C₅+ alkylate fraction having a RVP less than 7 psi, such as from 2.3 to 6.0 psi, or from 2.0 to 5.5 psi. In one embodiment the RVP is less than 4.0 psi. RVP can be determined by ASTM D323-15a, "Standard Test Method for Vapor Pressure of Petroleum Products (Reid Method)".

15 In some embodiments, the alkylate gasoline has a C₅+ average density greater than 0.65 g/cc, such as from 0.68 to 0.74 g/cc.

 In one embodiment, the alkylate gasoline comprises from zero to less than 0.1 wt% olefins, from zero to less than 0.1 wt% aromatics, from zero to less than 1.8 wt% C₁₂+ hydrocarbons, and greater than 60 wt% combined C₈ and C₉ hydrocarbons. In a sub-embodiment, this alkylate gasoline can comprise a high level of trimethylalkanes, which impart a high RON to the alkylate gasoline. For example, the alkylate gasoline can comprise an amount of a trimethylpentane in the C₈ hydrocarbons greater than 50 wt%, such as from 70 to 95 wt%, and a second amount of a trimethylhexane in the C₉ hydrocarbons greater than 70 wt%, such as from 85 to 95 wt%. In a sub-embodiment, the alkylate gasoline comprises

20 from 0.1 to less than 1 wt% C₁₂+ hydrocarbons.

 In one embodiment the alkylate gasoline comprises greater than 60 wt% C₈ hydrocarbons and C₉ hydrocarbons, such as from 61 to 90 wt% or 65 to 80 wt%. In one embodiment, the alkylate gasoline comprises greater than 10 wt% C₉ hydrocarbons, such as from 13 to 42 wt%. In one embodiment, the alkylate gasoline comprises greater than 20 wt% C₈ hydrocarbons, such as from 25 to 65 wt% C₈ hydrocarbons.

25 In one embodiment a C₅ olefin stream from a FCC unit can be easily isolated and then this C₅ olefin stream provides an attractive alternative source of olefins that can be converted to additional amounts of high quality, clean, alkylate gasoline without increasing the FCC unit throughput.

35 In one embodiment, the process is an effective alkylation process for a mixed C₄/C₅ olefin feed with isobutane using an acidic ionic liquid alkylation catalyst where the process

5 selectively converts C₅ olefins to alkylate gasoline with a minor incremental production of isopentane.

In one embodiment, with high C₅ olefin content (e.g., from greater than 8 wt% to 40 wt% total pentenes) and high isopentane content (e.g., from greater than 12.7 wt% to 55 wt%) in the olefin feed, our process is able to convert both isopentane and C₅ olefins in the
10 olefin feed to alkylate gasoline and also effectively lower the isopentane content in the alkylate gasoline product.

Alkylating

15 The processes comprise alkylating the olefin feed with the isoparaffin feed using an acidic ionic liquid alkylation catalyst under alkylation conditions. For example, the alkylating can be done at an alkylation temperature greater than -20 °C, such as from -15 °C to 100 °C, or from -10 °C to 50 °C. In one embodiment, the alkylation conditions may include one or more of a catalyst volume in an alkylation reactor of 2 vol % to 50 vol %, an alkylation
20 temperature of -10° C. to 100° C., an alkylating pressure of 300 kPa to 2500 kPa, an isoparaffin to olefin molar ratio of 2 to 16 and a residence time of 30 seconds to 1 hour.

While we do not want to be bound by the theory, data in hand suggests that the acidic ionic liquid alkylation catalyst does not have a high H-transfer tendency, unlike the conventional HF alkylation catalyst and to a lesser extent than the H₂SO₄ alkylation catalyst.
25 The acidic ionic liquid alkylation catalyst can preferably make the primary alkylation product of isobutane with C₅ olefins that is predominately trimethylhexane. With high reactivity in an alkylation reactor, the acidic ionic liquid alkylation catalyst is uniquely able to convert isopentane in the olefin feed when the isopentane concentration is above a threshold value, somewhere between 12.7 to 29.8 wt% isopentane in the olefin feed or 1-3 wt% isopentane in
30 the combined feed (isobutane and olefin feed).

In one embodiment, the acidic ionic liquid alkylation catalyst conducts simultaneous conversion of the isobutane and the isopentane into the alkylate gasoline during the alkylating. In one embodiment, the acidic ionic liquid alkylation catalyst conducts simultaneous conversion of isobutane and isopentane into high quality alkylate gasoline
35 products. The simultaneous conversion of isobutane and isopentane appears to be unique, and this may allow co-processing of isopentane and isobutane in the alkylation reactor, which was not possible with earlier conventional alkylation catalysts.

5 Acidic Ionic Liquid

Examples of acidic ionic liquid alkylation catalysts and their use for alkylation of paraffins with olefins are taught, for example, in U.S. Patent Numbers 7,432,408 and 7,432,409, 7,285,698, and U.S. Patent Application Number 12/184069, filed July 31, 2008. In one embodiment, the acidic ionic liquid alkylation catalyst is a composite ionic liquid
10 alkylation catalyst, wherein the cations come from a hydrohalide of an alkyl-containing amine or pyridine, and the anions are composite coordinate anions coming from two or more metal compounds.

The most common acidic ionic liquids are those prepared from organic-based cations and inorganic or organic anions. The acidic ionic liquid alkylation catalyst is composed of at
15 least two components which form a complex. The acidic ionic liquid alkylation catalyst comprises a first component and a second component. The first component of the acidic ionic liquid alkylation catalyst will typically comprise a Lewis acid compound selected from components such as Lewis acid compounds of Group 13 metals, including aluminum halides, alkyl aluminum dihalides, gallium halide, and alkyl gallium halide (see the Periodic Table,
20 which defines the elements that are Group 13 metals). Other Lewis acid compounds besides those of Group 13 metals may also be used. In one embodiment the first component is aluminum halide or alkyl aluminum dihalide. For example, aluminum trichloride (AlCl_3) may be used as the first component for preparing the ionic liquid alkylation catalyst. In one embodiment, the alkyl aluminum dihalides that can be used can have the general formula
25 $\text{Al}_2\text{X}_4\text{R}_2$, where each X represents a halogen, selected for example from chlorine and bromine, each R represents a hydrocarbyl group comprising 1 to 12 atoms of carbon, aromatic or aliphatic, with a branched or a linear chain. Examples of alkyl aluminum dihalides include dichloromethylaluminum, dibromomethylaluminum, dichloroethylaluminum, dibromoethylaluminum, dichloro n-hexylaluminum,
30 dichloroisobutylaluminum, either used separately or combined.

The second component making up the acidic ionic liquid can be an organic salt or mixture of salts. These salts may be characterized by the general formula Q^+A^- , wherein Q^+ is an ammonium, phosphonium, boronium, oxonium, iodonium, or sulfonium cation and A^- is a negatively charged ion such as Cl^- , Br^- , ClO_4^- , NO_3^- , BF_4^- , BCl_4^- , PF_6^- , SbF_6^- , AlCl_4^- ,
35 Al_2Cl_7^- , $\text{Al}_3\text{Cl}_{10}^-$, GaCl_4^- , Ga_2Cl_7^- , $\text{Ga}_3\text{Cl}_{10}^-$, AsF_6^- , TaF_6^- , CuCl_2^- , FeCl_3^- , AlBr_4^- , Al_2Br_7^- , $\text{Al}_3\text{Br}_{10}^-$, SO_3CF_3^- , and 3-sulfurtrioxyphenyl.

5 In one embodiment the second component is selected from those having quaternary ammonium halides containing one or more alkyl moieties having from about 1 to about 9 carbon atoms, such as, for example, trimethylammonium hydrochloride, methyltributylammonium, 1-butyl pyridinium, or alkyl substituted imidazolium halides, such as for example, 1-ethyl-3-methyl-imidazolium chloride.

10 In one embodiment, the acidic ionic liquid comprises a monovalent cation selected from the group consisting of a pyridinium ion, an imidazolium ion, a pyridazinium ion, a pyrazolium ion, an imidazolinium ion, a imidazolidinium ion, an ammonium ion, a phosphonium ion, and mixtures thereof. Examples of possible cations (Q+) include a butylethylimidazolium cation [beim], a butylmethylimidazolium cation [bmim],

15 butyldimethylimidazolium cation [bmmim], decaethylimidazolium cation [dceim], a decamethylimidazolium cation [dcim], a diethylimidazolium cation [eeim], dimethylimidazolium cation [mmim], an ethyl-2,4-dimethylimidazolium cation [e-2,4-mmim], an ethyldimethylimidazolium cation [emmim], an ethylimidazolium cation [eim], an ethylmethylimidazolium [emim] cation, an ethylpropylimidazolium cation [epim], an

20 ethoxyethylmethylimidazolium cation [etO-emim], an ethoxydimethylimidazolium cation [etO-mmim], a hexadecylmethylimidazolium cation [hexadmim], a heptylmethylimidazolium cation [hpmim], a hexaethylimidazolium cation [hxeim], a hexamethylimidazolium cation [hxmim], a hexadimethylimidazolium cation [hxmmim], a methoxyethylmethylimidazolium cation [meO-emim], a methoxypropylmethylimidazolium cation [meO-prmim], a

25 methylimidazolium cation [mim], dimethylimidazolium cation [mmim], a methylonylimidazolium cation [mnim], a methylpropylimidazolium cation [mpim], an octadecylmethylimidazolium cation [octadmim], a hydroxyethylmethylimidazolium cation [OH-emim], a hydroxyoctylmethylimidazolium cation [OH-omim], a hydroxylpropylmethylimidazolium cation [OH-prmim], an octylmethylimidazolium cation

30 [omim], an octyldimethylimidazolium cation [ommim], a phenylethylmethylimidazolium cation [ph-emim], a phenylmethylimidazolium cation [ph-mim], a phenyldimethylimidazolium cation [ph-mmim], a pentylmethylimidazolium cation [pnmim], a propylmethylimidazolium cation [prmim], a 1-butyl-2-methylpyridinium cation[1-b-2-mpy], 1-butyl-3-methylpyridinium cation[1-b-3-mpy], a butylmethylpyridinium [bmpy]

35 cation, a 1-butyl-4-dimethylacetylpyridinium cation [1-b-4-DMApy], a 1-butyl-4-35 methylpyridinium cation[1-b-4-mpy], a 1-ethyl-2-methylpyridinium cation[1-e-2-mpy], a 1-ethyl-3-methylpyridinium cation[1-e-3-mpy], a 1-ethyl-4-dimethylacetylpyridinium cation[1-

5 e-4-DMApy], a 1-ethyl-4-methylpyridinium cation[1-e-4-mpy], a 1-hexyl-5
 4dimethylacetylpyridinium cation[1-hx-4-DMApy], a 1-hexyl-4-methylpyridinium cation[1-
 hx-4-mpy], a 1-octyl-3-methylpyridinium cation[1-o-3-mpy], a 1-octyl-4-methylpyridinium
 cation[1-o-4-mpy], a 1-propyl-3-methylpyridinium cation[1-pr-3-mpy], a 1-propyl-4-
 10 methylpyridinium cation[1-pr-4-mpy], a butylpyridinium cation [bpy], an ethylpyridinium
 cation [epy], a heptylpyridinium cation [hppy], a hexylpyridinium cation [hxy], a
 hydroxypropylpyridinium cation [OH-prpy], an octylpyridinium cation [opy], a
 pentylpyridinium cation [pnpy], a propylpyridinium cation [prpy], a
 butylmethylpyrrolidinium cation [bmpyr], a butylpyrrolidinium cation [bpyr], a
 hexylmethylpyrrolidinium cation [hxmpyr], a hexylpyrrolidinium cation [hxypr], an
 15 octylmethylpyrrolidinium cation [ompyr], an octylpyrrolidinium cation [opyr], a
 propylmethylpyrrolidinium cation [prmpyr], a butylammonium cation [b-N], a
 tributylammonium cation [bbb-N], a tetrabutylammonium cation [bbbb-N], a
 butylethyldimethylammonium cation [bemmm-N], a butyltrimethylammonium cation [bmmmm-
 N], a N,N,N-trimethylethanolammonium cation [choline], an ethylammonium cation [e-N], a
 20 diethylammonium cation [ee-N], a tetraethylammonium cation [eeee-N], a
 tetraheptylammonium cation [hphphph-N], a tetrahexylammonium cation [hxhxhx-N], a
 methylammonium cation [m-N], a dimethylammonium cation [mm-N], a
 tetramethylammonium cation [mmmm-N], an ammonium cation [N], a
 butyldimethylethanolammonium cation [OHe-bmm-N], a dimethylethanolammonium cation
 25 [OHe-mm-N], an ethanolammonium cation [OHe—N], an ethyldimethylethanolammonium
 cation [OHe-emm-N], a tetrapentylammonium cation [pnpnpnpn-N], a tetrapropylammonium
 cation [prprprpr-N], a tetrabutylphosphonium cation [bbbb-P], a tributyl-octylphosphonium
 cation [bbbo-P], or combinations thereof.

In one embodiment, the second component is selected from those having quaternary
 30 phosphonium halides containing one or more alkyl moieties having from 1 to 12 carbon
 atoms, such as, for example, trialkylphosphonium hydrochloride, tetraalkylphosphonium
 chlorides, and methyltrialkylphosphonium halide.

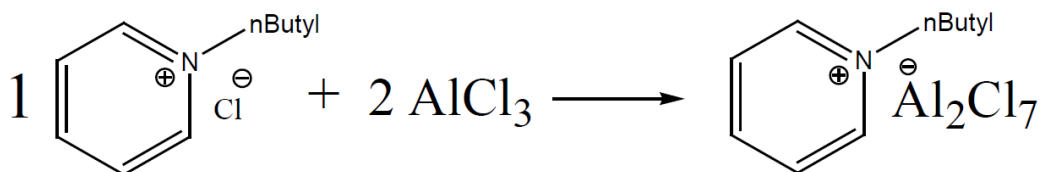
In one embodiment, the acidic ionic liquid comprises an unsubstituted or partly
 alkylated ammonium ion.

35 In one embodiment, the acidic ionic liquid is chloroaluminate or a bromoaluminate. In
 one embodiment the acidic ionic liquid is a quaternary ammonium chloroaluminate ionic
 liquid having the general formula $RR'R''N^+H^+Al_2Cl_7^-$, wherein R, R', and R'' are alkyl

5 groups containing 1 to 12 carbons. Examples of quaternary ammonium chloroaluminate ionic liquids are an N-alkyl-pyridinium chloroaluminate, an N-alkyl-alkylpyridinium chloroaluminate, a pyridinium hydrogen chloroaluminate, an alkyl pyridinium hydrogen chloroaluminate, a di alkyl- imidazolium chloroaluminate, a tetra-alkyl-ammonium chloroaluminate, a tri-alkyl-ammonium hydrogen chloroaluminate, or a mixture thereof.

10 The presence of the first component should give the acidic ionic liquid a Lewis or Franklin acidic character. Generally, the greater the mole ratio of the first component to the second component, the greater is the acidity of the acidic ionic liquid.

For example, a typical reaction mixture to prepare n-butyl pyridinium chloroaluminate ionic liquid is shown below:



15 In one embodiment, the acidic ionic liquid utilizes a co-catalyst to provide enhanced or improved alkylation activity. Examples of co-catalysts include alkyl halide or hydrogen halide. A co-catalyst can comprise, for example, anhydrous HCl or organic chloride (see, e.g., U.S. Pat. Nos. 7,495,144 to Elomari, and 7,531,707 to Harris et al.). When organic chloride is used as the co-catalyst with the acidic ionic liquid, HCl may be formed in situ in the apparatus either during the alkylating or during post-processing of the output of the alkylating. In one embodiment, the alkylating with the acidic ionic liquid is conducted in the presence of a hydrogen halide, e.g., HCl.

25 In one embodiment, the acidic ionic liquid alkylation catalyst additionally comprises a Brønsted acid. In one embodiment, the acidic ionic liquid alkylation catalyst comprises an ionic liquid catalyst and a Brønsted acid. In these embodiments, the Brønsted acid acts as a promoter or co-catalyst. Examples of Brønsted acids are sulfuric acid, HCl, HBr, HF, phosphoric acid, HI, etc. Other strong acids that are proton donors can also be suitable Brønsted acids. In one embodiment, the Brønsted acid is produced internally within the process by the conversion of an alkyl halide into the corresponding hydrogen halide. In one embodiment the Brønsted acid is formed by a reaction of a Lewis acid component of an ionic liquid, such as chloroaluminate ions for instance reacting with a weakly acidic proton donor such as an alcohol or water to form HCl.

30

5 The alkyl halides that may be used include alkyl bromides, alkyl chlorides and alkyl
iodides. Such alkyl halides include but are not limited to isopentyl halides, isobutyl halides, t-
butyl halides, n-butyl halides, propyl halides, and ethyl halides. Alkyl chloride versions of
these alkyl halides can be preferable when chloroaluminate ionic liquids are used. Other alkyl
chlorides or alkyl halides having from 1 to 8 carbon atoms can be also used. The alkyl halides
10 may be used alone or in combination.

When used, the alkyl halide or hydrogen halide co-catalysts are used in catalytic
amounts. In one embodiment, the amounts of the alkyl halides or hydrogen halide should be
kept at low concentrations and not exceed the molar concentration of the AlCl_3 in the acidic
ionic liquid. For example, the amounts of the alkyl halides or hydrogen halide used may
15 range from 0.05 mol %-100 mol %, or 0.05 mol% - 10 mol%, of the Lewis acid AlCl_3 in the
acidic ionic liquid in order to keep the acidity of the acidic ionic liquid alkylation catalyst at
the desired performing capacity.

In one embodiment, the acidic ionic liquid alkylation catalyst comprises an ionic
liquid catalyst and a Brønsted acid. In this embodiment, the Brønsted acid acts as a promoter
20 or co-catalyst. Examples of Brønsted acids are sulfuric acid, HCl , HBr , HF , phosphoric acid,
 HI , etc. Other strong acids that are proton donors can also be suitable Brønsted acids. In one
embodiment, the Brønsted acid is produced internally within the process by the conversion of
an alkyl halide into the corresponding hydrogen halide.

In one embodiment, the process can additionally comprise recycling an excess of the
25 isoparaffin feed to the alkylating. For example, the process can include distilling out an
excess isoparaffin after the alkylating and then recycling the excess isoparaffin to the
alkylating.

EXAMPLES

Example 1: Ionic Liquid Alkylation Catalyst

30 Various acidic ionic liquid alkylation catalysts made of metal halides, such as AlCl_3 ,
 AlBr_3 , GaCl_3 , GaBr_3 , InCl_3 , and InBr_3 could be used for catalytic processes. N-
butylpyridinium chloroaluminate ($\text{C}_5\text{H}_5\text{NC}_4\text{H}_9\text{Al}_2\text{Cl}_7$) was the acidic ionic liquid alkylation
catalyst used in the following examples. This acidic ionic liquid alkylation catalyst had a
35 density of 1.34 g/cc and had the composition shown in Table 1.

5

Table 1
Composition of Fresh Acidic Ionic Liquid Alkylation Catalyst

Fresh Ionic Liquid Alkylation Catalyst	
Al, wt%	11.18
Cl, wt%	56.5
C, wt%	25.95
H, wt%	3.29
N, wt%	3.32

10 **Example 2: Feed Compositions**

The isobutane feeds used in this example were either refinery isobutane feed consisting of 85 wt% isobutane and 15 wt% n-butane, or 100 wt% pure chemical grade isobutane. The isobutane streams were thoroughly dried to less than 1 wppm water by passing the isobutane feeds through a fixed bed containing a molecular sieve adsorbent.

Five different olefin feeds used in this example were refinery olefin streams from a Fluid Catalytic Cracker (FCC) containing varying amounts of C₅ olefins. The olefin feeds all had 1 wt% or less of C₃ olefins, and no ethylene. These olefin feeds were also thoroughly dried to less than 1 wppm water by passing the olefin feeds through a fixed bed containing a molecular sieve adsorbent. The water contents in the dried isobutane and olefin feeds were measured using a GE Panametrics on-line moisture analyzer with an aluminum oxide moisture sensor probe.

The detailed compositions of the five different olefin feeds are summarized in Table 2.

Table 2
Composition of Olefin Feeds

Mol% of C5 Olefins/ Total C3 - C5 Olefins Olefin Feed	2.2 Feed #1	14.2 Feed #2	39.5 Feed #3	59.3 Feed #4	75.0 Feed #5
Composition, wt%					
Propane	2.7	1.6	0.8	0.5	0.01
Propylene	1.1	0.8	0.9	0.6	0.01
Isobutane	30.6	30.5	17.5	9.3	0.5
n-Butane	9.8	4.7	3.0	2.0	1.5
Butenes (sum of C4= isomers)	51.0	40.3	24.9	16.1	9.7
Isopentane	3.2	12.7	29.8	37.8	48.5
n-Pentane	0.1	0.7	2.1	3.1	3.7
3-Methyl-1-Butene		0.6	1.4	1.6	2.2
1-Pentene		1.8	4.5	6.7	7.9
2-Methyl-1-Butene	1.5 (total C5=)	2.2	6.8	11.3	10.3
2-Pentenenes		3.1	6.4	7.9	11.9
2-Methyl-2-Butene		0.9	2.2	3.3	3.8
Cyclopentene	0		0.15		
1-3-Butadiene	0	0.07	0.03	0.03	~0.03
Isoprene (2-Methyl-1,3-Butadiene)	0		0.11		
<i>t</i> -1,3-Pentadiene	0		0.04		
Cyclopentadiene	0		0.05		
Sum of C5= isomers, wt%	1.5	8.6	21.4	30.7	36.2
Sum of C4 & C5 dienes, wt%	<0.01		0.23		
Total olefin content, wt%	53.6	49.7	47.0	47.4	45.9
mol% C3= in total olefins (C3=,C4= & C5=)	2.7	2.2	2.8	1.8	0.0
mol% C4= in total olefins (C3=,C4= & C5=)	95.0	83.6	57.6	38.9	25.0
mol% C5= in total olefins (C3=,C4= & C5=)	2.2	14.2	39.7	59.3	75.0
Sum	100.0	100.0	100.0	100.0	100.0

10 Note: Feed #3 was analyzed for precise cyclopentene and diene content measurements. Feed #2, Feed #4 and Feed #5 are expected to have similar amounts of cyclopentene and dienes.

5 Feed #1 was a typical refinery feed for a C₄ olefin alkylation plant and is a comparative example. The C₅ olefin content was low, 1.5 wt%, and the amount of C₅ olefin relative to the total olefins was only 2.2 mol%. The feed #1 contained only 3.2 wt% isopentane.

For this C₅ olefin alkylation study, olefin feeds with higher amounts of C₅ olefins were studied (Feed #2 through Feed #5). The C₅ olefin content relative to the total olefins (C₃, C₄
10 and C₅ olefins) in the olefin feeds varied in these samples from 14.2 mol% to 75 mol%. These olefin feeds contained from 12.7 to 48.5 wt% isopentane. These olefin feeds contained from 0.7 to 3.7 wt% n-pentane.

The olefin Feeds #2 through #5 were selectively hydrogenated at mild conditions to reduce their diene contents. These olefin feeds still contained about 300-700 ppm of butadiene, 1100
15 ppm of isoprene (2-methyl-1,3-butadiene), 400 ppm of trans-1,3-pentadiene and 500 ppm of cyclo-pentadiene. The selective hydrogenation of Feed #1, the comparative base case, was more extensive, and nearly complete removal of butadiene was observed (less than the detection limit of 100 ppm by GC).

20 **Examples 3 through 7: Alkylation Conditions and Alkylate Gasoline Products**

Evaluation of C₄/C₅ olefins alkylation with isobutane was performed in a continuously stirred tank reactor with the feeds described previously. A 10:1 molar mixture of isobutane and olefin was fed to the reactor while vigorously stirring. An acidic ionic liquid alkylation
25 catalyst as described in Example 1 was fed to the reactor via a second inlet port targeted to occupy about 3-5 vol% in the reactor. A small amount of *n*-butyl chloride was added to produce anhydrous HCl gas in situ. In these examples, the acidic ionic liquid alkylation catalyst is a N-butylpyridinium-heptachlorodialuminate and the Brønsted acid is hydrogen chloride. The average residence time in the reactor (combined volume of feeds and catalyst)
30 was about 5 minutes. The outlet pressure was maintained at 150 psig (1034 kPa) and the reactor temperature was maintained at 95 °F (35 °C) using a cooling coil.

The reactor effluent was separated with a coalescing separator into a hydrocarbon phase and an ionic liquid alkylation catalyst phase. The hydrocarbon phase was further separated with three distillation columns into multiple streams, including: a gas stream containing a C₃
35 fraction, an nC₄ stream, an iC₄ stream, and an alkylate gasoline stream. To maintain the activity of the acidic ionic liquid alkylation catalyst, the separated ionic liquid alkylation catalyst was sent to a regeneration reactor for reduction of the conjunct polymer level in the acidic ionic liquid alkylation catalyst. The conjunct polymer level in the acidic ionic liquid

- 5 alkylation catalyst was maintained at 3-6 wt%. The amount of conjunct polymer in the acidic ionic liquid alkylation catalyst was determined using an FT-IR quantitation method described in US patent No. US9290702B2.

The alkylation conditions and alkylate gasoline product properties from the various feeds are summarized in Table 3.

Table 3: Physical Properties of Alkylate Gasoline Products

Example Number	Example 3	Example 4	Example 5	Example 6	Example 7
	Base Case	Invention	Invention	Invention	Invention
	Alkylate	Alkylate	Alkylate	Alkylate	Alkylate
Olefin Feed Source	Feed #1	Feed #2	Feed #3	Feed #4	Feed #5
Mol% of C5 Olefins/ Total Olefins	2.2	14.2	39.5	59.3	75.0
Reactor Temperature, °F	95	95	95	95	95
Reactor Pressure, psig	150	150	150	150	150
Isobutane/Olefin Molar Ratio	10	10	10	10	10
Conversion of olefins, wt%	100.0	100.0	100.0	100.0	100.0
Alkylate Gasoline Product Properties					
Engine Test RON	94.5	92.9	92.8	92.6	90.0
Engine Test MON	92.3	90.6	90.2	90.1	89.0
Engine Test, (R+M)/2	93.4	91.8	91.5	91.4	89.5
<u>D86 Distillation (deg F)</u>					
T10	154	144	137	129	118
T30	212	214	216	214	202
T50	224	229	230	234	241
T70	239	239	246	247	257
FBP	379	383	377	381	385
C5+ Alkylate RVP	2.1	2.9	3.4	4.4	5.1
C5+ Alkylate Average density, g/cc	0.71	0.71	0.71	0.70	0.70
C5+ Alkylate Composition					
C5 (wt%)	2.8	4.6	6.9	10.1	12.7
C6 (wt%)	4.6	3.2	2.8	3.8	4.3
C7 (wt%)	7.9	5.1	4.5	5.1	3.0
C8 (wt%)	61.8	61.3	51.4	49.8	30.0
C9 (wt%)	10.4	16.1	26.2	24.7	38.8
C10 (wt%)	5.4	3.8	3.9	3.2	6.9
C11 (wt%)	6.4	5.5	3.9	3.1	3.3
C12+ (wt%)	0.8	0.5	0.4	0.2	0.9
Total	100.0	100.0	100.0	100.0	100.0
Trimethylpentane/ Total C8 (%)	83.9%	72.7%	76.4%	70.8%	71.5%
Trimethylhexane/ Total C9 (%)	75.7%	86.7%	86.2%	85.9%	85.9%

5 Research Octane numbers (RONs) and Motor Octane numbers (MONs) were measured by an engine test of the alkylate gasoline products. The distillation boiling point distributions of T10, T30, T50, T70 and the final boiling points were measured using ASTM D86-15, “Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure”. The detailed compositions of the alkylate gasoline products were analyzed using
10 gas chromatography. From the GC compositional data, the Reid Vapor Pressure (RVP) and average density of the C₅₊ alkylate gasolines were calculated.

 The base case (Example 3 with Feed #1) showed the typical yield and product properties for alkylation of C₄ olefins. Alkylation performance of Example 3 was compared with the other olefin feeds with higher C₅ (and varied) olefin feed compositions. Increases of
15 the C₅ olefin content in the olefin feed from 14.2 mol% to 75 mol% (Feed #2 through Feed #5), did not affect the unit operation in any negative ways. In all cases, the olefin conversions were maintained at 100% and the residual olefin contents in the alkylate gasoline products were less than 0.1 wt%. These examples demonstrated the process wherein a level of the pentene in the olefin feed was increased and did not create a deleterious formation of a
20 conjunct polymer in the acidic ionic liquid alkylation catalyst during the alkylating. The high C₅ olefin containing feeds (Feed #2 through Feed #5) contained a substantial amount of dienes, about 0.23 wt%, and 0.15 wt% cyclopentene. The alkylation process was not affected by the high diene and cyclopentene contents either. The conjunct polymer formation rates were comparable for all the olefin feeds, and the alkylation operations were maintained
25 easily. Unlike the H₂SO₄ alkylation process, we did not see any detrimental impact on conjunct polymer formation (i.e., there was no significant increase) with increasing amounts of pentene and dienes in the olefin feeds, which causes an expensive high acid consumption for the H₂SO₄ alkylation process.

 The alkylate gasoline products had RONs in the range of 94.5 to 90 and MONs in the
30 range of 92.3 to 89. These octane numbers were decreased slightly due to the increased C₅ (that came with the feed), a reduction of the C₈ hydrocarbons in the alkylate gasoline products, and an increase of the C₉ hydrocarbons in the alkylate gasoline products. The C₉ hydrocarbon fractions in the alkylate gasoline products were rich in trimethylhexanes (from 75.7 to 85.9 wt%), which have a relatively low RON of 90. The C₈ hydrocarbon fractions in
35 the alkylate gasoline products were also rich in trimethylpentanes, which have a high RON of 100.

5 The final boiling points of the alkylate gasoline products (Examples 3 through 7) were all comparable at 380 °F (193.3 degree Celsius) to 385 °F (196.1 degree Celsius), well below the typical gasoline specification of < 430 °F (221.1 degree Celsius), indicating higher quality alkylate gasoline products were produced. It was surprising to find all the alkylate gasoline product examples made with varying C₅ olefin contents in the feeds, had the similar, 10 excellent low final boiling points. Consistent with the boiling point distributions, all the alkylate gasoline products had comparable average C₅⁺ densities, in the range of 0.70-0.71 g/cc. Consistently, the heavy C₁₂⁺ fractions were less than 1 wt%. These features were far superior to those of any H₂SO₄ alkylation processes, where higher final boiling point (over 430 °F [over 221.1 °C]) alkylate gasoline products were commonly obtained with an olefin 15 feed containing substantial amounts of C₅ olefins.

Due to the high amount of isopentane that came with the C₅ olefin feeds, there was a slight decrease in the T10 distillation points and a slight increase in the RVPs as the amount of isopentane increased from Examples 3 to 7. Still the C₅⁺ alkylate gasoline RVP was well below the typical gasoline specification of less than 6-7 psi in all of these examples.

20 The isopentane and *n*-pentane that was present in the olefin feeds was incorporated into the alkylate gasoline products and made the analysis of the alkylate gasoline products more complicated. The alkylation process we employed can make isopentane or *n*-pentane, and the amount of the synthesized isopentane or *n*-pentane needed to be differentiated from the corresponding components that came with the olefin feeds. We conducted component 25 material balance around the unit to estimate the amount of isopentane and *n*-pentane produced by the alkylation process.

The yields of the synthesized hydrocarbon products by the alkylation process are called herein as “true” yields. To calculate the “true” yields of isopentane, *n*-pentane and C₆ – C₁₁⁺ carbon product fractions, material balance calculations around the alkylation process unit 30 were conducted. Using the data with >97% material balance closures, the isopentane and *n*-pentane amounts supplied by the olefin feeds were subtracted from the apparent alkylate gasoline product amounts, and the “true” yields were thus estimated. The “true” yield results are summarized in Table 4.

Table 4
 “True” Yield Estimate of Isopentane and *n*-Pentane and Carbon Number Distribution

Example Number	Example 3	Example 4	Example 5	Example 6	Example 7
	Base Case	Invention	Invention	Invention	Invention
	Alkylate	Alkylate	Alkylate	Alkylate	Alkylate
Olefin Feed Source	Feed #1	Feed #2	Feed #3	Feed #4	Feed #5
Mol% of C5 Olefins/ Total Olefins	2.2	14.2	39.5	59.3	75.0
Wt% of Olefins in Olefin Feed	53.6	49.7	47.0	47.4	45.9
Wt% of Isopentane in Olefin Feed	3.2	12.7	29.8	37.8	48.5
nC5 formation/ total olefins (mol/mol)	0.0	0.0	0.0	0.0	0.0
iC5 formation/ total olefins (mol/mol)	0.14	0.15	-0.04	-0.07	-0.15
mol% of C5= converted to iC5	Base case	About 14%	0 %	0 %	0 %
True Alkylate Yield, wt%					
Isopentane	9.0	9.1	-2.3	-4.4	-9.7
n-pentane	-0.9	0.1	-0.1	-1.1	-0.8
C6	9.1	6.4	9.6	15.9	9.2
C7	7.1	5.2	5.3	5.2	3.5
C8	56.9	59.5	50.4	48.4	36.3
C9	10.1	13.7	28.2	27.0	46.2
C10	4.4	3.1	6.3	6.2	13.1
C11+	4.3	3.0	2.6	2.8	2.2
Sum	100.0	100.0	100.0	100.0	100.0
C8 + C9 Selectivity	67.0	73.2	78.6	75.4	82.5

5 The results in Table 4 show that the *n*-pentane product yield, relative to the total olefin content in the olefin feed, was zero for all of the olefin feeds, indicating that our alkylation process produces negligible amount of *n*-pentane.

 When the olefin feed contained only 2.2 mol% C₅ olefins (97 mol% C₄ olefins, Feed #1), the alkylation process made about 9.0 wt% isopentane (Example 3). With Feed #2
10 containing 14 mol% C₅ olefins, the amount of isopentane produced by the alkylation process was about the same as for Feed #1 (9.1 vs. 9.0 wt% isopentane) and the C₉ yield was increased from 10.1 to 13.7 wt% (Example 4). The results suggested that the incremental increase in C₅ olefins in Feed #2 was converted selectively to C₉ alkylate gasoline, without producing any more isopentane than the C₄ olefins in Feed #1.

15 While it was difficult to calculate the isopentane-make from the C₅ olefins only for these mixed feeds, by comparing them with the base case, one could roughly estimate the amount of net C₅ olefin conversion to isopentane. Since the true isopentane yield of the feed containing 2.2 mol% C₅ olefin (Example 3 with Feed #1) and 14.2 mol% C₅ olefin (Example 4 with Feed #2) were nearly identical, we could say that only a small portion of the additional
20 C₅ olefins in Feed #2 was converted to isopentane, not any more than C₄ olefins in the Feed #1. The yield of isopentane from C₅ olefins for the Example 4 was estimated to be about 9 wt% or 14 mol%..

 As the C₅ olefin contents in the olefin feeds were further increased to 39.5 mol%, 59.3 mol% and 75 mol% in Feed #3 through Feed #5, the “true” C₉ alkylate gasoline yields were
25 steadily increased from 28.2 wt% to 46.2 wt% (Examples 5 through 7).

 For the high C₅ olefin containing feeds (Feed #3 through Feed #5), the amount of isopentane in the olefin feeds also increased. Surprisingly, for these same feeds, we observed net decreases of isopentane yields by about 2-10 wt% after the alkylation process (Examples 5 through 7). Apparently some of isopentane in the olefin feeds reacted with olefins to form
30 alkylate gasoline product. The ability of the acidic ionic liquid alkylation catalyst to perform simultaneous conversion of isobutane and isopentane into high quality alkylate gasoline product appeared to be unique.

 For the Examples 5 through 7, there were rather net reductions of isopentane content in the alkylate products. We could clearly say that additional C₅ olefins in Feed #3 through 5
35 were not converted to isopentane, thus the yields of isopentane from C₅ olefins for the Examples 5 through 7 were zero.

5 The transitional term "comprising", which is synonymous with "including," "containing,"
or "characterized by," is inclusive or open-ended and does not exclude additional, unrecited
elements or method steps. The transitional phrase "consisting of" excludes any element, step,
or ingredient not specified in the claim. The transitional phrase "consisting essentially of"
limits the scope of a claim to the specified materials or steps "and those that do not materially
10 affect the basic and novel characteristic(s)" of the claimed invention.

For the purposes of this specification and appended claims, unless otherwise indicated,
all numbers expressing quantities, percentages or proportions, and other numerical values
used in the specification and claims, are to be understood as being modified in all instances
by the term "about." Furthermore, all ranges disclosed herein are inclusive of the endpoints
15 and are independently combinable. Whenever a numerical range with a lower limit and an
upper limit are disclosed, any number falling within the range is also specifically disclosed.
Unless otherwise specified, all percentages are in weight percent.

Any term, abbreviation or shorthand not defined is understood to have the ordinary
meaning used by a person skilled in the art at the time the application is filed. The singular
20 forms "a," "an," and "the," include plural references unless expressly and unequivocally
limited to one instance.

All of the publications, patents and patent applications cited in this application are
herein incorporated by reference in their entirety to the same extent as if the disclosure of
each individual publication, patent application or patent was specifically and individually
25 indicated to be incorporated by reference in its entirety.

This written description uses examples to disclose the invention, including the best
mode, and also to enable any person skilled in the art to make and use the invention. Many
modifications of the exemplary embodiments of the invention disclosed above will readily
occur to those skilled in the art. Accordingly, the invention is to be construed as including all
30 structure and methods that fall within the scope of the appended claims. Unless otherwise
specified, the recitation of a genus of elements, materials or other components, from which an
individual component or mixture of components can be selected, is intended to include all
possible sub-generic combinations of the listed components and mixtures thereof.

The invention illustratively disclosed herein suitably may be practiced in the absence
35 of any element which is not specifically disclosed herein.

CLAIMS

1. A process to make an alkylate gasoline, comprising:

- a. providing an olefin feed, comprising at least 8 wt% pentenes, a butene, and less than 60 wt% isopentane, wherein the olefin feed comprises C3, C4 and C5 olefins, wherein an amount of the pentenes in the olefin feed is from 35 to 100 mol% of a total olefins in the olefin feed;
- b. providing an isoparaffin feed comprising an isobutane; and
- c. alkylating the olefin feed with the isoparaffin feed using an acidic ionic liquid alkylation catalyst under alkylation conditions to make the alkylate gasoline, wherein the alkylation conditions include a catalyst volume in an alkylation reactor of 2 vol % to 50 vol %, an alkylation temperature of -10°C to 100°C, an alkylating pressure of 300 kPa to 2500 kPa, an isoparaffin to olefin molar ratio of 2 to 16 and a residence time of 30 seconds to 1 hour;

wherein a yield of isopentane in the alkylate gasoline corresponds to less than 15 mol% of C5 olefins in the olefin feed and wherein the alkylate gasoline has a final boiling point from 370 °F (187.8 °Celsius) to 400 °F (204.4 °Celsius) and a RON of 85 or greater.

2. The process of claim 1, wherein the acidic ionic liquid alkylation catalyst conducts simultaneous conversion of the isobutane and the isopentane into the alkylate gasoline during the alkylating.

3. The process of claim 1, additionally comprising: isolating a C5 olefin stream from a FCC unit to provide the olefin feed and the alkylating converts the C5 olefin stream to the alkylate gasoline without increasing a throughput from the FCC unit.

4. The process of claim 1, wherein the alkylating converts 100 wt% of the olefins in the olefin feed.

5. The process of claim 1, wherein an amount of a trimethylpentane in C8 hydrocarbons in the alkylate gasoline is from 70 to 95 wt%.

6. The process of claim 1, wherein an amount of a trimethylhexane in C9 hydrocarbons in the alkylate gasoline is from 85 to 95 wt%.
7. The process of claim 1, wherein the alkylate gasoline comprises a C5+ alkylate fraction having a RVP from 2.3 to 6.0 psi (15.9 to 41.4 kPa).
8. The process of claim 1, wherein the RON is from 90.0 to 94.5.
9. The process of claim 1, wherein a level of the pentenes in the olefin feed is increased and does not create a deleterious formation of a conjunct polymer in the acidic ionic liquid alkylation catalyst during the alkylating.
10. The process of claim 1, wherein an w-pentane product yield relative to a total olefin content in the olefin feed is from zero to less than 0.2 mol/mol.
11. The process of claim 1, additionally comprising selectively hydrogenating a refinery olefin stream to make the olefin feed, and wherein the olefin feed comprises from zero to 0.5 wt% dienes.
12. The process of claim 1, additionally comprising selectively hydrogenating the olefin feed to increase the RON or a MON of the alkylate gasoline.

ABSTRACT

10 A process, comprising: providing an olefin feed comprising pentenes, butenes, and
isopentane; and alkylating the olefin feed with isobutane using acidic ionic liquid catalyst;
wherein a yield of the isopentane in an alkylate gasoline product corresponds to less than 15
mol% of C₅ olefins in the feed, and the alkylate gasoline has defined final boiling point and
high RON. A process comprising: alkylating an olefin feed comprising pentenes and
15 isopentane, with isobutane using acidic ionic liquid catalyst; wherein a yield of the isopentane
in the alkylate gasoline corresponds to less than 15 mol% of C₅ olefins in the feed; and
wherein an *n*-pentane product yield is low. An alkylate gasoline, comprising less than 0.1
wt% olefins and aromatics, less than 1.8 wt% C₁₂₊ hydrocarbons, and greater than 60 wt%
combined C₈ and C₉ hydrocarbons, wherein the trimethylpentane in the C₈ hydrocarbons and
20 the trimethylhexane in the C₉ hydrocarbons are defined.

No figure