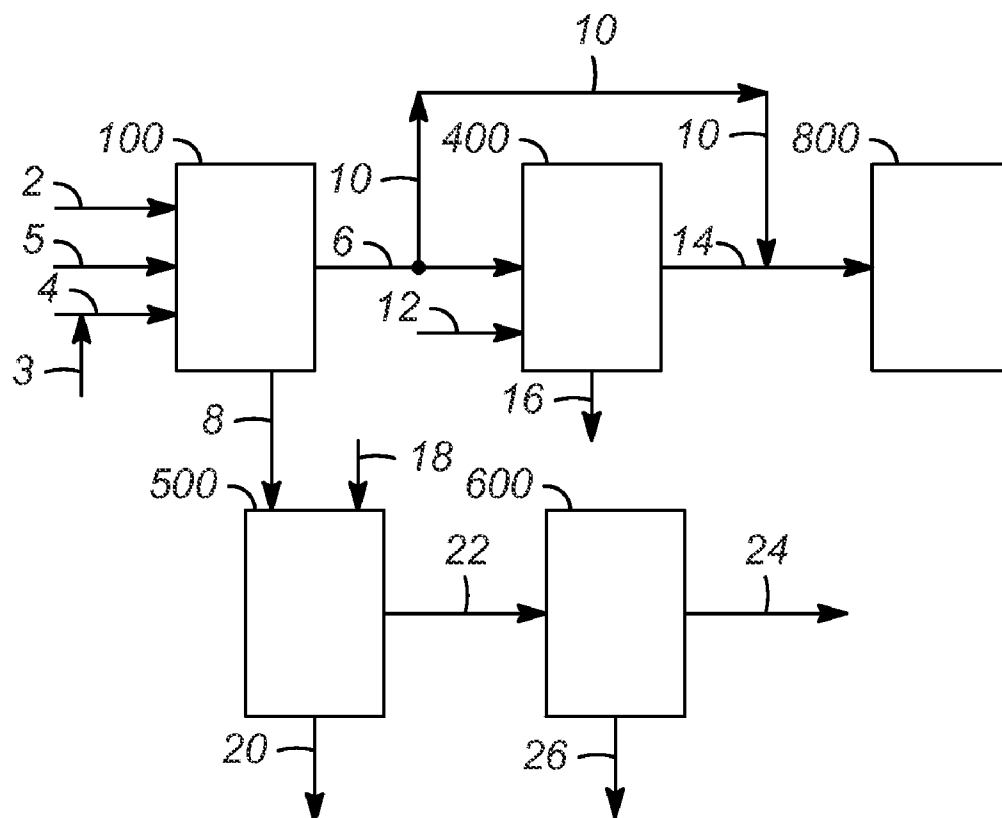




US 20160168482A1

(19) **United States**(12) **Patent Application Publication**  
**Mezza et al.**(10) **Pub. No.: US 2016/0168482 A1**(43) **Pub. Date: Jun. 16, 2016**(54) **CONTAMINANT REMOVAL FROM  
HYDROCARBON STREAMS WITH IONIC  
LIQUIDS**(52) **U.S. Cl.**CPC ..... *C10G 17/04* (2013.01); *C10G 17/06*  
(2013.01); *C10G 69/04* (2013.01); *C10G 67/08*  
(2013.01); *C10G 55/06* (2013.01); *C10G 17/10*  
(2013.01)(71) Applicant: **UOP LLC**, Des Plaines, IL (US)(72) Inventors: **Beckay J. Mezza**, Arlington Heights, IL  
(US); **Alakananda Bhattacharyya**,  
Glen Ellyn, IL (US); **Steven F. Zink**,  
Westmont, IL (US); **Massimo Sangalli**,  
Des Plaines, IL (US)(21) Appl. No.: **14/568,731**(22) Filed: **Dec. 12, 2014****Publication Classification**(51) **Int. Cl.***C10G 17/04* (2006.01)  
*C10G 17/10* (2006.01)  
*C10G 67/08* (2006.01)  
*C10G 55/06* (2006.01)  
*C10G 17/06* (2006.01)  
*C10G 69/04* (2006.01)(57) **ABSTRACT**

A process for removing sulfur and nitrogen contaminants from a hydrocarbon stream using a Brønsted acid or an ionic liquid and a Brønsted acid is described. The process includes contacting the hydrocarbon stream comprising the contaminant with a Brønsted acid or a hydrocarbon-immiscible ionic liquid and the Brønsted acid to produce a mixture comprising the hydrocarbon and the Brønsted acid comprising at least a portion of the removed contaminant or a hydrocarbon-immiscible ionic liquid comprising at least a portion of the removed contaminant; and separating the mixture to produce a hydrocarbon effluent having a reduced level of the contaminant and a Brønsted acid effluent comprising the Brønsted acid comprising at least the portion of the removed contaminant or a hydrocarbon-immiscible ionic liquid effluent comprising the hydrocarbon-immiscible ionic liquid comprising at least the portion of the removed contaminant.



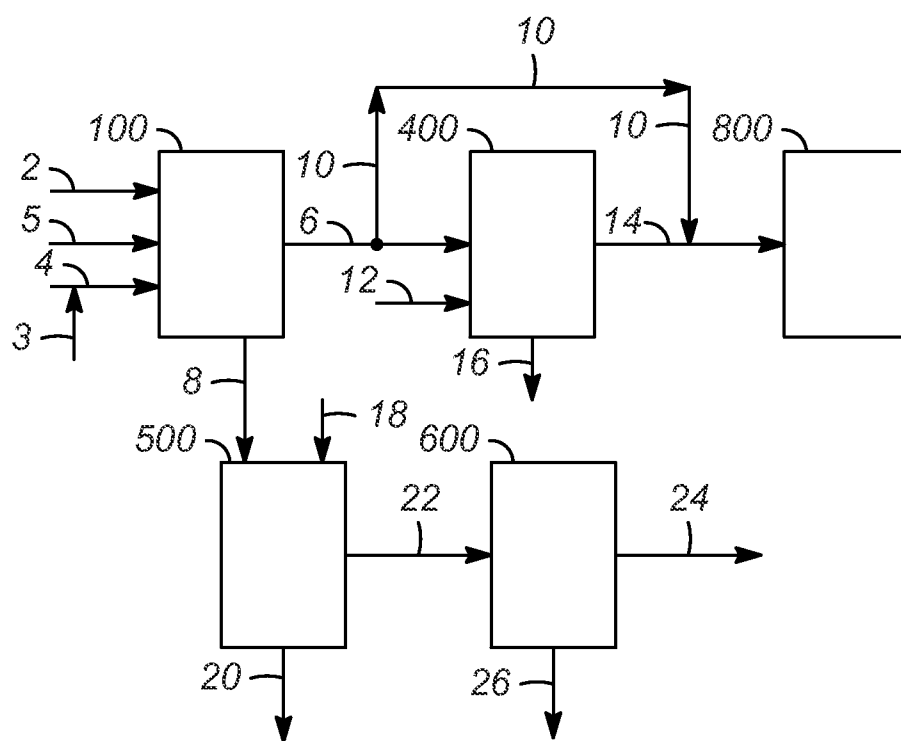


FIG. 1

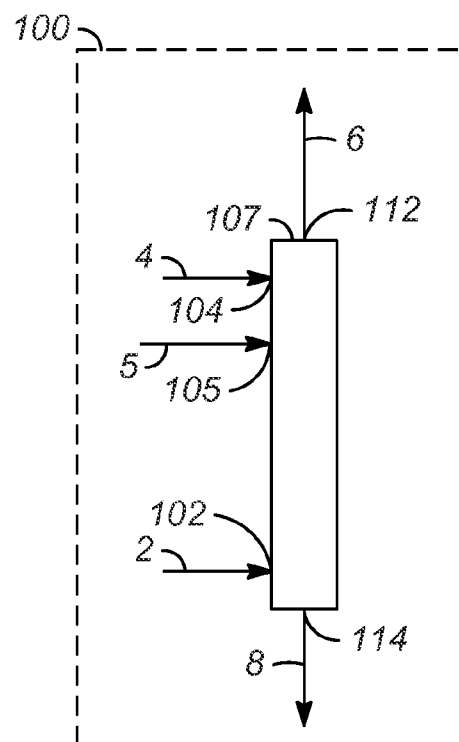


FIG. 2A

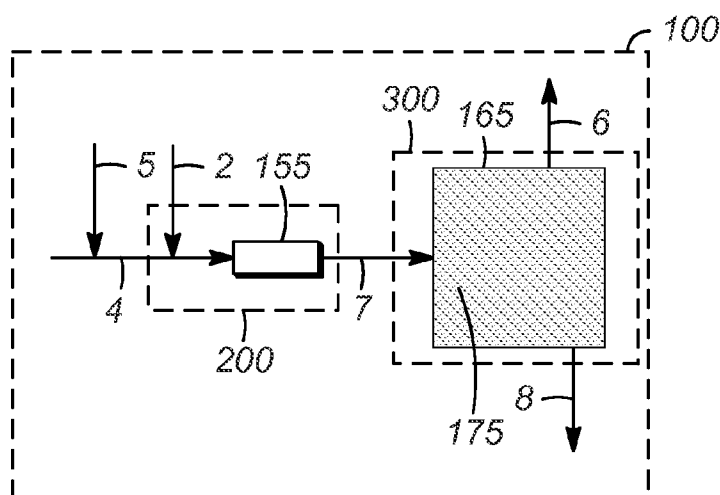


FIG. 2B

## CONTAMINANT REMOVAL FROM HYDROCARBON STREAMS WITH IONIC LIQUIDS

### BACKGROUND OF THE INVENTION

[0001] Various hydrocarbon streams, such as vacuum gas oil (VGO), light cycle oil (LCO), and naphtha, may be converted into higher value hydrocarbon fractions such as diesel fuel, jet fuel, naphtha, gasoline, and other lower boiling fractions in refining processes such as hydrocracking and fluid catalytic cracking (FCC). However, hydrocarbon feed streams for these materials often have high amounts of nitrogen which are more difficult to convert. For example, the degree of conversion, product yields, catalyst deactivation, and/or ability to meet product quality specifications may be adversely affected by the nitrogen content of the feed stream. It is known to reduce the nitrogen content of these hydrocarbon feed streams by catalytic hydrogenation reactions such as in a hydrotreating process unit. However, hydrogenation processes require relatively high pressures and temperatures.

[0002] Various processes using ionic liquids to remove sulfur and nitrogen compounds from hydrocarbon fractions are also known. U.S. Pat. No. 7,001,504 discloses a process for the removal of organosulfur compounds from hydrocarbon materials which includes contacting an ionic liquid with a hydrocarbon material to extract sulfur containing compounds into the ionic liquid. U.S. Pat. No. 7,553,406 discloses a process for removing polarizable impurities from hydrocarbons and mixtures of hydrocarbons using ionic liquids as an extraction medium. U.S. Pat. No. 7,553,406 also discloses that different ionic liquids show different extractive properties for different polarizable compounds.

[0003] There remains a need in the art for improved processes that enable the removal of contaminants from hydrocarbon streams.

### SUMMARY OF THE INVENTION

[0004] One aspect of the invention is a process for removing a contaminant comprising at least one of sulfur and nitrogen from a hydrocarbon stream. In one embodiment, the process includes contacting the hydrocarbon stream comprising the contaminant with a Brønsted acid or a hydrocarbon-immiscible ionic liquid and a Brønsted acid under contacting conditions so that the Brønsted acid, or the hydrocarbon-immiscible ionic liquid and the Brønsted acid are in a liquid state to produce a mixture comprising the hydrocarbon and the Brønsted acid comprising at least a portion of the removed contaminant or a hydrocarbon-immiscible ionic liquid comprising at least a portion of the removed contaminant. The mixture is separated to produce a hydrocarbon effluent having a reduced level of the contaminant and a Brønsted acid effluent comprising the Brønsted acid comprising at least the portion of the removed contaminant or a hydrocarbon-immiscible ionic liquid effluent comprising the hydrocarbon-immiscible ionic liquid comprising at least the portion of the removed contaminant.

### BRIEF DESCRIPTION OF THE DRAWINGS

[0005] FIG. 1 is a simplified flow scheme illustrating various embodiments of the invention.

[0006] FIGS. 2A and 2B are simplified flow schemes illustrating different embodiments of an extraction zone of the invention.

### DETAILED DESCRIPTION OF THE INVENTION

[0007] In general, the invention may be used to remove sulfur and nitrogen contaminants from a hydrocarbon stream using a Brønsted acid or an ionic liquid and a Brønsted acid. The Brønsted acid can remove sulfur and nitrogen contaminants. The combination of the ionic liquid and the Brønsted acid removes more of the sulfur and nitrogen contaminants than the ionic liquid alone.

[0008] The hydrocarbon stream typically has a boiling point in the range of about 30° C. to about 525° C. Examples of hydrocarbon streams include, but are not limited to, at least one of vacuum gas oil streams, light cycle oil streams, naphtha streams, coker gas oil streams, kerosene streams, streams made from biorenewable sources, fracking condensate streams, streams from hydrocracking zones, streams from hydrotreating zones, and streams from fluid catalytic cracking zones.

[0009] The sulfur and nitrogen contaminants are one or more species found in the hydrocarbon material that is detrimental to further processing. The total sulfur content may range from 0.1 to 7 wt %, and the nitrogen content may be from about 40 ppm to 30,000 ppm.

[0010] The ionic liquid and the Brønsted acid can remove one or more of the sulfur and nitrogen contaminants in the hydrocarbon feed. The hydrocarbon feed will usually comprise a plurality of nitrogen compounds of different types in various amounts. Thus, at least a portion of at least one type of nitrogen compound may be removed from the hydrocarbon feed. The same or different amounts of each type of nitrogen compound can be removed, and some types of nitrogen compounds may not be removed. In an embodiment, up to about 99 wt % of the nitrogen can be removed. The nitrogen content of the hydrocarbon feed is typically reduced by at least about 10 wt %, at least about 20 wt %, or at least about 30 wt %, or at least about 40 wt %, at least about 50 wt %, or at least about 60 wt %, or at least about 70 wt %, or at least about 80 wt %, or at least about 90 wt %, or at least about 95 wt %.

[0011] The hydrocarbon feed will typically also comprise a plurality of sulfur compounds of different types in various amounts. Thus, at least a portion of at least one type of sulfur compound may be removed from the hydrocarbon feed. The same or different amounts of each type of sulfur compound may be removed, and some types of sulfur compounds may not be removed. In an embodiment, up to about 30 wt % of the sulfur can be removed. Typically, the sulfur content of the hydrocarbon feed is reduced by at least about 1 wt %, or at least about 2 wt %, or at least 3 wt %, or at least 5 wt %, or at least 10 wt %, or at least 15 wt %, or at least 20 wt %, or at least 25 wt %.

[0012] Consistent with common terms of art, the ionic liquid introduced to the feed extraction zone may be referred to

as a “lean ionic liquid” generally meaning a hydrocarbon feed-immiscible ionic liquid that is not saturated with one or more extracted contaminants. Lean ionic liquid may include one or both of fresh and regenerated ionic liquid and is suitable for accepting or extracting contaminants from the hydrocarbon feed. Likewise, the ionic liquid effluent may be referred to as “rich ionic liquid”, which generally means a hydrocarbon feed-immiscible ionic liquid effluent produced by a contaminant removal step or process or otherwise including a greater amount of extracted contaminants than the amount of extracted contaminants included in the lean ionic liquid. A rich ionic liquid may require regeneration or dilution, e.g. with fresh ionic liquid, before recycling the rich ionic liquid to the same or another contaminant removal step of the process.

**[0013]** Generally, ionic liquids are non-aqueous, organic salts composed of ions where the positive ion is charge balanced with a negative ion. These materials have low melting points, often below 100° C., undetectable vapor pressure, and good chemical and thermal stability. The cationic charge of the salt is localized over hetero atoms, such as nitrogen, phosphorous, sulfur, arsenic, boron, antimony, and aluminum, and the anions may be any inorganic, organic, or organometallic species.

**[0014]** Ionic liquids suitable for use in the instant invention are hydrocarbon feed-immiscible ionic liquids. As used herein the term “hydrocarbon feed-immiscible ionic liquid” means the ionic liquid is capable of forming a separate phase from hydrocarbon feed under the operating conditions of the process. Ionic liquids that are miscible with hydrocarbon feed at the process conditions will be completely soluble with the hydrocarbon feed; therefore, no phase separation will be feasible. Thus, hydrocarbon feed-immiscible ionic liquids may be insoluble with or partially soluble with the hydrocarbon feed under the operating conditions. An ionic liquid capable of forming a separate phase from the hydrocarbon feed under the operating conditions is considered to be hydrocarbon feed-immiscible. Ionic liquids according to the invention may be insoluble, partially soluble, or completely soluble (miscible) with water.

**[0015]** In an embodiment, the hydrocarbon feed-immiscible ionic liquid comprises at least one of an imidazolium ionic liquid, a pyridinium ionic liquid, a phosphonium ionic liquid, a lactamium ionic liquid, an ammonium ionic liquid, and a pyrrolidinium ionic liquid. In another embodiment, the hydrocarbon feed-immiscible ionic liquid consists essentially of imidazolium ionic liquids, pyridinium ionic liquids, phosphonium ionic liquids, lactamium ionic liquids, ammonium ionic liquids, pyrrolidinium ionic liquids, and combinations thereof. In still another embodiment, the hydrocarbon feed-immiscible ionic liquid is selected from the group consisting of imidazolium ionic liquids, pyridinium ionic liquids, phosphonium ionic liquids, lactamium ionic liquids, ammonium ionic liquids, pyrrolidinium ionic liquids, and combinations thereof. Imidazolium, pyridinium, lactamium, ammonium, and pyrrolidinium ionic liquids have a cation

comprising at least one nitrogen atom. Phosphonium ionic liquids have a cation comprising at least one phosphorous atom.

**[0016]** The ionic liquid comprises at least one ionic liquid from the following ionic liquids: tetraalkylphosphonium dialkylphosphates, tetraalkylphosphonium dialkyl phosphinates, tetraalkylphosphonium phosphates, tetraalkylphosphonium tosylates, tetraalkylphosphonium sulfates, tetraalkylphosphonium sulfonates, tetraalkylphosphonium carbonates, tetraalkylphosphonium metalates, oxometalates, tetraalkylphosphonium mixed metalates, tetraalkylphosphonium polyoxometalates, tetraalkylphosphonium halides, trihexyl(tetradecyl)phosphonium halides imidazolium imides, imidazolium hexafluorophosphates, imidazolium thiocyanates, imidazolium dicyanamides, imidazolium acetates, imidazolium bromides, imidazolium chlorides, imidazolium tetrafluoroborates, pyridinium tetrafluoroborates, pyridinium imides, pyridinium hexafluorophosphates, pyridinium bromides, pyridinium trifluoromethanesulfonates, pyrrolidinium imides, and pyrrolidinium trifluoromethanesulfonates, and pyrrolidinium sulfonium imides.

**[0017]** In an embodiment, the hydrocarbon feed-immiscible ionic liquid comprises at least one of 1-ethyl-3-methylimidazolium dicyanamide, 1-ethyl-3-methylimidazolium ethyl sulfate, 1-butyl-3-methylimidazolium hydrogen sulfate, 1-ethyl-3-methylimidazolium chloride, 1-butyl-3-methylimidazolium chloride, 1-butyl-3-methylimidazolium trifluoromethanesulfonate, 1-ethyl-3-methylimidazolium bis (trifluoromethylsulfonyl)imide, 1-butyl-3-methylimidazolium hexafluorophosphate, 1-butyl-3-methylimidazolium tetrafluoroborate, methylimidazolium trifluoroacetate, 1-butyl-3-methylimidazolium bromide, 1-ethyl-3-methylimidazolium trifluoroacetate, 1-methylimidazolium hydrogen sulfate, 1-butyl-4-methylpyridinium chloride, N-butyl-3-methylpyridinium methylsulfate, 1-butyl-4-methylpyridinium hexafluorophosphate, pyridinium p-toluene sulfonate, 1-butylpyridinium chloride, tetraethylammonium acetate, trihexyl(tetradecyl)phosphonium chloride, trihexyl(tetradecyl)phosphonium bromide, tributyl(methyl)phosphonium bromide, tributyl(methyl)phosphonium chloride, tributyl(hexyl)phosphonium bromide, tributyl(hexyl)phosphonium chloride, tributyl(octyl)phosphonium bromide, tributyl(octyl)phosphonium chloride, tributyl(decyl)phosphonium bromide, tributyl(decyl)phosphonium chloride, tetrabutylphosphonium bromide, tetrabutylphosphonium chloride, triisobutyl(methyl)phosphonium tosylate, tributyl(ethyl)phosphonium diethylphosphate, tetrabutylphosphonium methanesulfonate, pyridinium p-toluene sulfonate, tributyl(methyl)phosphonium methylsulfate.

**[0018]** Lactamium ionic liquids include, but are not limited to, those described in U.S. Pat. No. 8,709,236, U.S. application Ser. No. 14/271,308, entitled Synthesis of Lactam Based Ionic Liquids, filed May 6, 2014, and U.S. application Ser. No. 14/271,319, entitled Synthesis of N-Derivatized Lactam Based Ionic Liquids, filed May 6, 2014, which are incorporated by reference.

**[0019]** Brønsted acids suitable for use include, but are not limited to, sulfonic acid, derivatives of sulfonic acid, sulfuric

acid, phosphoric acid, derivatives of phosphoric acid, phosphonic acids, hydrochloric acid, hydrobromic acid, nitric acid, sulfurous acid, carboxylic acids having from 1 to 8 carbons, and combinations thereof. By derivatives of sulfonic acid and phosphoric acid, we mean ordinary chemical reactions that change one compound to another while keeping the base structure unaltered. Examples of derivatives of sulfonic acid include, but are not limited to p-toluenesulfonic acid, methanesulfonic acid, benzenesulfonic acid, propane-1-sulfonic acid, hexadecane-1-sulfonic acid, and butane-2-sulfonic acid. Examples of derivatives of phosphoric acid include, but are not limited to tris(2-ethylhexyl)phosphate, 2-ethylhexylphosphate, dibutyl hydrogen phosphate, tributyl hydrogen phosphate, and bis(2-ethylhexyl) hydrogen phosphate. Examples of derivatives of phosphonic acid include, but are not limited to, amino-tris-methylenephosphonic acid (ATMP) and 1-hydroxyethylidene-1,1-diphosphonic acid (HEDP).

**[0020]** The ratio of the Brønsted acid to the hydrocarbon-immiscible ionic liquid is in a range of about 0.01:1 to about 0.5:1, or about 0.1:1 to about 0.3:1.

**[0021]** In an embodiment, the invention is a process for removing sulfur and nitrogen contaminants from a hydrocarbon feed stream comprising a contacting step and a separating step. In the contacting step, a hydrocarbon feed stream comprising a contaminant, a hydrocarbon-immiscible ionic liquid, and a Brønsted acid are contacted or mixed. The contacting may facilitate transfer or extraction of the one or more contaminants from the hydrocarbon feed stream to the ionic liquid. Although an ionic liquid that is partially soluble in the hydrocarbon may facilitate transfer of the contaminant from the hydrocarbon to the ionic liquid, partial solubility is not required. Insoluble hydrocarbon/ionic liquid mixtures may have sufficient interfacial surface area between the hydrocarbon and ionic liquid to be useful. In the separation step, the mixture of hydrocarbon and ionic liquid settles or forms two phases, a hydrocarbon phase and an ionic liquid phase, which are separated to produce a hydrocarbon-immiscible ionic liquid effluent and a hydrocarbon effluent.

**[0022]** The process may be conducted in various equipment which is well known in the art and is suitable for batch or continuous operation. For example, in a small scale form of the invention, the hydrocarbon, the hydrocarbon-immiscible ionic liquid, and the Brønsted acid may be mixed in a beaker, flask, or other vessel, e.g., by stirring, shaking, use of a mixer, or a magnetic stirrer. The mixing or agitation is stopped and the mixture forms a hydrocarbon phase and an ionic liquid phase which can be separated, for example, by decanting, centrifugation, or use of a pipette to produce a hydrocarbon effluent having a lower contaminant content relative to the incoming hydrocarbon. The process also produces a hydrocarbon-immiscible ionic liquid effluent comprising the one or more contaminants.

**[0023]** The contacting and separating steps may be repeated, for example, when the contaminant content of the hydrocarbon effluent is to be reduced further to obtain a desired contaminant level in the ultimate hydrocarbon product stream from the process. Each set, group, or pair of con-

tacting and separating steps may be referred to as a contaminant removal step. Thus, the invention encompasses single and multiple contaminant removal steps. A contaminant removal zone may be used to perform a contaminant removal step. As used herein, the term “zone” can refer to one or more equipment items and/or one or more sub-zones. Equipment items may include, for example, one or more vessels, heaters, separators, exchangers, conduits, pumps, compressors, and controllers. Additionally, an equipment item can further include one or more zones or sub-zones. The contaminant removal process or step may be conducted in a similar manner and with similar equipment as is used to conduct other liquid-liquid wash and extraction operations. Suitable equipment includes, for example, columns with: trays, packing, rotating discs or plates, and static mixers. Pulse columns and mixing/settling tanks may also be used.

**[0024]** FIG. 1 is a flow scheme illustrating various embodiments of the invention and some of the optional and/or alternate steps and apparatus encompassed by the invention. Hydrocarbon stream **2**, hydrocarbon-immiscible ionic liquid stream **4**, and Brønsted acid stream **5** are introduced to and contacted and separated in contaminant removal zone **100** to produce hydrocarbon-immiscible ionic liquid effluent stream **8** and hydrocarbon effluent stream **6** as described above. The ionic liquid stream **4** may be comprised of fresh ionic liquid stream **3** and/or one or more ionic liquid streams which are recycled in the process as described below. In an embodiment, a portion or all of hydrocarbon effluent stream **6** is passed via conduit **10** to a hydrocarbon conversion zone **800**. Hydrocarbon conversion zone **800** may, for example, comprise at least one of a fluid catalytic cracking and a hydrocracking process, which are well known in the art.

**[0025]** The contacting takes place under conditions such that the Brønsted acid or the Brønsted acid and ionic liquid are in the liquid state.

**[0026]** The contact step can take place at a temperature in the range of about 20° C. to the decomposition temperature of the ionic liquid, or about 20° C. to about 150° C., or about 20° C. to about 120° C., or about 20° C. to about 80° C.

**[0027]** The pressure is typically in the range of about 100 kPa to about 3 MPa.

**[0028]** The contacting time is sufficient to obtain good contact between the ionic liquid, the Brønsted acid, and the hydrocarbon feed. The contacting time is typically in the range of about 1 min to about 1 hr, or about 5 min to about 30 min.

**[0029]** An optional hydrocarbon washing step may be used, for example, to recover ionic liquid that is entrained or otherwise remains in the hydrocarbon effluent stream by using water to wash or extract the ionic liquid from the hydrocarbon effluent. In this embodiment, a portion or all of hydrocarbon effluent stream **6** (as feed) and a water stream **12** (as solvent) are introduced to hydrocarbon washing zone **400**. The hydrocarbon effluent and water streams introduced to hydrocarbon washing zone **400** are mixed and separated to produce a washed hydrocarbon stream **14** and a spent water stream **16**, which comprises the ionic liquid. The hydrocarbon washing step may be conducted in a similar manner and with similar

equipment as used to conduct other liquid-liquid wash and extraction operations as discussed above. Various hydrocarbon washing step equipment and conditions such as temperature, pressure, times, and solvent to feed ratio may be the same as or different from the contaminant removal zone equipment and conditions. In general, the hydrocarbon washing step conditions will fall within the same ranges as given for the contaminant removal step conditions. A portion or all of the washed hydrocarbon stream **14** may be passed to hydrocarbon conversion zone **800**.

**[0030]** A similar arrangement would be used for the Brønsted acid alone. The Brønsted acid could be removed from the hydrocarbon by dilution with water or water washing.

**[0031]** An optional ionic liquid regeneration step may be used, for example, to regenerate the ionic liquid by removing the contaminant from the ionic liquid, i.e. reducing the contaminant content of the rich ionic liquid. In an embodiment, a portion or all of hydrocarbon-immiscible ionic liquid effluent stream **8** (as feed) comprising the contaminant and a regeneration solvent stream **18** are introduced to ionic liquid regeneration zone **500**. The hydrocarbon-immiscible ionic liquid effluent stream **8** and regeneration solvent stream **18** are mixed and separated to produce an extract stream **20** comprising the contaminant, and a regenerated ionic liquid stream **22**. The ionic liquid regeneration step may be conducted in a similar manner and with similar equipment as used to conduct other liquid-liquid wash and extraction operations. Various ionic liquid regeneration step conditions such as temperature, pressure, times, and solvent to feed may be the same as or different from the contaminant removal conditions. In general, the ionic liquid regeneration step conditions will fall within the same ranges as given for the contaminant removal step conditions.

**[0032]** In an embodiment, the regeneration solvent stream **18** comprises a hydrocarbon fraction lighter than the hydrocarbon and which is immiscible with the ionic liquid. The lighter hydrocarbon fraction may consist of a single hydrocarbon compound or may comprise a mixture of hydrocarbons. In an embodiment, the lighter hydrocarbon fraction comprises at least one of a naphtha, gasoline, diesel, light cycle oil (LCO), and light coker gas oil (LCGO) hydrocarbon fraction. The lighter hydrocarbon fraction may comprise straight run fractions and/or products from conversion processes such as hydrocracking, hydrotreating, fluid catalytic cracking (FCC), reforming, coking, and visbreaking. In this embodiment, extract stream **20** comprises the lighter hydrocarbon regeneration solvent and the contaminant. Other suitable regeneration solvents include, but are not limited to, alcohols, aldehydes, ketones, ether, and combinations thereof. In these embodiments, extract stream **20** comprises the alcohol, aldehyde, ketone, or ether regeneration solvent and the contaminant. In another embodiment, the regeneration solvent stream **18** comprises water, and the ionic liquid regeneration step produces extract stream **20** comprising the contaminant and regenerated hydrocarbon-immiscible ionic liquid **22** comprising water and the ionic liquid. In an embodiment wherein regeneration solvent stream **18** comprises water, a portion or all of spent water stream **16** may provide a

portion or all of regeneration solvent stream **18**. Regardless of which regeneration solvent is used, a portion or all of regenerated hydrocarbon-immiscible ionic liquid stream **22** may be recycled to the contaminant removal step via a conduit not shown consistent with other operating conditions of the process. For example, a constraint on the water content of the hydrocarbon-immiscible ionic liquid stream **4** or the ionic liquid/hydrocarbon mixture in contaminant removal zone **100** may be met by controlling the proportion and water content of fresh and recycled ionic liquid streams.

**[0033]** Optional ionic liquid drying step is illustrated by drying zone **600**. The ionic liquid drying step may be employed to reduce the water content of one or more of the streams comprising ionic liquid to control the water content of the contaminant removal step as described above. In the embodiment of FIG. 1, a portion or all of regenerated hydrocarbon-immiscible ionic liquid stream **22** is introduced to drying zone **600**. Although not shown, other streams comprising ionic liquid such as the fresh ionic liquid stream **3**, hydrocarbon-immiscible ionic liquid effluent stream **8**, and spent water stream **16**, may also be dried in any combination in drying zone **600**. To dry the ionic liquid stream or streams, water may be removed by one or more various well known methods including distillation, flash distillation, and using a dry inert gas to strip water. Generally, the drying temperature may range from about 100° C. to less than the decomposition temperature of the ionic liquid, usually less than about 300° C. The pressure may range from about 35 kPa(g) to about 250 kPa(g). The drying step produces a dried hydrocarbon-immiscible ionic liquid stream **24** and a drying zone water effluent stream **26**. Although not illustrated, a portion or all of dried hydrocarbon-immiscible ionic liquid stream **24** may be recycled or passed to provide all or a portion of the hydrocarbon-immiscible ionic liquid introduced to contaminant removal zone **100**. In the case of recycle to the contaminant removal zone, additional Brønsted acid can be added as needed. A portion or all of drying zone water effluent stream **26** may be recycled or passed to provide all or a portion of the water introduced into hydrocarbon washing zone **400** and/or ionic liquid regeneration zone **500**.

**[0034]** FIG. 2A illustrates an embodiment of the invention which may be practiced in contaminant removal or extraction zone **100** that comprises a multi-stage, counter-current extraction column **107** wherein hydrocarbon and hydrocarbon-immiscible ionic liquid are contacted and separated. The hydrocarbon feed stream **2** enters extraction column **107** through feed inlet **102**, lean ionic liquid stream **4** enters extraction column **107** through ionic liquid inlet **104**, and Brønsted acid stream **5** enters extraction column **107** through Brønsted acid inlet **105**. Alternatively, the lean ionic liquid stream **4** and Brønsted acid stream **5** could be mixed before being introduced into the extraction column **107**. In the Figures, reference numerals of the streams and the lines or conduits in which they flow are the same. Hydrocarbon feed inlet **102** is located below ionic liquid inlet **104** and Brønsted acid inlet **105**. The hydrocarbon effluent passes through hydrocarbon effluent outlet **112** in an upper portion of extraction column **107** to hydrocarbon effluent conduit **6**. The hydrocar-

bon-immiscible ionic liquid effluent including the contaminants removed from the hydrocarbon feed passes through ionic liquid effluent outlet **114** in a lower portion of extraction column **107** to ionic liquid effluent conduit **8**.

**[0035]** FIG. 2B illustrates another embodiment of contaminant removal washing zone **100** that comprises a contacting zone **200** and a separation zone **300**. In this embodiment, lean ionic liquid stream **4**, Brønsted acid stream **5**, and hydrocarbon feed stream **2** are introduced into the contacting zone **200** and mixed by introducing Brønsted acid stream **5** and hydrocarbon feed stream **2** into the flowing lean ionic liquid stream **4** and passing the combined streams through static in-line mixer **155**. Static in-line mixers are well known in the art and may include a conduit with fixed internals such as baffles, fins, and channels that mix the fluid as it flows through the conduit. In other embodiments, not illustrated, lean ionic liquid stream **4** and Brønsted acid stream **5** may be introduced into hydrocarbon feed stream **2**. In another embodiment, lean ionic liquid stream **4**, Brønsted acid stream **5**, and hydrocarbon feed stream **2** are separately introduced into the static in-line mixer **155**. In other embodiments, the streams may be mixed by any method well known in the art, including stirred tank and blending operations. The mixture comprising hydrocarbon, ionic liquid, and Brønsted acid is transferred to separation zone **300** via transfer conduit **7**. Separation zone **300** comprises separation vessel **165** wherein the two phases are allowed to separate into a rich ionic liquid phase which is withdrawn from a lower portion of separation vessel **165** via ionic liquid effluent conduit **8** and a hydrocarbon phase which is withdrawn from an upper portion of separation vessel **165** via hydrocarbon effluent conduit **6**. Separation vessel **165** may comprise a boot, not illustrated, from which rich ionic liquid is withdrawn via conduit **8**.

**[0036]** Separation vessel **165** may contain a solid media **175** and/or other coalescing devices which facilitate the phase separation. In other embodiments, the separation zone **300** may comprise multiple vessels which may be arranged in series, parallel, or a combination thereof. The separation vessels may be of any shape and configuration to facilitate the separation, collection, and removal of the two phases. In a further embodiment, contaminant removal zone **100** may include a single vessel wherein lean ionic liquid stream **4**, Brønsted acid stream **5**, and hydrocarbon feed stream **2** are mixed, then remain in the vessel to settle into the hydrocarbon effluent and rich ionic liquid phases.

**[0037]** In an embodiment, the process comprises at least two contaminant removal steps. For example, the hydrocarbon effluent from one contaminant removal step may be passed directly as the hydrocarbon feed to a second contaminant removal step. In another embodiment, the hydrocarbon effluent from one contaminant removal step may be treated or processed before being introduced as the hydrocarbon feed to the second contaminant removal step. There is no requirement that each contaminant removal zone comprises the same type of equipment. Different equipment and conditions may be used in different contaminant removal zones.

**[0038]** The contaminant removal step may be conducted under contaminant removal conditions including tempera-

tures and pressures sufficient to keep the hydrocarbon-immiscible ionic liquid and hydrocarbon feeds and effluents as liquids. For example, the contaminant removal step temperature may range between about 10° C. and less than the decomposition temperature of the ionic liquid, and the pressure may range between about atmospheric pressure and about 3 MPa (g). When the hydrocarbon-immiscible ionic liquid comprises more than one ionic liquid component, the decomposition temperature of the ionic liquid is the lowest temperature at which any of the ionic liquid components decompose. The contaminant removal step may be conducted at a uniform temperature and pressure, or the contacting and separating steps of the contaminant removal step may be operated at different temperatures and/or pressures. In an embodiment, the contacting step is conducted at a first temperature, and the separating step is conducted at a temperature at least 5° C. lower than the first temperature. In a non-limiting example, the first temperature is about 80° C. Such temperature differences may facilitate separation of the hydrocarbon and ionic liquid phases.

**[0039]** The above and other contaminant removal step conditions such as the contacting or mixing time, the separation or settling time, and the ratio of hydrocarbon feed to hydrocarbon-immiscible ionic liquid (lean ionic liquid) may vary greatly based, for example, on the specific ionic liquid or liquids employed, the Brønsted acid used, the nature of the hydrocarbon feed (straight run or previously processed), the contaminant content of the hydrocarbon feed, the degree of contaminant removal required, the number of contaminant removal steps employed, and the specific equipment used. In general, it is expected that contacting time may range from less than one minute to about two hours; settling time may range from about one minute to about eight hours.

**[0040]** The weight ratio of hydrocarbon feed to lean ionic liquid introduced to the contaminant removal step may range from about 1:10,000 to about 10,000:1, or about 1:1,000 to about 1,000:1, or about 1:100 to about 100:1, or about 1:20 to about 20:1, or about 1:10 to about 10:1. In an embodiment, the weight of hydrocarbon feed is greater than the weight of ionic liquid introduced to the contaminant removal step.

**[0041]** The degree of phase separation between the hydrocarbon and ionic liquid phases is another factor to consider as it affects recovery of the ionic liquid and hydrocarbon. The degree of contaminant removed and the recovery of the hydrocarbon and ionic liquid may be affected differently by the nature of the hydrocarbon feed, the variations in the specific ionic liquid or liquids, the Brønsted acid, the equipment, and the contaminant removal conditions such as those discussed above.

**[0042]** The amount of water present in the hydrocarbon/hydrocarbon-immiscible ionic liquid mixture during the contaminant removal step may also affect the amount of contaminant removed and/or the degree of phase separation, i.e., recovery of the hydrocarbon and ionic liquid. In an embodiment, the hydrocarbon/hydrocarbon-immiscible ionic liquid mixture has a water content of less than about 10% relative to the weight of the ionic liquid, or less than about 5% relative to the weight of the ionic liquid, or less than about 2% relative to



the weight of the ionic liquid. In a further embodiment, the hydrocarbon/hydrocarbon-immiscible ionic liquid mixture is water free, i.e., the mixture does not contain water.

**[0043]** Unless otherwise stated, the exact connection point of various inlet and effluent streams within the zones is not essential to the invention. For example, it is well known in the art that a stream to a distillation zone may be sent directly to the column, or the stream may first be sent to other equipment within the zone such as heat exchangers, to adjust temperature, and/or pumps to adjust the pressure. Likewise, streams entering and leaving contaminant removal, washing, and regeneration zones may pass through ancillary equipment such as heat exchanges within the zones. Streams, including recycle streams, introduced to washing or extraction zones may be introduced individually or combined prior to or within such zones.

**[0044]** The invention encompasses a variety of flow scheme embodiments including optional destinations of streams, splitting streams to send the same composition, i.e. aliquot portions, to more than one destination, and recycling various streams within the process. Examples include: various streams comprising ionic liquid and water may be dried and/or passed to other zones to provide all or a portion of the water and/or ionic liquid required by the destination zone. The various process steps may be operated continuously and/or intermittently as needed for a given embodiment e.g. based on the quantities and properties of the streams to be processed in such steps. As discussed above the invention encompasses multiple contaminant removal steps, which may be performed in parallel, sequentially, or a combination thereof. Multiple contaminant removal steps may be performed within the same contaminant removal zone and/or multiple contaminant removal zones may be employed with or without intervening washing, regeneration and/or drying zones.

**[0045]** By the term “about,” we mean within 10% of the value, or within 5%, or within 1%.

## EXAMPLES

**[0046]** A digitally controlled Optichem hot plate magnetic stirrer with 17 individual sample wells was used to screen ionic liquids for decontamination properties. Each well could be fitted with a 6 dram (20 cc) glass vial. The experiments were conducted in the vials with a ¾ inch (1.9 cm) cross shaped magnetic stir bars for mixing. For the purposes of the screening study, typically 1 gram of ionic liquid was com-

glass pipette. In some experiments, acid was added to the ionic liquid, and in other experiments acid was used without ionic liquid.

**[0047]** FCC naphtha, with the properties described in Table 1, was the hydrocarbon feed used in examples 1, 2 and 3. The boiling point range of the FCC naphtha was determined by ASTM method D2887, and the nitrogen, sulfur, water, density, and research octane number analyses were performed using ASTM methods D4629, D2622, D1364, D4052, and D2699M respectively.

TABLE 1

FCC Naphtha	
Nitrogen, ppm	115
Sulfur, ppm	2777
Water, ppm	109
Research octane number	93
Density, g/cc	0.773
Boiling Range ° C.	
Initial boiling point at 0.5 wt %	30
Boiling point at 25.0 wt %	85
Boiling point at 50.0 wt %	123
Boiling point at 75.0 wt %	162
Boiling point at 95.0 wt %	201
Final boiling point at 99.5 wt %	241

## Example 1

**[0048]** FCC naphtha was weighed into 4 tared glass vials. In the first vial, triisobutylmethylphosphonium tosylate ionic liquid (IL) was added at a ratio of 0.1 IL:naphtha. Triisobutylmethylphosphonium tosylate mixed with H<sub>2</sub>SO<sub>4</sub> was added to the IL in the second vial, the IL:naphtha ratio was 0.1, and the acid:naphtha ratio was 0.03. The other 2 vials contained naphtha plus H<sub>2</sub>SO<sub>4</sub> at acid:naphtha ratios of 0.25 and 0.5. The vials were placed in the wells of the Optichem stir plate and stirred at room temperature for 30 minutes at 500 rpm. After 30 minutes, the stirring was stopped, and the mixtures were allowed to settle for 30 minutes. A pipette was used to draw off the extracted naphtha from the extraction media. The naphtha phase was weighed and analyzed for nitrogen and sulfur. The extract yield was calculated based on the differences in weight. The % denitrogenation and extract yields for these experiments are shown in Table 2.

TABLE 2

FCC Naphtha	H2SO4/feed	IL/Feed	temp, ° C.	mixing time	settling time	de-N, wt %	Extract Yield, wt %
triisobutylmethylphosphonium tosylate	0	0.1	RT	30	30	81.74	2.2
triisobutylmethylphosphonium tosylate	0.03	0.1	RT	30	30	82.61	3
triisobutylmethylphosphonium tosylate	0.05	0.1	RT	30	30	90.43	~1
5% H2SO4	0.25	0	RT	30	30	73.04	NA
10% H2SO4	0.5	0	RT	30	30	76.52	NA

bined in a vial with 10 grams of feed, heated to appropriate temperature and mixed at 500 rpm for 30 minutes. After 30 minutes, the mixing was stopped, and the samples were held static at temperature. In successful experiments, separation occurred, and the extracted feed was suctioned off with a

## Example 2

**[0049]** FCC naphtha was weighed into 5 tared glass vials. In the first vial tributylethylphosphonium diethylphosphate ionic liquid (IL) was added at a ratio of 0.1 IL:naphtha.

Tributylethylphosphonium diethylphosphate mixed with  $\text{H}_3\text{PO}_4$  was added to the second and third vials. The ratio of IL:naphtha was 0.1, and the ratios of acid:naphtha 0.03 and 0.05. The other 2 vials contained naphtha plus  $\text{H}_3\text{PO}_4$  at acid:naphtha ratios of 0.25 and 0.5. The vials were placed in the wells of the Optichem stir plate and stirred at room temperature for 30 minutes at 500 rpm.

**[0050]** After 30 minutes, the stirring was stopped, and the mixtures were allowed to settle for 30 minutes. A pipette was used to draw off the extracted naphtha from the extraction media. The naphtha phase was weighed and analyzed for nitrogen and sulfur. The extract yield was calculated based on the differences in weight. The % denitrogenation, % desulfurization and extract yields for these experiments are shown in Table 3.

TABLE 3

FCC Naphtha	$\text{H}_3\text{PO}_4$ /feed	IL/Feed	temp, ° C.	mixing time	settling time	de-N, wt %	de-S, wt %	Extract Yield
tributylethylphosphonium diethylphosphate	0	0.1	RT	30	30	80.87	4.72	6
tributylethylphosphonium diethylphosphate	0.03	0.1	RT	30	30	76.52	4.25	3.9
tributylethylphosphonium diethylphosphate	0.05	0.1	RT	30	30	80.87	1.98	1.8
5% $\text{H}_3\text{PO}_4$	0.25	0	RT	30	30	75.65	0.18	NA
10% $\text{H}_3\text{PO}_4$	0.5	0	RT	30	30	74.78	1.98	NA

## Example 3

**[0051]** FCC naphtha was weighed into 4 tared glass vials. Triisobutylmethylphosphonium tosylate ionic liquid (IL) was added at an IL:naphtha ratio of 0.1. P-toluene sulfonic acid was mixed in with the IL at different acid:naphtha ratios. The vials were placed in the wells of the Optichem stir plate and stirred at room temperature for 30 minutes at 500 rpm. After 30 minutes, the stirring was stopped, and the mixtures were allowed to settle for 30 minutes. A pipette was used to draw off the extracted naphtha from the extraction media. The naphtha phase was weighed and analyzed for nitrogen and sulfur. The extract yield was calculated based on the differences in weight. The % denitrogenation, % desulfurization and extract yields for these experiments are shown in Table 4.

TABLE 4

FCC Naphtha	P-toluenesulfonic acid/feed	IL/Feed	temp, ° C.	mixing time	settling time	de-N, wt %	de-S, wt %	Extract Yield
triisobutylmethylphosphonium tosylate	0	0.1	RT	30	30	83.48	4.86	4
triisobutylmethylphosphonium tosylate	0.03	0.1	RT	30	30	83.48	4.86	4
triisobutylmethylphosphonium tosylate	0.05	0.1	RT	30	30	84.35	5.33	4
triisobutylmethylphosphonium tosylate	0.1	0.1	RT	30	30	84.35	2.92	3

## Example 4

**[0052]** Light cycle oil (LCO) with the properties described in Table 5, was used in Example 4. The boiling point range of the LCO was determined by ASTM method D2887, and the

nitrogen, sulfur, water, density, and research cetane number analyses were performed using ASTM methods D4629, D2622, D1364, D4052, and D613 respectively.

TABLE 5

LCO	
nitrogen, ppm	1500
density	0.9655
Sulfur, ppm	9442
cetane	18.41
water, ppm	228
% C5-203° C.	4.84
% 204-343° C.	82.46

TABLE 5-continued

LCO	
% 344-524° C.	12.70
% 524+° C.	0.00

**[0053]** Light cycle oil (LCO) was weighed into 5 tared glass vials. In the first vial, triisobutylmethylphosphonium tosylate ionic liquid (IL) was added at a ratio of 0.1 IL:LCO. Triisobutylmethylphosphonium tosylate mixed with  $\text{H}_2\text{SO}_4$  was added to the second and third vials. The ratio of IL:LCO was 0.1, and the ratios of acid:LCO were 0.03 and 0.05. The other 2 vials contained LCO plus  $\text{H}_2\text{SO}_4$  at acid:LCO ratios of 0.25

and 0.5. The vials were placed in the wells of the Optichem stir plate and stirred at room temperature for 30 minutes at 500 rpm. After 30 minutes, the stirring was stopped, and the mixtures were allowed to settle for 30 minutes. A pipette was used to draw off the extracted LCO from the extraction media.

The LCO phase was weighed and analyzed for nitrogen. The extract yield was calculated based on the differences in weight. The % denitrogenation and extract yields for these experiments are shown in Table 6.

TABLE 6

Light Cycle Oil	H2SO4/feed	IL/Feed	temp, ° C.	mixing time	settling time	de-N, wt %	Extract Yield, wt %
triisobutylmethylphosphonium tosylate	0	0.1	RT	30	30	85.76	10
triisobutylmethylphosphonium tosylate	0.03	0.1	RT	30	30	68.61	7
triisobutylmethylphosphonium tosylate	0.05	0.1	RT	30	30	64.49	6
H2SO4	0.25	0	RT	30	30	44.77	6
H2SO4	0.5	0	RT	30	30	32.25	2

## Example 5

**[0054]** Vacuum gas oil (VGO) with properties described in Table 7, was used in Example 5. The boiling point range of the VGO was determined by ASTM method D2887, nitrogen, sulfur, and density analyses were performed using ASTM methods D4629, D2622, and D4052 respectively.

TABLE 7

Feed	VGO
Density (g/mL)	0.9271
Sulfur, wt %	2.99
Nitrogen, wt-ppm	1400
Boiling Range, ° C.	
Initial Boiling point at 0.5 wt %	291.8
Boiling point at 25 wt %	399.4
Boiling point at 50 wt %	437.8
Boiling point at 75 wt %	478.8
Boiling point at 95 wt %	532.6
Final boiling point at 99.5 wt %	659

water at a 1:1 weight ratio. The water addition freed the extract from the ionic liquid and the extract was suctioned away using a pipette. The water was evaporated from the ionic liquid via rotary flash evaporation. P-toluene sulfonic acid (PTSA) was added to the regenerated ionic liquid at a ratio of PTSA:IL of 0.03. The acid IL mixture was combined with fresh VGO at a ratio of IL:VGO of 0.1. The mixture was stirred for 30 minutes at 80° C. and then settled for 30 minutes at 80° C. The extracted VGO floated to the top of the beaker and was suctioned away with a pipette. The Brønsted acid and the ionic liquid phase containing the extract from the VGO was diluted with water at a 1:1 weight ratio. The water addition freed the extract from the Brønsted acid and the ionic liquid and the extract was suctioned away using a pipette. The water and the Brønsted acid were evaporated from the ionic liquid via rotary flash evaporation. Additional PTSA was added to the regenerated IL to make-up for the loss to evaporation. The IL with added PTSA was then used to extract fresh VGO. This procedure was repeated four additional times. The % denitrogenation and the extract yields for these experiments are shown in Table 8.

TABLE 8

VGO	Cycle #	PTSA/IL	IL/Feed	temp, ° C.	mixing time	settling time	de-N, wt %	Extract Yield, wt %
triisobutylmethylphosphonium tosylate	1	0.00	0.1	80	30	30	38.79	2.90
triisobutylmethylphosphonium tosylate	2	0.03	0.1	80	30	30	35.35	2.90
triisobutylmethylphosphonium tosylate	3	0.03	0.1	80	30	30	39.21	3.27
triisobutylmethylphosphonium tosylate	4	0.03	0.1	80	30	30	39.21	3.05
triisobutylmethylphosphonium tosylate	5	0.03	0.1	80	30	30	38.37	3.19
triisobutylmethylphosphonium tosylate	6	0.03	0.1	80	30	30	44.27	3.23

**[0055]** Vacuum gas oil (VGO) was weighed into a beaker. Triisobutylmethyl phosphonium tosylate ionic liquid (IL) was added at a ratio of 0.1 IL:VGO. The mixture was stirred

**[0056]** While at least one exemplary embodiment has been presented in the foregoing detailed description of the invention, it should be appreciated that a vast number of variations

exist. It should also be appreciated that the exemplary embodiment or exemplary embodiments are only examples, and are not intended to limit the scope, applicability, or configuration of the invention in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing an exemplary embodiment of the invention. It being understood that various changes may be made in the function and arrangement of elements described in an exemplary embodiment without departing from the scope of the invention as set forth in the appended claims.

What is claimed is:

1. A process for removing a contaminant comprising at least one of sulfur and nitrogen from a hydrocarbon stream comprising:

contacting the hydrocarbon stream comprising the contaminant with a Brønsted acid, or a hydrocarbon-immiscible ionic liquid and a Brønsted acid under contacting conditions so that the Brønsted acid, or the hydrocarbon-immiscible ionic liquid and the Brønsted acid are in a liquid state to produce a mixture comprising the hydrocarbon and the Brønsted acid comprising at least a portion of the removed contaminant or a hydrocarbon-immiscible ionic liquid comprising at least a portion of the removed contaminant; and

separating the mixture to produce a hydrocarbon effluent having a reduced level of the contaminant and a Brønsted acid effluent comprising the Brønsted acid comprising at least the portion of the removed contaminant or a hydrocarbon-immiscible ionic liquid effluent comprising the hydrocarbon-immiscible ionic liquid comprising at least the portion of the removed contaminant.

2. The process of claim 1 wherein the hydrocarbon-immiscible ionic liquid comprises at least one of nitrogen containing ionic liquids and phosphorus containing ionic liquids.

3. The process of claim 1 wherein the Brønsted acid comprises sulfonic acid, derivatives of sulfonic acid, sulfuric acid, phosphoric acid, derivatives of phosphoric acid, phosphonic acid, derivatives of phosphonic acid, hydrochloric acid, hydrobromic acid, nitric acid, sulfurous acid, carboxylic acids having from 1 to 8 carbons, and combinations thereof.

4. The process of claim 1 wherein a ratio of the Brønsted acid to the hydrocarbon-immiscible ionic liquid is in a range of about 0.01:1 to about 0.5:1.

5. The process of claim 1 wherein the hydrocarbon stream has a boiling point in a range of about 30° C. to about 525° C.

6. The process of claim 1 wherein the contacting step is conducted at a temperature in a range of about 20° C. to about 150° C., and a pressure in a range of about 100 kPa (g) to about 3 MPa(g).

7. The process of claim 1 further comprising passing at least a portion of the hydrocarbon effluent to a hydrocarbon conversion process.

8. The process of claim 1 further comprising:  
regenerating the hydrocarbon-immiscible ionic liquid effluent; and

recycling the regenerated hydrocarbon-immiscible based ionic liquid effluent to the contacting step.

9. The process of claim 1 wherein a ratio of the hydrocarbon to the hydrocarbon-immiscible ionic liquid is in a range of about 1:1,000 to about 1,000:1.

10. The process of claim 1 further comprising contacting the hydrocarbon-immiscible ionic liquid effluent with a

regeneration solvent to form an extract stream comprising the contaminant and a stream of regenerated hydrocarbon-immiscible ionic liquid.

11. The process of claim 10 wherein the regeneration solvent comprises water, naphtha, gasoline, diesel, light cycle oil, light coker gas oil, alcohols, aldehydes, ketones, ether, and combinations thereof.

12. The process of claim 10 further comprising separating the stream of regenerated hydrocarbon-immiscible ionic liquid from the regeneration solvent.

13. The process of claim 12 further comprising recycling the stream of regenerated hydrocarbon-immiscible ionic liquid to the contacting step.

14. The process of claim 1 wherein the ionic liquid comprises an imidazolium ionic liquid, an ammonium ionic liquid, a pyridinium ionic liquid, a phosphonium ionic liquid, a lactamium ionic liquid, a pyrrolidinium ionic liquid, or combinations thereof.

15. The process of claim 1 wherein the hydrocarbon effluent contains less than 25 ppm hydrocarbon-immiscible ionic liquid.

16. A process for removing a contaminant comprising at least one of sulfur and nitrogen from a hydrocarbon stream comprising:

contacting the hydrocarbon stream comprising the contaminant with a hydrocarbon-immiscible ionic liquid and a Brønsted acid under contacting conditions so that the hydrocarbon-immiscible ionic liquid and the Brønsted acid are in a liquid state to produce a mixture comprising the hydrocarbon and a hydrocarbon-immiscible ionic liquid comprising at least a portion of the removed contaminant, wherein the hydrocarbon stream has a boiling point in a range of about 30° C. to about 525° C., wherein the hydrocarbon-immiscible ionic liquid comprises an imidazolium ionic liquid, an ammonium ionic liquid, a pyridinium ionic liquid, a phosphonium ionic liquid, a lactamium ionic liquid, a pyrrolidinium ionic liquid, or combinations thereof, and wherein the Brønsted acid comprises sulfonic acid, derivatives of sulfonic acid, sulfuric acid, phosphoric acid, derivatives of phosphoric acid, phosphonic acids, derivatives of phosphonic acid, hydrochloric acid, hydrobromic acid, nitric acid, sulfurous acid, carboxylic acids having from 1 to 8 carbons, and combinations thereof, and wherein a ratio of the Brønsted acid to the hydrocarbon-immiscible ionic liquid is in a range of about 0.01:1 to about 0.5:1; and

separating the mixture to produce a hydrocarbon effluent having a reduced level of the contaminant and a hydrocarbon-immiscible ionic liquid effluent comprising the hydrocarbon-immiscible ionic liquid comprising at least the portion of the removed contaminant, wherein the hydrocarbon effluent contains less than 25 ppm hydrocarbon-immiscible ionic liquid.

17. The process of claim 16 wherein the contacting step is conducted at a temperature in a range of about 20° C. to about 150° C.

18. The process of claim 18 further comprising:  
regenerating the hydrocarbon-immiscible ionic liquid effluent; and

recycling the regenerated hydrocarbon-immiscible based ionic liquid effluent to the contacting step.

19. The process of claim 1 wherein the hydrocarbon-immiscible ionic liquid effluent is regenerated by contacting the

hydrocarbon-immiscible ionic liquid effluent with a regeneration solvent to form an extract stream comprising the contaminant and a stream of regenerated hydrocarbon-immiscible ionic liquid, and further comprising:

separating the stream of regenerated hydrocarbon-immiscible ionic liquid from the regeneration solvent.

**20.** The process of claim **19** wherein the regeneration solvent comprises water, naphtha, gasoline, diesel, light cycle oil, light coker gas oil, alcohols, aldehydes, ketones, ether, and combinations thereof.

\* \* \* \* \*