

RECOVERY OF ALIPHATIC HYDROCARBONS

Field of the invention

The present invention relates to a process for the
5 recovery of aliphatic hydrocarbons from a liquid hydrocarbon
feedstock stream comprising aliphatic hydrocarbons,
heteroatom containing organic compounds and optionally
aromatic hydrocarbons; to a process for the recovery of
aliphatic hydrocarbons from plastics comprising the above-
10 mentioned process; and to a process for steam cracking a
hydrocarbon feed comprising aliphatic hydrocarbons as
recovered in one of the above-mentioned processes.

Background of the invention

Waste plastics can be converted via cracking of the
15 plastics, for example by pyrolysis, to high-value chemicals,
including olefins and aromatic hydrocarbons. Pyrolysis of
plastics can yield product streams containing hydrocarbons in
a wide boiling range. Hydrocarbons from such pyrolysis
product streams can be further cracked in a steam cracker to
20 produce high-value chemicals, including ethylene and
propylene which are monomers that can be used in making new
plastics.

WO2018069794 discloses a process for producing olefins
and aromatic hydrocarbons from plastics wherein a liquid
25 pyrolysis product stream is separated into a first fraction
having a boiling point $<300\text{ }^{\circ}\text{C}$ and a second fraction having a
boiling point $\geq 300\text{ }^{\circ}\text{C}$. Only said first fraction is fed to a
liquid steam cracker, whereas said second fraction is
recycled to the pyrolysis unit. In the process shown in
30 Figure 1 of WO2018069794, said separation is performed in a
hydrocarbon liquid distillation unit. Having to separate the
liquid pyrolysis product stream into two fractions is

cumbersome (e.g. energy intensive). A further disadvantage is that the heavier portion of the liquid pyrolysis product stream has to be sent back to the pyrolysis unit for a deeper pyrolysis. This results in yield loss through the formation of gas and an increasing amount of solid side-product (coke) which is eventually not sent to the steam cracker. In one embodiment of the process of above-mentioned WO2018069794 (see Figure 2), the first fraction having a boiling point <300 °C is first conveyed together with hydrogen to a hydroprocessing unit to produce a treated hydrocarbon liquid stream which is then fed to the liquid steam cracker. Such hydroprocessing is also cumbersome, as it is capital intensive and requires the use of expensive hydrogen (H₂).

Further, US20180355256 discloses a method for deriving fuel from plastics, the method comprising subjecting a quantity of plastics to a pyrolytic process, thereby to convert at least part of the plastics to a crude fuel; and extracting the fuel in a directly usable form by way of: 1) a first extraction step comprising counterflow liquid-liquid extraction using one or more extraction solvents to extract one or more impurities from the crude fuel; and 2) a second extraction step comprising counterflow extraction of resultant contaminated extraction solvent(s) from the first extraction step. In the process as shown in Figure 2 of US20180355256, a crude fuel (i.e. a crude diesel) that is made by pyrolysis of plastics, is first subjected to extraction with N-methyl-2-pyrrolidone (NMP) to extract one or more impurities, including sulfur compounds and aromatics, from the crude fuel. The contaminated NMP from the first extraction step is then subjected to a second extraction step using water, to increase the polarity of the contaminated extraction solvent, thereby separating off said impurities. In a final step, the water-contaminated NMP from the second

extraction step is distilled using a standard distillation column, which gives rise to recycle water and recycle NMP.

The feed to the distillation column as disclosed in above-mentioned US20180355256 (Figure 2) may still comprise a
5 certain amount of heteroatom containing organic contaminants and aromatic contaminants. Said distillation may result in that part of said contaminants is separated off together with the recycle water because water and such contaminants may form an azeotrope, thereby reducing the quality of the water
10 recycle stream. In case that recycle water is recycled to the column used in the second extraction step, the concentration of these contaminants in the recycle water will increase in what is denominated "build-up", in addition to a build-up of these contaminants in the recycle NMP to be used in the first
15 extraction step. This can result in a lower efficiency of the first and second extraction steps. US20180355256 concerns a method for deriving fuel from plastics. Such build-up of these contaminants (in said recycle NMP) may result in that the cleaned oil still comprises a relatively high amount of
20 these contaminants, which is of particular concern when such cleaned oil would be fed to a steam cracker, instead of being used as a fuel, because of the negative impact of these contaminants on the yield, selectivity and reliability of steam crackers.

25 There is an ongoing need to develop improved processes for the recovery of aliphatic hydrocarbons from liquid streams comprising aliphatic hydrocarbons, heteroatom containing organic compounds and optionally aromatic hydrocarbons which may originate from cracking waste
30 plastics, in specific mixed waste plastics, especially before feeding such recovered aliphatic hydrocarbons to a steam cracker. It is an object of the present invention to provide such process for the recovery of aliphatic hydrocarbons from

such liquid streams, which process is technically advantageous, efficient and affordable, in particular a process which does not have one or more of the above-mentioned disadvantages, as discussed above in connection
5 with WO2018069794 and US20180355256. Such technically advantageous process would preferably result in a relatively low energy demand and/or relatively low capital expenditure.

Summary of the invention

Surprisingly it was found by the present inventors that
10 such process can be provided by a) liquid-liquid extraction of a liquid stream which comprises aliphatic hydrocarbons, heteroatom containing organic compounds and optionally aromatic hydrocarbons, with an extraction solvent a) which contains one or more heteroatoms; b) mixing a stream
15 resulting from step a) which comprises extraction solvent a), heteroatom containing organic compounds and optionally aromatic hydrocarbons, with a demixing solvent b) to remove part of the heteroatom containing organic compounds and optional aromatic hydrocarbons, wherein demixing solvent b)
20 contains one or more heteroatoms and has a miscibility in heptane which is lower than the miscibility of extraction solvent a) in heptane; and c) separation of at least part of a stream resulting from step b), which comprises extraction solvent a), demixing solvent b), heteroatom containing
25 organic compounds and optionally aromatic hydrocarbons, into a demixing solvent b) containing stream and an extraction solvent a) containing stream, wherein (i) before step c) at least part of said stream resulting from step b) is contacted with a sorption agent (or sorbent); and/or (ii) after step c)
30 at least part of a stream resulting from step c), which comprises demixing solvent b), heteroatom containing organic compounds and optionally aromatic hydrocarbons, is contacted with a sorption agent (or sorbent), wherein said sorption

agent removes at least part of the heteroatom containing organic compounds and optional aromatic hydrocarbons from the latter stream(s).

Accordingly, the present invention relates to a process
5 for the recovery of aliphatic hydrocarbons from a liquid hydrocarbon feedstock stream comprising aliphatic hydrocarbons, heteroatom containing organic compounds and optionally aromatic hydrocarbons, said process comprising the steps of:

10 a) contacting at least part of the liquid hydrocarbon feedstock stream with an extraction solvent a) which contains one or more heteroatoms and subjecting the liquid hydrocarbon feedstock stream to liquid-liquid extraction with the extraction solvent a), resulting in a first stream comprising
15 aliphatic hydrocarbons and a second stream comprising extraction solvent a), heteroatom containing organic compounds and optionally aromatic hydrocarbons;

b) mixing at least part of the second stream resulting from step a) with a demixing solvent b) which contains one or
20 more heteroatoms and has a miscibility in heptane which is lower than the miscibility of extraction solvent a) in heptane, and separating the resulting mixture into a first stream comprising heteroatom containing organic compounds and optionally aromatic hydrocarbons and a second stream
25 comprising extraction solvent a), demixing solvent b), heteroatom containing organic compounds and optionally aromatic hydrocarbons;

c) separating at least part of the second stream resulting from step b) into a first stream comprising
30 demixing solvent b), optionally heteroatom containing organic compounds and optionally aromatic hydrocarbons and a second stream comprising extraction solvent a);

d) recycling at least part of the extraction solvent a) from the second stream resulting from step c) to step a); and

e) optionally recycling at least part of the demixing solvent b) from the first stream resulting from step c) to
5 step b),

wherein:

(i) before step c), heteroatom containing organic compounds and optionally aromatic hydrocarbons are removed from the second stream resulting from step b) by contacting
10 at least part of that stream with a sorption agent; and/or

(ii) after step c), heteroatom containing organic compounds and optionally aromatic hydrocarbons are removed from the first stream resulting from step c), wherein that stream comprises demixing solvent b), heteroatom containing
15 organic compounds and optionally aromatic hydrocarbons, by contacting at least part of that stream with a sorption agent.

Advantageously, in the present invention, there is no need for hydrotreating (treatment with H₂) because of said
20 liquid-liquid extraction in step a). Furthermore, advantageously, a liquid hydrocarbon stream having a wide boiling range, such as plastics pyrolysis oil, may be treated in the present process with a relatively low yield loss and feed degradation. This implies that the costs of a
25 hydrocarbon feed to a steam cracker may be reduced considerably by applying the present invention.

Further, heteroatom containing organic compounds and any aromatic hydrocarbons may eventually partition into the stream comprising extraction solvent a) and demixing solvent
30 b) resulting from step b) of the present process. Said heteroatom containing organic compounds and aromatic compounds may comprise the components with the highest polarity of all the heteroatom containing organic compounds

and aromatic compounds as extracted in step a) of the present process. In such case, advantageously, by the sorption step(s) in the process of the present invention, relatively pure demixing solvent b) recycle and relatively pure extraction solvent a) recycle streams, that are substantially free of heteroatom containing organic compounds and aromatic hydrocarbons, can then still be delivered. In turn, such pure demixing solvent b) stream can then advantageously be recycled and used to extract extraction solvent a), either in step a) itself or in another additional step, thereby preventing extraction solvent a) from entering the final hydrocarbon raffinate stream, without contaminating such raffinate stream with heteroatom containing organic compounds and aromatic hydrocarbons. Likewise, such pure extraction solvent a) stream can then advantageously be recycled to step a) and used to extract further heteroatom containing organic compounds and optional aromatic hydrocarbons from fresh feed. Thus, in the present invention, contaminants not removed in step b), will advantageously be concentrated into the sorption agent(s) as used in such sorption step(s), thereby preventing a build-up of such contaminants in the recycle stream(s) in the present process.

Because of the above-described use of sorption agent(s) in the present invention, there is no need or a substantially reduced need to apply other, cumbersome methods for mitigating a build-up of these contaminants. For example, there is no need or a substantially reduced need to bleed part of the recycle streams before recycling, wherein either (i) such bleed stream is discarded resulting in a loss of extraction solvent or (ii) the extraction solvent may be recovered from such bleed stream, for example by distillation thereof, which is however cumbersome.

Further, the present invention relates to a process for the recovery of aliphatic hydrocarbons from plastics, wherein at least part of the plastics comprises heteroatom containing organic compounds, said process comprising the steps of:

5 (I) cracking the plastics and recovering a hydrocarbon product comprising aliphatic hydrocarbons, heteroatom containing organic compounds and optionally aromatic hydrocarbons; and

(II) subjecting a liquid hydrocarbon feedstock stream,
10 which comprises at least part of the hydrocarbon product obtained in step (I), to the above-mentioned process for the recovery of aliphatic hydrocarbons from a liquid hydrocarbon feedstock stream.

Still further, the present invention relates to a process
15 for steam cracking a hydrocarbon feed, wherein the hydrocarbon feed comprises aliphatic hydrocarbons as recovered in one of the above-mentioned processes for the recovery of aliphatic hydrocarbons.

Brief description of the drawings

20 Figure 1 shows one embodiment of the process for the recovery of aliphatic hydrocarbons in accordance with the present invention.

Figure 2 shows another embodiment of the above-mentioned process.

Detailed description of the invention

25 Each of the processes of the present invention comprises multiple steps. In addition, said process may comprise one or more intermediate steps between consecutive steps. Further, said process may comprise one or more additional steps
30 preceding the first step and/or following the last step. For example, in a case where said process comprises steps a), b) and c), said process may comprise one or more intermediate steps between steps a) and b) and between steps b) and c).

Further, said process may comprise one or more additional steps preceding step a) and/or following step c).

Within the present specification, a phrase like "step y) comprises subjecting at least part of the stream resulting from step x) to" means "step y) comprises subjecting part or
5 all of the stream resulting from step x) to" or, similarly, "step y) comprises partially or completely subjecting the stream resulting from step x) to". For example, the stream resulting from step x) may be split into one or more parts
10 wherein at least one of these parts may be subjected to step y). Further, for example, the stream resulting from step x) may be subjected to an intermediate step between steps x) and y) resulting in a further stream at least part of which may be subjected to step y).

15 While the process(es) of the present invention and the stream(s) and composition(s) used in said process(es) are described in terms of "comprising", "containing" or "including" one or more various described steps and components, respectively, they can also "consist essentially
20 of" or "consist of" said one or more various described steps and components, respectively."

In the context of the present invention, in a case where a stream comprises two or more components, these components are to be selected in an overall amount not to exceed 100%.

25 Further, where upper and lower limits are quoted for a property then a range of values defined by a combination of any of the upper limits with any of the lower limits is also implied.

Within the present specification, by "substantially no"
30 in relation to the amount of a specific component in a stream, it is meant an amount which is at most 1,000, preferably at most 500, more preferably at most 100, more preferably at most 50, more preferably at most 30, more

preferably at most 20, and most preferably at most 10 ppmw (parts per million by weight) of the component in question, based on the amount (i.e. weight) of said stream.

Within the present specification, by "top stream" or
5 "bottom stream" from a column reference is made to a stream which exits the column at a position, which is between 0% and 30%, more suitably between 0% and 20%, even more suitably between 0% and 10%, based on the total column length, from the top of the column or the bottom of the column,
10 respectively.

Unless indicated otherwise, where in the present specification reference is made to a boiling point this means the boiling point at 760 mm Hg pressure (101.3 kPa).

Liquid hydrocarbon feedstock stream

15 In the present invention, the liquid hydrocarbon feedstock stream comprises aliphatic hydrocarbons, heteroatom containing organic compounds and optionally aromatic hydrocarbons.

Preferably, the liquid hydrocarbon feedstock stream
20 comprises both aliphatic hydrocarbons having a boiling point of from 30 to 300 °C and aliphatic hydrocarbons having a boiling point of from greater than 300 to 600 °C in a weight ratio of from 99:1 to 1:99. The amount of aliphatic hydrocarbons having a boiling point of from 30 to 300 °C,
25 based on the total amount of aliphatic hydrocarbons having a boiling point of from 30 to 600 °C, may be at most 99 wt.% or at most 80 wt.% or at most 60 wt.% or at most 40 wt.% or at most 30 wt.% or at most 20 wt.% or at most 10 wt.%. Further, the amount of aliphatic hydrocarbons having a boiling point
30 of from 30 to 300 °C, based on the total amount of aliphatic hydrocarbons having a boiling point of from 30 to 600 °C, may be at least 1 wt.% or at least 5 wt.% or at least 10 wt.% or at least 20 wt.% or at least 30 wt.%.

Thus, advantageously, the liquid hydrocarbon feedstock stream may comprise varying amounts of aliphatic hydrocarbons within a wide boiling point range of from 30 to 600 °C. Accordingly, as with the boiling point, the carbon number of the aliphatic hydrocarbons in the liquid hydrocarbon feedstock stream may also vary within a wide range, for example of from 5 to 50 carbon atoms. The carbon number of the aliphatic hydrocarbons in the liquid hydrocarbon feedstock stream may be at least 4 or at least 5 or at least 6 and may be at most 50 or at most 40 or at most 30 or at most 20.

The amount of aliphatic hydrocarbons in the liquid hydrocarbon feedstock stream, based on the total weight of the liquid hydrocarbon feedstock stream, may be at least 30 wt.% or at least 50 wt.% or at least 80 wt.% or at least 90 wt.% or at least 95 wt.% or at least 99 wt.% and may be smaller than 100 wt.% or at most 99 wt.% or at most 90 wt.% or at most 80 wt.% or at most 70 wt.%. The aliphatic hydrocarbons may be cyclic, linear and branched.

The aliphatic hydrocarbons in the liquid hydrocarbon feedstock stream may comprise non-olefinic (paraffinic) and olefinic aliphatic compounds. The amount of paraffinic aliphatic compounds in the liquid hydrocarbon feedstock stream, based on the total weight of the liquid hydrocarbon feedstock stream, may be at least 20 wt.% or at least 40 wt.% or at least 60 wt.% or at least 80 wt.% and may be smaller than 100 wt.% or at most 99 wt.% or at most 80 wt.% or at most 60 wt.%. Further, the amount of olefinic aliphatic compounds in the liquid hydrocarbon feedstock stream, based on the total weight of the liquid hydrocarbon feedstock stream, may be smaller than 100 wt.% or at least 20 wt.% or at least 40 wt.% or at least 60 wt.% or at least 80 wt.% and may be at most 99 wt.% or at most 80 wt.% or at most 60 wt.%.

Further, the olefinic compounds may comprise aliphatic compounds having one carbon-carbon double bond (mono-olefins) and/or aliphatic compounds having two or more carbon-carbon double bonds which latter compounds may be conjugated or non-
5 conjugated. That is to say, the two or more carbon-carbon double bonds may be conjugated or not conjugated. The aliphatic compounds having two or more carbon-carbon double bonds may include compounds having double bonds at alpha and omega positions. The amount of mono-olefins in the liquid
10 hydrocarbon feedstock stream, based on the total weight of the liquid hydrocarbon feedstock stream, may be at least 20 wt.% or at least 40 wt.% or at least 60 wt.% or at least 80 wt.% and may be smaller than 100 wt.% or at most 99 wt.% or at most 80 wt.% or at most 60 wt.%. Further, the amount of
15 conjugated aliphatic compounds having two or more carbon-carbon double bonds in the liquid hydrocarbon feedstock stream, based on the total weight of the liquid hydrocarbon feedstock stream, may be greater than 0 wt.% or at least 10 wt.% or at least 20 wt.% or at least 40 wt.% or at least 60
20 wt.% and may be at most 80 wt.% or at most 60 wt.% or at most 40 wt.%.

Within the present specification, an aliphatic hydrocarbon which contains one or more heteroatoms is a "heteroatom containing organic compound" as further described
25 below. Unless indicated otherwise, either explicitly or by context, within the present specification, the term "aliphatic hydrocarbons" does not include heteroatom containing aliphatic hydrocarbons. Further, unless indicated otherwise, either explicitly or by context, within the
30 present specification, the term "aliphatic hydrocarbons" does not include conjugated aliphatic compounds having two or more carbon-carbon double bonds.

In addition to the above-described aliphatic hydrocarbons, the liquid hydrocarbon feedstock stream comprises heteroatom containing organic compounds and optionally aromatic hydrocarbons.

5 The amount of aromatic hydrocarbons in the liquid hydrocarbon feedstock stream, based on the total weight of the liquid hydrocarbon feedstock stream, may be 0 wt.% or greater than 0 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.% or
10 at least 30 wt.% and may be at most 50 wt.% or at most 40 wt.% or at most 30 wt.% or at most 20 wt.%. The aromatic hydrocarbons may comprise monocyclic and/or polycyclic aromatic hydrocarbons. An example of a monocyclic aromatic hydrocarbon is styrene. The polycyclic aromatic hydrocarbons
15 may comprise non-fused and/or fused polycyclic aromatic hydrocarbons. An example of a non-fused polycyclic aromatic hydrocarbon is oligostyrene. Styrene and oligostyrene may originate from polystyrene. Examples of fused polycyclic aromatic hydrocarbons are naphthalene and anthracene, as well
20 as alkyl naphthalene and alkyl anthracene. The aromatic ring or rings in the aromatic hydrocarbons may be substituted by one or more hydrocarbyl groups, including alkyl groups (saturated) and alkylene groups (unsaturated).

 Within the present specification, an aromatic hydrocarbon
25 which contains one or more heteroatoms is a "heteroatom containing organic compound" as further described below. Unless indicated otherwise, either explicitly or by context, within the present specification, the term "aromatic hydrocarbons" does not include heteroatom containing aromatic
30 hydrocarbons.

 Further, the amount of heteroatom containing organic compounds in the liquid hydrocarbon feedstock stream, based on the total weight of the liquid hydrocarbon feedstock

stream, is greater than 0 wt.% and may be at least 0.5 wt.% or at least 1 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.% and may be at most 30 wt.% or at most 20 wt.% or at most 10 wt.%
5 or at most 5 wt.%.

The heteroatom containing organic compounds in the liquid hydrocarbon feedstock stream contain one or more heteroatoms, which may be oxygen, nitrogen, sulfur and/or a halogen, such as chlorine, suitably oxygen, nitrogen and/or a halogen. The
10 heteroatom containing organic compounds may comprise one or more of the following moieties: amine, imine, nitrile, alcohol, ether, ketone, aldehyde, ester, acid, amide, carbamate (occasionally named urethane) and urea.

Further, the above-mentioned heteroatom containing
15 organic compounds may be aliphatic or aromatic. An example of an aliphatic, heteroatom containing organic compound is oligomeric polyvinyl chloride (PVC). Oligomeric PVC may originate from polyvinyl chloride. Aromatic, heteroatom containing organic compounds may comprise monocyclic and/or
20 polycyclic aromatic, heteroatom containing organic compounds. Examples of monocyclic aromatic, heteroatom containing organic compounds are terephthalic acid and benzoic acid. An example of a polycyclic aromatic, heteroatom containing organic compound is oligomeric polyethylene terephthalate
25 (PET). Terephthalic acid, benzoic acid and oligomeric PET may originate from polyethylene terephthalate. Examples of nitrogen containing organic compounds are compounds originating from polyurethane and polyamides including nylon.

Unless indicated otherwise, either explicitly or by
30 context, within the present specification, the term "heteroatom containing organic compounds" means heteroatom containing organic compounds in or originating from the liquid hydrocarbon feedstock stream. Further, unless

indicated otherwise, either explicitly or by context, within the present specification, the term "heteroatom containing organic compounds" does not include the extraction solvent, demixing solvent and/or washing solvent as defined in the
5 present specification.

Additionally, the liquid hydrocarbon feedstock stream may comprise salts. Said salts may comprise organic and/or inorganic salts. The salts may comprise ammonium, an alkali metal, an alkaline earth metal or a transition metal as the
10 cation and a carboxylate, sulphate, phosphate or a halide as the anion.

Preferably, at least part of the components in the liquid hydrocarbon feedstock stream, which comprises aliphatic hydrocarbons, heteroatom containing organic compounds and
15 optionally aromatic hydrocarbons, are synthetic compounds, and not natural compounds as present in for example fossil oil. For example, such synthetic compounds include compounds originating from the pyrolysis of plastics synthesized from biomass, for example polyethylene synthesized from bio-
20 ethanol through dehydration of the ethanol and subsequent polymerization of the ethylene thus formed.

Further, since in the present process heteroatom containing organic compounds are easily removed, the feed to the present process can advantageously tolerate a relatively
25 high amount of such heteroatom containing organic compounds. Thus, waste plastic that may be pyrolyzed to produce a feed to the present process may comprise heteroatom-containing plastics, such as polyvinyl chloride (PVC), polyethylene terephthalate (PET) and polyurethane (PU). In specific, mixed
30 waste plastic may be pyrolyzed that in addition to heteroatom-free plastics, such as polyethylene (PE) and polypropylene (PP), contains a relatively high amount of such heteroatom-containing plastics.

Step a) - Extraction with extraction solvent a)

In step a) of the present process, at least part of the liquid hydrocarbon feedstock stream, comprising aliphatic hydrocarbons, heteroatom containing organic compounds and optionally aromatic hydrocarbons, is contacted with an extraction solvent a) which contains one or more heteroatoms, and the liquid hydrocarbon feedstock stream is subjected to liquid-liquid extraction with the extraction solvent a), resulting in a first stream comprising aliphatic hydrocarbons and a second stream comprising extraction solvent a), heteroatom containing organic compounds and optionally aromatic hydrocarbons.

In step a) of the present process, the liquid hydrocarbon feedstock stream may be fed to a first column (first extraction column). Further, a first solvent stream which comprises the extraction solvent a) may be fed to the first column at a position which is higher than the position at which the liquid hydrocarbon feedstock stream is fed, thereby enabling a counterflow liquid-liquid extraction and resulting in a top stream from the first column (above "first stream") comprising aliphatic hydrocarbons and a bottom stream from the first column (above "second stream") comprising extraction solvent a), heteroatom containing organic compounds and optionally aromatic hydrocarbons.

In step a), the weight ratio of the extraction solvent a) to the liquid hydrocarbon feedstock stream may be at least 0.05:1 or at least 0.2:1 or at least 0.5:1 or at least 1:1 or at least 2:1 or at least 3:1 and may be at most 5:1 or at most 3:1 or at most 2:1 or at most 1:1. Further, the temperature in step a) may be at least 0 °C or at least 20 °C or at least 30 °C or at least 40 °C or at least 50 °C and may be at most 200 °C or at most 150 °C or at most 100 °C or at most 70 °C or at most 60 °C or at most 50 °C or at most 40

°C. The pressure in step a) may be at least 100 mbara or at least 500 mbara or at least 1 bara or at least 1.5 bara or at least 2 bara and may be at most 50 bara or at most 30 bara or at most 20 bara or at most 15 bara or at most 10 bara or at most 5 bara or at most 3 bara or at most 2 bara or at most 1.5 bara. The temperature and pressure in step a) are preferably such that both the hydrocarbons from the feedstock stream and the extraction solvent a) are in the liquid state.

In step a), aliphatic hydrocarbons are recovered by liquid-liquid extraction of heteroatom containing organic compounds and optionally aromatic hydrocarbons with extraction solvent a). Further, preferably, the recovered aliphatic hydrocarbons comprise aliphatic hydrocarbons having a boiling point of from 30 to 300 °C and aliphatic hydrocarbons having a boiling point of from greater than 300 to 600 °C in a weight ratio of from 99:1 to 1:99. The above description of the weight ratio of aliphatic hydrocarbons having a boiling point of from 30 to 300 °C to aliphatic hydrocarbons having a boiling point of from greater than 300 to 600 °C in relation to aliphatic hydrocarbons in the liquid hydrocarbon feedstock stream also applies to the recovered aliphatic hydrocarbons.

In step a), said liquid-liquid extraction results in a first stream comprising aliphatic hydrocarbons and a second stream comprising extraction solvent a), heteroatom containing organic compounds and optionally aromatic hydrocarbons. Within the present specification, the former stream (first stream) comprising recovered aliphatic hydrocarbons may also be referred to as a "raffinate stream" and the latter stream (second stream) may also be referred to as an "extract stream". Such raffinate stream has a reduced content of aromatic hydrocarbons, conjugated aliphatic compounds having two or more carbon-carbon double bonds, and

heteroatom containing organic compounds. Such raffinate stream comprises no or at most 10 wt.% or at most 5 wt.% or at most 1 wt.% or substantially no aromatic hydrocarbons. Further, such raffinate stream comprises no or at most 15 wt.% or at most 10 wt.% or at most 5 wt.% or at most 1 wt.% or substantially no conjugated aliphatic compounds having two or more carbon-carbon double bonds. Further, such raffinate stream comprises no or at most 1 wt.% or substantially no heteroatom containing organic compounds.

10 The extraction solvent a) used in step a) of the present process, which may be fed as a first solvent stream to a first column in step a), preferably has a density which is at least 3% or at least 5% or at least 8% or at least 10% or at least 15% or at least 20% higher than the density of the liquid hydrocarbon feedstock stream. Further, said density
15 may be at most 50% or at most 40% or at most 35% or at most 30% higher than the density of the liquid hydrocarbon feedstock stream.

 Further, the extraction solvent a) used in step a)
20 contains one or more heteroatoms, which may be oxygen, nitrogen and/or sulfur. Still further, it is preferred that said extraction solvent a) is thermally stable at a temperature of 200 °C. Still further, said extraction solvent a) may have a boiling point which is at least 50 °C or at
25 least 80 °C or at least 100 °C or at least 120 °C and at most 300 °C or at most 200 °C or at most 150 °C. Still further, it is preferred that said extraction solvent a) has no or a relatively low miscibility in heptane. Preferably, extraction solvent a) has such miscibility in heptane that at most 30
30 wt.% or at most 20 wt.% or at most 10 wt.% or at most 3 wt.% or at most 1 wt.% of extraction solvent a), based on weight of heptane, is miscible in heptane. The miscibility of a certain compound in another compound, such as heptane, may be

determined by any general method known to a skilled person in the art, including ASTM method D1476. Where in the present specification reference is made to the miscibility of a compound in another compound, this means miscibility at 25 °C.

Further, the extraction solvent a) in step a) may have a Hansen solubility parameter distance $R_{a,heptane}$ with respect to heptane as determined at 25 °C of at least 3 MPa^{1/2}, preferably at least 5 MPa^{1/2}, more preferably at least 10 MPa^{1/2}, more preferably at least 15 MPa^{1/2}. Further, said $R_{a,heptane}$ for extraction solvent a) may be lower than 45 MPa^{1/2} or at most 40 MPa^{1/2}, preferably at most 35 MPa^{1/2}, more preferably at most 30 MPa^{1/2}, more preferably at most 25 MPa^{1/2}. For example, said $R_{a,heptane}$ for N-methylpyrrolidone (NMP) is 15 MPa^{1/2}.

Still further, said extraction solvent a) may have a difference in Hansen solubility parameter distance $R_{a,heptane}$ with respect to heptane compared to Hansen solubility parameter distance $R_{a,toluene}$ with respect to toluene (i.e. $R_{a,heptane} - R_{a,toluene}$) as determined at 25 °C of at least 1.5 MPa^{1/2}, preferably at least 2 MPa^{1/2}. Further, said difference in $R_{a,heptane}$ compared to $R_{a,toluene}$ for extraction solvent a) may be at most 4.5 MPa^{1/2}, preferably at most 4 MPa^{1/2}.

Hansen solubility parameters (HSP) can be used as a means for predicting the likeliness of one component compared to another component. More specifically, each component is characterized by three Hansen parameters, each generally expressed in MPa^{0.5}: δ_d , denoting the energy from dispersion forces between molecules; δ_p , denoting the energy from dipolar intermolecular forces between molecules; and δ_h , denoting the energy from hydrogen bonds between molecules. The affinity between compounds can be described using a multidimensional vector that quantifies these solvent atomic

and molecular interactions, as a Hansen solubility parameter (HSP) distance R_a which is defined in Equation (1):

$$(R_a)^2 = 4(\delta_{d2} - \delta_{d1})^2 + (\delta_{p2} - \delta_{p1})^2 + (\delta_{h2} - \delta_{h1})^2 \quad (1)$$

wherein

5 R_a = distance in HSP space between compound 1 and compound 2 ($\text{MPa}^{0.5}$)

δ_{d1} , δ_{p1} , δ_{h1} = Hansen (or equivalent) parameter for compound 1 (in $\text{MPa}^{0.5}$)

10 δ_{d2} , δ_{p2} , δ_{h2} = Hansen (or equivalent) parameter for compound 2 (in $\text{MPa}^{0.5}$)

Thus, the smaller the value for R_a for a given solvent calculated with respect to the compound to be recovered (i.e., the compound to be recovered being compound 1 and the solvent being compound 2, or vice versa), the higher the affinity of this solvent for the compound to be recovered will be.

Hansen solubility parameters for numerous solvents can be found in, among others, *CRC Handbook of Solubility Parameters and Other Cohesion Parameters, Second Edition* by Allan F.M. Barton, CRC press 1991; *Hansen Solubility Parameters: A User's Handbook* by Charles M. Hansen, CRC press 2007.

In specific, the extraction solvent a) used in step a) of the present process may comprise ammonia or, preferably, one or more organic solvents selected from the group consisting of diols and triols, including monoethylene glycol (MEG), 25 monopropylene glycol (MPG), any isomer of butanediol and glycerol; glycol ethers, including oligoethylene glycols, including diethylene glycol, triethylene glycol and tetraethylene glycol, and monoalkyl ethers thereof, including diethylene glycol ethyl ether; amides, including N- 30 alkylpyrrolidone, wherein the alkyl group may contain 1 to 8 or 1 to 3 carbon atoms, including N-methylpyrrolidone (NMP), formamide and di- and monoalkyl formamides and acetamides,

wherein the alkyl group may contain 1 to 8 or 1 to 3 carbon atoms, including dimethyl formamide (DMF), methyl formamide and dimethyl acetamide; dialkylsulfoxide, wherein the alkyl group may contain 1 to 8 or 1 to 3 carbon atoms, including dimethylsulfoxide (DMSO); sulfones, including sulfolane; N-formyl morpholine (NFM); furan ring containing components and derivatives thereof, including furfural, 2-methyl-furan, furfuryl alcohol and tetrahydrofurfuryl alcohol; hydroxy esters, including lactates, including methyl and ethyl lactate; trialkyl phosphates, including triethyl phosphate; phenolic compounds, including phenol and guaiacol; benzyl alcoholic compounds, including benzyl alcohol; aminic compounds, including ethylenediamine, monoethanolamine, diethanolamine and triethanolamine; nitrile compounds, including acetonitrile and propionitrile; trioxane compounds, including 1,3,5-trioxane; carbonate compounds, including propylene carbonate and glycerol carbonate; and cycloalkanone compounds, including dihydrolevoglucosenone.

More preferably, said extraction solvent a) comprises one or more of above-mentioned dialkylsulfoxide, in specific DMSO; sulfones, in specific sulfolane; above-mentioned N-alkylpyrrolidone, in specific NMP; and a furan ring containing component, in specific furfural. Even more preferably, said extraction solvent a) comprises one or more of above-mentioned N-alkylpyrrolidone, in specific NMP, and a furan ring containing component, in specific furfural. Most preferably, extraction solvent a) comprises NMP.

An aqueous solution of a quaternary ammonium salt, in specific trioctyl methyl ammonium chloride or methyl tributyl ammonium chloride, may also be used as the extraction solvent a) in step a).

In addition to extraction solvent a), a washing solvent, such as water, may also be added to step a). This washing

solvent is herein referred to as washing solvent c) and is further described below. In such case, step a) preferably results in a first stream comprising aliphatic hydrocarbons and a second stream comprising washing solvent c), extraction solvent a), heteroatom containing organic compounds and optionally aromatic hydrocarbons. Thus, advantageously, said washing solvent c) as added in step a), functions as an extraction solvent extracting extraction solvent a) and thereby making it possible that no or substantially no extraction solvent a) ends up in the first stream resulting from step a) and comprising recovered aliphatic hydrocarbons. In case washing solvent c) is also added to step a), the weight ratio of extraction solvent a) to washing solvent c) in step a) may be at least 0.5:1 or at least 1:1 or at least 2:1 or at least 3:1 and may be at most 30:1 or at most 25:1 or at most 20:1 or at most 15:1 or at most 10:1 or at most 5:1 or at most 3:1 or at most 2:1.

In case washing solvent c) is also added to step a), a second solvent stream which comprises washing solvent c) may be fed to the above-mentioned first column (first extraction column) at a position which is higher than the position at which the above-mentioned first solvent stream which comprises the extraction solvent a) is fed, thereby enabling a counterflow liquid-liquid extraction and resulting in a top stream from the first column (above "first stream") comprising aliphatic hydrocarbons and a bottom stream from the first column (above "second stream") comprising washing solvent c), extraction solvent a), heteroatom containing organic compounds and optionally aromatic hydrocarbons. In the above case, the first solvent stream in extraction step a) may comprise demixing solvent b), such as water, and/or above-mentioned optional washing solvent c) in addition to extraction solvent a). Demixing solvent b) is also further

described below. Said demixing solvent b) and washing solvent c) may originate from one or more recycle streams after step c) of the present process.

In case washing solvent c) is also added to step a), it
5 is preferred that the stream comprising washing solvent c) to be added comprises no or substantially no heteroatom containing organic compounds originating from the liquid hydrocarbon feedstock stream. This preference applies especially in a case where said stream is fed to the first
10 extraction column at a relatively high position, as described above, where these heteroatom containing organic compounds could re-contaminate the raffinate (top) stream resulting from step a). Advantageously, in the present invention, at least part of the demixing solvent b) containing stream
15 resulting from step c) or at least part of the demixing solvent b) containing treated stream resulting from sorption step (ii), which may contain no or substantially no heteroatom containing organic compounds, may be used as such washing solvent c) stream for feeding (recycling) to step a),
20 especially in case demixing solvent b) is identical to washing solvent c), especially water.

As mentioned above, the second stream resulting from step a), which stream for the above-mentioned first (extraction) column corresponds with the bottom stream from such column,
25 comprises extraction solvent a), heteroatom containing organic compounds and optionally aromatic hydrocarbons. Said stream may additionally comprise salts and/or conjugated aliphatic compounds having two or more carbon-carbon double bonds in a case wherein such salts and/or compounds are
30 present in the liquid hydrocarbon feedstock stream.

In the present invention, extraction solvent a) is recovered from the second stream resulting from step a) and

then advantageously recycled to step a), through steps b), c) and d) of the present process.

Step b) - Demixing with demixing solvent b)

In step b) of the present process, at least part of the
5 second stream resulting from step a), comprising extraction
solvent a), heteroatom containing organic compounds and
optionally aromatic hydrocarbons, is mixed with a demixing
solvent b) which contains one or more heteroatoms and has a
miscibility in heptane which is lower than the miscibility of
10 extraction solvent a) in heptane, and the resulting mixture
is separated into a first stream comprising heteroatom
containing organic compounds and optionally aromatic
hydrocarbons and a second stream comprising extraction
solvent a), demixing solvent b), heteroatom containing
15 organic compounds and optionally aromatic hydrocarbons.
Depending on the partition coefficient, a certain amount of
heteroatom containing organic compounds and any aromatic
hydrocarbons also ends up in said second stream, wherein the
first stream is more hydrophobic than the second stream.
20 Thus, said second stream additionally comprises heteroatom
containing organic compounds and optionally aromatic
hydrocarbons.

The demixing solvent b) used in step b) contains one or
more heteroatoms, which may be oxygen, nitrogen and/or
25 sulfur. Still further, it is preferred that just like
extraction solvent a), said demixing solvent b) has no or a
relatively low miscibility in heptane. Preferably, demixing
solvent b) has such miscibility in heptane that at most 10
wt.% or at most 3 wt.% or at most 1 wt.% or at most 0.5 wt.%
30 or at most 0.1 wt.% of demixing solvent b), based on weight
of heptane, is miscible in heptane. In the present invention,
the miscibility of demixing solvent b) in heptane is lower
than the miscibility of extraction solvent a) in heptane. The

miscibility of said solvents a) and b) in heptane may be determined by any general method known to a skilled person in the art, including above-mentioned ASTM method D1476.

Further, suitably, demixing solvent b) is miscible in
5 extraction solvent a). This implies that up to 50 wt.% of demixing solvent b), based on total amount of demixing solvent b) and extraction solvent a), can be mixed in extraction solvent a).

Further, the demixing solvent b) in step b) may have a
10 Hansen solubility parameter distance $R_{a, \text{heptane}}$ with respect to heptane as determined at 25 °C of at least 10 MPa^{1/2}, preferably at least 20 MPa^{1/2}, more preferably at least 30 MPa^{1/2}, more preferably at least 40 MPa^{1/2}. Further, said $R_{a, \text{heptane}}$ for demixing solvent b) may be at most 55 MPa^{1/2}, more
15 preferably at most 50 MPa^{1/2}, more preferably at most 45 MPa^{1/2}. For example, said $R_{a, \text{heptane}}$ for water is 45 MPa^{1/2}.

As mentioned above, the miscibilities, in heptane, of extraction solvent a) and demixing solvent b) are different. Hence, said solvents a) and b) are not identical. In
20 specific, demixing solvent b) may have a Hansen solubility parameter distance $R_{a, \text{heptane}}$ with respect to heptane as determined at 25 °C which is greater than such $R_{a, \text{heptane}}$ for extraction solvent a). Preferably, said difference in $R_{a, \text{heptane}}$ for solvents a) and b) is at least 1 MPa^{1/2}, more preferably
25 at least 5 MPa^{1/2}, more preferably at least 10 MPa^{1/2}, more preferably at least 15 MPa^{1/2}, more preferably at least 20 MPa^{1/2}, more preferably at least 25 MPa^{1/2}. Further, preferably, said difference in $R_{a, \text{heptane}}$ for solvents a) and b) is at most 55 MPa^{1/2}, more preferably at most 50 MPa^{1/2}, more
30 preferably at most 45 MPa^{1/2}, more preferably at most 40 MPa^{1/2}, more preferably at most 35 MPa^{1/2}, more preferably at most 30 MPa^{1/2}.

In specific, the demixing solvent b) used in step b) of the present process may comprise one or more solvents selected from the group consisting of water and the solvents from the group of solvents as defined hereinabove for
5 extraction solvent a). Preferably, said demixing solvent b) comprises one or more of water and above-mentioned diols and triols, in specific monoethylene glycol (MEG) and glycerol. More preferably, demixing solvent b) comprises water, most preferably consists of water. Other preferences and
10 embodiments as described above with reference to the extraction solvent a) used in step a) also apply to demixing solvent b), with the exception that demixing solvent b) is not identical to extraction solvent a), as it has a lower miscibility in heptane, and that demixing solvent b) may
15 comprise and preferably comprises water.

Further, the second stream resulting from step b) may additionally comprise salts. Any conjugated aliphatic compounds having two or more carbon-carbon double bonds may end up in the first or second stream resulting from step b),
20 together with heteroatom containing organic compounds and optionally aromatic hydrocarbons. Generally, in the present invention, said conjugated aliphatic compounds may behave similarly as aromatic compounds so that these may end up in the same stream or streams as the optional aromatic
25 hydrocarbons.

In step b), demixing solvent b) is added, separately from the second stream resulting from step a), and in addition to any demixing solvent b) that may be present in the latter stream, and mixed with the latter stream. In step b), at
30 least part of a second stream comprising washing solvent c), such as water, and extraction solvent a), resulting from the below-described optional, additional extraction step wherein at least part of the first stream resulting from step a),

wherein said first stream comprises recovered aliphatic hydrocarbons and extraction solvent a), is subjected to liquid-liquid extraction with a washing solvent c), may be added to provide for said demixing solvent b) that needs to be added in step b).

The mixing in step b) may be performed in any way known to a skilled person. For example, a mixer may be used upstream of a phase separation apparatus as described below. Further, for example, in-line (or static) mixing may be performed upstream of such phase separation apparatus. Still further, mixing may be effected in a column as described below.

Through such addition of demixing solvent b) and mixing in step b), different phases are formed including a more hydrophobic, first phase and a less hydrophobic, second phase comprising extraction solvent a), demixing solvent b), heteroatom containing organic compounds and optionally aromatic hydrocarbons, which phases are separated in step b) into said first stream and second stream, respectively. Thus, advantageously, said demixing solvent b) as added in step b) separately from the second stream resulting from step a), functions as a so-called "demixer" (or "antisolvent"), thereby removing the more hydrophobic compounds from the extraction solvent a) to be recovered and recycled.

The phase separation in step b) may be performed by any apparatus capable of separating two phases, including a decanter, a flotation device, a coalescer and a centrifuge, suitably a decanter. It is preferred that the phase separation in step b) is carried out in a single stage, for example in a decanter, a flotation device, a coalescer or a centrifuge. For example, when using a decanter in step b), a first, upper phase comprising more hydrophobic compounds and a second, lower phase comprising extraction solvent a),

demixing solvent b) and less hydrophobic compounds (i.e. less hydrophobic than compounds in said first phase) may be separated into said first stream and second stream, respectively.

5 Further, step b) may be carried out in a column comprising multiple separation stages. In the latter case, step b) comprises mixing at least part of the second stream resulting from step a), respectively, with demixing solvent b) in the column and separating the resulting mixture into
10 the above-mentioned first stream and second stream, suitably resulting in a top stream from the column (above "first stream") and a bottom stream from the column (above "second stream"). Preferably, said demixing solvent b) and the other, extraction solvent a) rich stream are fed co-currently to the
15 column, at the bottom thereof.

Internals in the above-mentioned column contribute to the mixing of the extraction solvent a) rich stream and the demixing solvent b). Such column internals are known in the art. The column internals may comprise a packing such as
20 Raschig rings, Pall rings, Lessing rings, Bialecki rings, Dixon rings; sieving plates; or a random structured packing, among others, as described in Perry's Chemical Engineer's Handbook. Furthermore, the column may be provided with stirring means. For example, a shaft may run along the column
25 and may be provided with rotors and stators fixed to the column.

Further, the above description of temperature and pressure in extraction step a) also applies to step b). Still further, in step b), the weight ratio of the demixing solvent
30 b) to the extraction solvent a), based on the amount of extraction solvent a) in the second stream resulting from step a), may be at least 0.005:1 or at least 0.01:1 or at least 0.5:1 or at least 1:1 or at least 2:1 and may be at

most 10:1 or at most 7:1 or at most 5:1 or at most 4:1 or at most 2:1. Suitably, the amount of demixing solvent b) added in step b), based on total amount of (i) said amount of demixing solvent b) and (ii) the amount of extraction solvent a) in the second stream resulting from step a), may be of from 0.1 to 45 wt.%, more suitably of from 1 to 40 wt.%, more suitably of from 5 to 35 wt.%, more suitably of from 10 to 30 wt.%.

Thus, advantageously, in step b) part of the heteroatom containing organic compounds and optional aromatic hydrocarbons are removed from the extraction solvent a) to be recycled, so that there is no need to separate the extraction solvent a) from such removed compounds in a later step, for example by means of distillation which is cumbersome and energy consuming. Further, advantageously, any aromatic hydrocarbons and conjugated aliphatic compounds having two or more carbon-carbon double bonds removed in step b) may be blended with pygas and processed into fuel or used in the production of aromatic compounds. Likewise, the heteroatom containing organic compounds removed in step b) may also be converted into fuel, optionally after a hydrotreatment to remove the heteroatoms. Further, said compounds removed in step b) may be further separated into various fractions which may be used as solvents.

25 Step c) - Separation of extraction solvent a) and demixing solvent b)

In step c) of the present process, at least part of the second stream resulting from step b), and comprising extraction solvent a) and demixing solvent b), is separated into a first stream comprising demixing solvent b) and a second stream comprising extraction solvent a). In case the below-described optional washing solvent c) is used in the present invention, which washing solvent c) may be identical

to or different from, preferably identical to, demixing solvent b), such washing solvent c) may end up in said second stream resulting from step b) and subsequently in said first stream resulting from step c).

5 Thus, a feed stream to step c) comprises at least part of the second stream resulting from step b). In step c), demixing solvent b) and extraction solvent a) may be separated from each other in any known way, preferably by evaporation, for example through distillation. The latter
10 separation may be performed in a distillation column. Advantageously, in distillation, at least part of any heteroatom containing organic compounds and aromatic hydrocarbons in the feed stream to step c) is removed azeotropically with the demixing solvent b), especially
15 water.

 Thus, it is preferred that step c) comprises separating at least part of the second stream resulting from step b), by distillation into a top stream comprising demixing solvent b) and a bottom stream comprising extraction solvent a). In a
20 case wherein the feed stream to step c) additionally comprises heteroatom containing organic compounds and optionally aromatic hydrocarbons, said top stream additionally comprises such compounds.

 Further, in a case wherein the feed stream to step c)
25 additionally comprises salts, the second stream resulting from step c) additionally comprises such salts. If the feed stream to step c) or the second stream resulting from step c) contains any solid salts, they may be removed therefrom by any method, including filtering.

30 In the present invention, the amount of demixing solvent b) in the feed stream to step c) may be at least 10 wt.% or at least 20 wt.% and may be at most 70 wt.% or at most 50 wt.% or at most 40 wt.%. The second stream resulting from

step c) may still comprise demixing solvent b), for example in an amount of at most 10 wt.% or at most 5 wt.% or at most 3 wt.% or at most 1 wt.%. Advantageously, in case the amount of demixing solvent b) in said second stream is relatively
5 low, for example up to 5 wt.%, such demixing solvent b) does not need to be removed before extraction solvent a) from said same stream is recycled to step a) of the present process.

As mentioned above, in a case wherein the feed stream to the above-mentioned distillation step, as step c) in the
10 present process, comprises heteroatom containing organic compounds and optionally aromatic hydrocarbons in addition to extraction solvent a) and demixing solvent b), the top stream resulting from the distillation step comprises demixing solvent b), heteroatom containing organic compounds and
15 optionally aromatic hydrocarbons. For, advantageously, in distillation, at least part of said heteroatom containing organic compounds and aromatic hydrocarbons is removed azeotropically with the demixing solvent b), especially water. In the latter case, said top stream may be separated
20 into two phases, one phase comprising demixing solvent b) and another phase comprising heteroatom containing organic compounds and optionally aromatic hydrocarbons. Such phase separation may be performed by any apparatus capable of separating two phases, including a decanter, a flotation
25 device, a coalescer and a centrifuge, suitably a decanter. Advantageously, demixing solvent b) from such separated phase comprising demixing solvent b) may be recycled as further described below, whereas the other phase may be bled from the process thereby reducing the risk of any build-up of
30 heteroatom containing organic compounds and aromatic hydrocarbons in the present process.

Sorption steps (i) and (ii)

In the present invention, advantageously, a sorption agent is used in steps (i) and (ii) to remove heteroatom containing organic compounds and optionally aromatic hydrocarbons, which are not completely removed in step b) but which are entrained in the second stream resulting from step b) which comprises extraction solvent a) and demixing solvent b) to be separated from each other in subsequent step c). By such sorption, advantageously, a build-up of these contaminants in the recycle stream(s) in the present process is avoided.

It is envisaged that the removal of heteroatom containing organic compounds and optionally aromatic hydrocarbons by the above-mentioned sorption is applied in the present process in either or both of the following steps:

(i) before step c): contacting at least part of the second stream resulting from step b), which stream comprises extraction solvent a), demixing solvent b), heteroatom containing organic compounds and optionally aromatic hydrocarbons, with a sorption agent; and/or

(ii) after step c): contacting at least part of the first stream resulting from step c), wherein that stream comprises demixing solvent b), heteroatom containing organic compounds and optionally aromatic hydrocarbons, with a sorption agent.

Further, sorption step (ii) is performed before any recycle of at least part of the demixing solvent b) from the first stream resulting from step c), as for example in optional recycle step e). Further, step (ii) is preferably performed before any recycle of at least part of the first stream resulting from step c) to step c).

In this way, at least part of the contaminants will advantageously be concentrated into the sorption agent(s) as used in such sorption step(s), thereby preventing a build-up of such contaminants in the recycle stream(s) in the present

process. Thus, the sorption agent retains contaminants, which sorption agent may eventually be regenerated or be removed from the process and replaced by fresh sorption agent, thereby avoiding the risk of a build-up of heteroatom
5 containing organic compounds and aromatic hydrocarbons in the present process.

The treated streams resulting from sorption steps (i) and (ii) preferably comprise no or substantially no heteroatom containing organic compounds and aromatic hydrocarbons.

10 In case of sorption step (i), at least part of the treated stream resulting from sorption step (i) and comprising demixing solvent b) and extraction solvent a) may be fed to step c) wherein it is separated into a first stream comprising demixing solvent b) and a second stream comprising
15 extraction solvent a). At least part of the extraction solvent a) from the second stream resulting from step c) is recycled as further described below. Advantageously, there is no need to separate heteroatom containing organic compounds and aromatic hydrocarbons from said first stream, as the
20 major part of these contaminants has already been removed in sorption step (i). Consequently, at least part of the demixing solvent b) from said first stream may be recycled as further described below.

Further, in case of sorption step (ii), at least part of
25 the demixing solvent b) from the treated stream resulting from sorption step (ii) may be recycled as further described below. As mentioned above, in step c), extraction solvent a) and demixing solvent b) may be separated from each other by distillation, wherein at least part of any heteroatom
30 containing organic compounds and aromatic hydrocarbons in the feed stream to step c) is removed azeotropically with the demixing solvent b). Generally, the relative amount of demixing solvent b) in the top stream resulting from such

distillation is relatively high as compared to the amount of the contaminants, comprising said heteroatom containing organic compounds and optional aromatic hydrocarbons, so that it may be cumbersome to remove these contaminants by phase separation whereby such contaminants less readily form a separate phase upon condensation. Such cumbersome phase formation and separation may advantageously be prevented in the present invention through performing above-described sorption steps (i) and/or (ii).

10 In the present specification, sorption means a process in which one substance (the sorption agent) takes up or holds another substance by absorption, adsorption or a combination of both. Preferably, the sorption agent used in the present invention is a sorption agent, which preferentially sorbs
15 heteroatom containing organic compounds and optionally aromatic hydrocarbons. In specific, it is preferred that heteroatom containing organic compounds and optionally aromatic hydrocarbons are preferentially sorbed as compared to the extraction solvent, demixing solvent and/or washing
20 solvent as defined in the present specification. In this way, the quality of an extraction solvent a) recycle stream, any demixing solvent b) recycle stream and/or any washing solvent c) recycle stream may advantageously be increased in the present process.

25 Suitably, the sorption agent separates heteroatom containing organic compounds and optional aromatic hydrocarbons by affinity. Further, the sorption agent may have a relatively low polarity.

In the present invention, the heteroatom containing
30 organic compounds and optional aromatic hydrocarbons to be removed may be relatively large molecules as compared to the extraction solvent a), demixing solvent b) and optional washing solvent c). In the present invention, a suitable

sorption agent has preferably pore diameters that are large enough to partially or fully sorb heteroatom containing organic compounds and optional aromatic hydrocarbons.

Sorption agents for use in steps (i) and (ii) of the present process suitably have a porous structure comprised of micro-, meso- or macropores or a combination thereof. According to IUPAC notation, microporous structures have pore diameters of less than 2 nm (20 Å, angstroms), mesoporous structures have pore diameters between 2 and 50 nm (20-500 Å), and macroporous structures have pore diameters greater than 50 nm (500 Å).

Sorption agents which may suitably be used in steps (i) and (ii) are not limited to the specific materials listed in the present specification. In general, any material characterized by having a relatively high specific surface area, a porous structure comprising micro-, meso- or macropores or a combination thereof, from natural origin or synthetic, from a mineral or an organic source, with a treated or untreated surface, and in any form may be used in this invention. Said specific surface area may be in the range of from 1 to 3000 m²/g, preferably 50 to 2000 m²/g, more preferably 100 to 1000 m²/g. Said specific surface area may be at least 1 m²/g or at least 10 m²/g or at least 50 m²/g. Further, it may be at most 3000 m²/g or at most 1000 m²/g or at most 500 m²/g. Furthermore, suitable sorption agents for use in steps (i) and (ii) have a pore volume of at least 0.001 cm³/g or at least 0.01 cm³/g or at least 0.1 cm³/g, and at most 1 cm³/g or at most 3 cm³/g or at most 5 cm³/g or at most 10 cm³/g. Suitable sorption agents for use in steps (i) and (ii) may fulfill two from the above-mentioned characteristics, namely pore size and surface area, or pore size and pore volume, or surface area and pore volume. As mentioned above, a relatively high affinity of the

sorption agent for heteroatom containing organic compounds and optional aromatic hydrocarbons is preferred.

Sorption agents that may be conveniently used in steps (i) and (ii) of the process of the present invention may be
5 molecular sieves of inorganic origin, such as metal oxides wherein the metal is one or more of alkaline earth, transition and post-transition metals, such as Al, Si, Zn, Mg, Ti, Zr; or may be molecular sieves of organic origin, such as activated carbon, cross-linked and porous polymers,
10 carbonaceous materials; or may be hybrid molecular sieves, such as metal-organic frameworks. The sorption agent may be dispersed in a porous amorphous inorganic or organic matrix (also referred to as binder material), having channels and cavities therein that enable liquid access to the sorption
15 agent. Alternatively, the sorption agent may be used without a binder material.

Suitable sorption agents for this invention with predominant microporous structure are zeolites, porous glass, activated carbon, carbon char ("char" stands for "charcoal"),
20 clays such as bauxite, preferably activated clays, activated alumina, aerogels, graphene-based nanomaterials and single-wall or multi-wall carbon nanotubes. Suitable sorption agents for this invention with predominant mesoporous structure are ordered mesoporous carbon (OMC), mesoporous activated carbon,
25 mesoporous zeolites, activated alumina, silica gel and mesoporous silicas such as M-41-S, MAS-5, MCM-41, SBA-15, SBA-16, TUD-1, HMM-33, FSM-16, MSM-48. A suitable sorption agent for this invention with predominant macroporous structure is macroporous silica.

30 Sorption agents comprising carbon such as activated carbon and carbon char, as mentioned above, may consist mainly of carbon, for example, a substance comprising 80 to 100 wt.% of carbon, preferably 90 to 100 wt.% of carbon, more

preferably 95 to 100 wt.%, most preferably 98 to 100 wt.% of carbon, and highly preferably 99 to 100 wt.% of carbon.

A preferred activated carbon as sorption agent for removing heteroatom containing organic compounds and optionally aromatic hydrocarbons in steps (i) and (ii), especially in step (ii), has an iodine number in the range of from 500 to 1200 mg/g, and a molasses number in the range of from 95 to 1500, more preferably in the range of from 200 to 1500. "Iodine number" is a relative measure of pores at sizes of 10 to 28 Angstroms. It is reported in milligrams of elemental iodine sorbed per gram of granulated activated carbon and determines the area available on the activated carbon to sorb low molecular weight organic compounds. Iodine number may be determined according to ASTM D4607. "Molasses number" measures the degree to which an activated carbon removes color from a stock solution. It measures the pores greater than 28 Angstroms. These are the pores responsible for removing larger molecular weight organic compounds. In this case, the amount of sorbed molasses is quantified.

Furthermore, suitable activated carbons for this invention have a total specific surface area in the range of from 600 to 2000 m²/g and a total pore volume in the range of from 0.9 to 2.5 ml/g. Still further, a preferred activated carbon for this invention has a specific surface area above 100 m²/g and a pore volume above 0.5 ml/g, for pores larger than 20 Angstroms. These properties are advantageous in removing relatively large molecules comprising said heteroatom containing organic compounds and optional aromatic hydrocarbons to be removed in steps (i) and (ii).

Activated carbons and carbon chars, of which the surfaces are modified and/or functionalized, may also suitably be used in steps (i) and (ii). Suitable methods to produce functional properties on carbon material surfaces include oxidation by

liquid and gaseous oxidants, grafting of functional groups onto the material surfaces, physisorption of ligands, vapor deposition, and/or functional groups developed during carbon activation processes.

5 Zeolites are also suitable sorption agents for removing heteroatom containing organic compounds and optionally aromatic hydrocarbons in steps (i) and (ii). Zeolites can be produced in several aluminosilicate ring arrangements, and zeolites of any framework type may suitably be used in the
10 present invention. Exemplary zeolites for use in steps (i) and (ii) are faujasite-type such as 13X (sodium form of Zeolite X) or 10X and NaX, LTA-type such as pore-closed zeolite 4A and zeolite 4A, ZSM-type, and mixtures thereof. Preferably, zeolites for the removal of heteroatom containing
15 organic compounds in this invention have pores and/or surface cavities with a cross-sectional dimension greater than 5.6 Angstroms. Examples of such zeolites include MFI-types such as ZSM-5 and Pentasil Zeolite, Mordenite (MOR) types, zeolite L (LTL-type), FAU-types zeolites such as X and Y,
20 dealuminated zeolite Y, low sodium Ultrastable Y (USY), MTW-type such as ZSM-12, zeolite beta (BEA-type), and zeolite omega (MAZ-type). Furthermore, sorption agents with surface cavities with a cross-sectional size greater than 5.6 Angstroms, regardless of the dimensions of the pores, are
25 also suitable for sorbing heteroatom containing organic compounds. Examples of such sorption agents with such surface cavities are MWW-type zeolites such as MCM-22, PSH-3, SSZ-25, MCM-41, MCM-49 and MCM-56, IFR-type zeolites such as MCM-58, MEL-type zeolites such as ZSM-11, FER-type zeolites such as
30 ZSM-35, and clinoptilolite, ferrierite, stilbite, EU-1, NU-87, mordenite, faujasites, gmelinite, and cancrinite.

Preferred molecular sieve zeolite-based sorption agents suitable for use in steps (i) and (ii) of this invention,

have a relatively low polarity and low affinity for polar components, which may include the heteroatom containing organic compounds. The polarity of a molecular sieve zeolite is determined by its Si/Al ratio, a low ratio resulting in a high polarity and vice versa. A preferred sorption agent for this invention comprises a zeolite with a Si/Al ratio above 20. Such zeolites are relatively organophilic and may advantageously sorb compounds such as phenol. A suitable example of such preferred sorption agent is MCM-22 which has a Si/Al ratio of 30. Alternatively, a preferred sorption agent for this invention comprises a zeolite with a Si/Al ratio below 20 which has undergone a treatment, such as cation exchange or surface modification, to increase its affinity for the heteroatom containing organic compounds and/or aromatic compounds.

Further, molecular sieve zeolites suitable for use as sorption agent in steps (i) and (ii) may be modified by cation exchange. For instance, cationic sites can be filled with one or more metal cations selected from the metals of Groups I-A, I-B, II-B and II-A (IUPAC 1, 11, 12 and 2) of the Periodic Table of Elements by ion-exchange. Preferred metal cations for ion exchange include beryllium, lithium, sodium, magnesium, potassium, calcium, rubidium, strontium, cesium, barium, gold, copper, silver, zinc and cadmium.

Furthermore, sorption agents suitable for use in steps (i) and (ii) may be of the silicalite type, organosilicates or crystalline silica polymorph. Silicalite type sorption agents have a very high silica to alumina ratio (>1000). Silicalite type sorption agents are not zeolites because they lack ion exchange capacity. Organosilicates are synthesized from reaction systems essentially free of aluminum-containing reagents and which are either entirely free of framework AlO_4^- tetrahedra or contain no crystallographically

significant amounts thereof. Organosilicates may be made with a combination of alkali metal cations, preferably sodium, potassium or lithium, silica and tetraethylammonium (TEA) cations. Due to their organophilic character, silicalites
5 advantageously selectively sorb organic molecules, including heteroatom containing organic compounds and any aromatic hydrocarbons, from polar media such as water or a mixture of polar media and organic solvent.

Crystalline hybrid porous materials may also be used as
10 sorption agents in steps (i) and (ii). These may be characterized by a high porosity, a high surface area and a low density. There are two classes of hybrid porous materials: covalent organic frameworks (COF's) which consist purely of organic materials, and metal-organic frameworks
15 (MOF's) which consist of individual metal cations or clusters of cations mutually linked by polyfunctional organic molecules. Both types may suitably be used in the present invention.

Preferably, the sorption agent used in step (i) in the
20 present invention preferentially sorbs heteroatom containing organic compounds and optionally aromatic hydrocarbons and sorbs no or substantially no demixing solvent b) and extraction solvent a), thereby eventually increasing the quality of the demixing solvent b) recycle and extraction
25 solvent a) recycle streams. A preferred sorption agent in step (i) comprises a zeolite such as ZSM-12, a silicalite and/or MCM-22.

Preferably, the sorption agent used in step (ii) in the
present invention preferentially sorbs heteroatom containing
30 organic compounds and aromatic hydrocarbons and sorbs no or substantially no demixing solvent b), thereby eventually increasing the quality of the demixing solvent b) recycle

stream(s). A preferred sorption agent material in step (ii) comprises activated carbon.

Temperatures in steps (i) and (ii) may be in the range of from ambient temperature to about 160 °C, preferably of from 40 to 90 °C, more preferably of from 40 to 60 °C. In steps (i) and (ii) of this invention, pressure is not critical for the performance of the sorption agent and it can vary in the range of from atmospheric to 100 barg.

Heteroatom containing organic compounds and optionally aromatic hydrocarbons build up in sorbent material producing a "spent sorbent". As it is known in the art, eventually, it is required to replace or regenerate the sorbent. In either case, the corresponding vessel containing the spent sorbent is taken out of service. In case of regeneration, the spent sorbent is put in contact with a stream that does not contain heteroatom containing organic compounds and optionally aromatic hydrocarbons. Preferably, this stream is heated to facilitate the desorption of the heteroatom containing organic compounds and optionally aromatic hydrocarbons. The regeneration stream can be a gas, liquid or supercritical fluid. It can be inert such as nitrogen, or reactive such as hydrogen, oxygen and hydrogen peroxide. Depending on the regeneration method, regeneration temperatures are in the range of from 20 to 350 °C. Regeneration of the sorbent material can be carried out by stripping with a stream such as steam, or nitrogen, or by heating the sorbent in air to burn off the sorbed material. Alternatively, in case the sorbent material used in the invention cannot be fully regenerated, it must be discarded when its sorption capacity is reached.

Recycle steps

In step d) of the present process, at least part of the extraction solvent a) from the second stream resulting from step c) is recycled to step a).

The second stream resulting from step c) may additionally
5 comprise aromatic hydrocarbons and/or heteroatom containing organic compounds. In a case where a stream comprising extraction solvent a) to be recycled to step a) comprises a relatively high amount of such compounds, additional demixing solvent b) may be added to step b) so as to prevent any
10 build-up of these contaminants in such recycle stream to step a). Further, these contaminants may be removed before recycling extraction solvent a) to step a), by bleeding part of the stream comprising extraction solvent a) to be recycled to step a) wherein either such bleed stream may be discarded
15 or extraction solvent a) may be recovered from such bleed stream, for example by distillation thereof.

Further, in optional step e) of the present process, at least part of the demixing solvent b) from the first stream resulting from step c) is recycled to step b). In case
20 sorption step (ii) is performed in the present process, at least part of the demixing solvent b) from the treated stream resulting from sorption step (ii) may be recycled in step e) to step b).

The latter recycle to step b), in step e), is suitable in
25 a case wherein said first stream resulting from step c) or said treated stream resulting from sorption step (ii) still comprises a relatively high amount of heteroatom containing organic compounds and/or aromatic hydrocarbons originating from the liquid hydrocarbon feedstock stream. However, in a
30 case wherein such stream comprises no or substantially no or a relatively low amount of heteroatom containing organic compounds and/or aromatic hydrocarbons, which is advantageously enabled by the sorption step(s) in the present

process, it is preferred to recycle at least part of the demixing solvent b) from such stream to step a) in case a washing solvent c), such as water, is added to step a) as described above or to the below-described optional, additional extraction step wherein such washing solvent c) is added.

Separation of extraction solvent a) from raffinate stream

In a case wherein the stream comprising recovered aliphatic hydrocarbons resulting from the liquid-liquid extraction by the extraction solvent a) in step a) (raffinate stream) additionally comprises extraction solvent a), it is preferred that extraction solvent a) is separated from that stream which is the first stream resulting from step a), and is optionally recycled to step a). In this way, the recovered aliphatic hydrocarbons are advantageously separated from any extraction solvent a) in the above-mentioned raffinate stream, and the separated extraction solvent a) may advantageously be recycled to step a).

Extraction solvent a) may be separated from the above-mentioned first stream resulting from step a), wherein said stream comprises aliphatic hydrocarbons and extraction solvent a), in any way, including distillation, extraction, absorption and membrane separation.

In specific, in the above-mentioned case wherein the first stream resulting from step a) comprises aliphatic hydrocarbons and extraction solvent a), in an additional step, at least part of said first stream is contacted with a washing solvent c) and is subjected to liquid-liquid extraction with the washing solvent c), resulting in a first stream comprising aliphatic hydrocarbons and a second stream comprising washing solvent c) and extraction solvent a).

In the present invention, the optional washing solvent c) that may be used in the above-mentioned additional extraction

step or that may be separately added to step a) or that may be added together with extraction solvent a) in a stream to step a), may be identical to or different from, preferably identical to, demixing solvent b). The preferences and
5 embodiments as described above with reference to demixing solvent b) also apply to optional washing solvent c). Preferably, washing solvent c) comprises water, more preferably consists of water. Further, preferably, both demixing solvent b) and washing solvent c) comprise water,
10 more preferably consist of water.

In the above-mentioned additional step, the first stream resulting from step a) and comprising aliphatic hydrocarbons and extraction solvent a) may be fed to a second column (second extraction column). Further, a second solvent stream
15 which comprises washing solvent c) may be fed to the second column at a position which is higher than the position at which said first stream resulting from step a) is fed, thereby enabling a counterflow liquid-liquid extraction and resulting in a top stream from the second column (above
20 "first stream") comprising aliphatic hydrocarbons and a bottom stream from the second column (above "second stream") comprising washing solvent c) and extraction solvent a).

Thus, advantageously, said washing solvent c) as added in the above-mentioned additional step, functions as an
25 extraction solvent extracting extraction solvent a) thereby making it possible that advantageously no or substantially no extraction solvent a) ends up in the recovered aliphatic hydrocarbons. In the above-mentioned additional step, the weight ratio of extraction solvent a) to washing solvent c)
30 may be at least 0.5:1 or at least 1:1 or at least 2:1 or at least 3:1 and may be at most 30:1 or at most 25:1 or at most 20:1 or at most 15:1 or at most 10:1 or at most 5:1 or at most 3:1 or at most 2:1. Further, the above description of

temperature and pressure in extraction step a) also applies to the above-mentioned additional (extraction) step. In case the present process comprises the above-mentioned additional step, the first solvent stream in extraction step a) may
5 comprise demixing solvent b) in addition to extraction solvent a) in which case the bottom stream from the first extraction column additionally comprises demixing solvent b).

In the above-mentioned additional step wherein washing solvent c) is added, it is preferred that the stream
10 comprising washing solvent c) to be added comprises no or substantially no heteroatom containing organic compounds originating from the liquid hydrocarbon feedstock stream. This preference applies especially in a case where said stream is fed to the second extraction column at a relatively
15 high position, as described above, where these heteroatom containing organic compounds could re-contaminate the raffinate (top) stream. Advantageously, in the present invention, at least part of the first stream resulting from step c) and comprising demixing solvent b) and optionally
20 washing solvent c), and in case sorption step (ii) is performed in the present process, at least part of the treated stream resulting from sorption step (ii), which streams may contain no or substantially no heteroatom containing organic compounds originating from the liquid
25 hydrocarbon feedstock stream, may be used as such washing solvent c) stream for feeding (recycling) to said additional step, especially in case demixing solvent b) is identical to washing solvent c), especially water.

Further, at least part of the second stream comprising
30 washing solvent c) and extraction solvent a) resulting from the above-mentioned additional (extraction) step may be fed to step b) to provide for at least part of the demixing solvent b) that needs to be added in step b), especially in

case demixing solvent b) is identical to washing solvent c). Thus, advantageously, such washing solvent c) may function both as an extraction solvent extracting residual extraction solvent a) in said additional step and as a so-called
5 "demixer" (or "antisolvent") in step b), i.e. as demixing solvent b), as further discussed above.

In case a washing solvent other than water is fed to an extraction column for extracting extraction solvent a) used in step a), either in the above-mentioned additional step or
10 in step a) itself as described above, it may be preferred that in addition to such other solvent, water is fed to the extraction column at a position which is higher than the position at which that other solvent is fed. In this way, advantageously, the water fed at the higher position may
15 extract any washing solvent other than water away thereby preventing such other washing solvent from entering the (final) raffinate stream. Alternatively, the latter raffinate stream may be washed with water in a separate step.

Upstream and downstream integration

20 In the present invention, the liquid hydrocarbon feedstock stream may comprise at least part of a hydrocarbon product formed in a process comprising cracking of plastics, preferably waste plastics, more preferably mixed waste plastics, wherein at least part of the plastics comprises
25 heteroatom containing organic compounds.

Accordingly, the present invention also relates to a process for the recovery of aliphatic hydrocarbons from plastics, wherein at least part of the plastics comprises heteroatom containing organic compounds, said process
30 comprising the steps of:

(I) cracking the plastics and recovering a hydrocarbon product comprising aliphatic hydrocarbons, heteroatom

containing organic compounds and optionally aromatic hydrocarbons; and

(II) subjecting a liquid hydrocarbon feedstock stream, which comprises at least part of the hydrocarbon product
5 obtained in step (I), to the above-described process for the recovery of aliphatic hydrocarbons from a liquid hydrocarbon feedstock stream.

The preferences and embodiments as described above with reference to the present aliphatic hydrocarbons recovery
10 process as such also apply to step (II) of the present process for the recovery of aliphatic hydrocarbons from plastics. In above-mentioned step (I), the resulting hydrocarbon product may be either a liquid or a solid or wax. In the latter case, the solid or wax is first heated to make
15 it liquid, before subjecting it to the aliphatic hydrocarbons recovery process in step (II).

In the above-mentioned process, at least part of the plastics as fed to step (I) comprises heteroatom containing organic compounds, which plastics are preferably waste
20 plastics, more preferably mixed waste plastics. In said step (I), the cracking of the plastics may involve a thermal cracking process and/or a catalytic cracking process. The cracking temperature in step (I) may be of from 300 to 800 °C, suitably of from 400 to 800 °C, more suitably of from 400
25 to 700 °C, more suitably of from 500 to 600 °C. Further, any pressure may be applied, which pressure may be sub-atmospheric, atmospheric or super-atmospheric. Heat treatment in step (I) causes melting of the plastics and cracking of its molecules into smaller molecules. The cracking in step
30 (I) may be carried out as pyrolysis or as liquefaction. Both in pyrolysis and in liquefaction a continuous liquid phase is formed. In addition, in pyrolysis a discontinuous gas phase is formed that escapes the liquid phase and segregates into a

continuous gas phase. In liquefaction, there is no significant gas phase by applying a relatively high pressure.

Further, in step (I), subsequent condensation of a gas phase and/or cooling of a liquid phase provides a hydrocarbon
5 product, which may be either a liquid or a solid or wax, comprising aliphatic hydrocarbons, heteroatom containing organic compounds and optionally aromatic hydrocarbons, at least part of which is subjected to the above-described aliphatic hydrocarbons recovery process in step (II).

10 Above-described step (I) may be carried out in any known way, for example in a way as disclosed in above-mentioned WO2018069794 and in WO2017168165, the disclosures of which are herein incorporated by reference.

Advantageously, aliphatic hydrocarbons as recovered in
15 one of the above-described processes for the recovery of aliphatic hydrocarbons, which may comprise varying amounts of aliphatic hydrocarbons within a wide boiling point range, may be fed to a steam cracker without a further pre-treatment, such as treatment with hydrogen (hydrotreating or
20 hydroprocessing) as disclosed in above-mentioned WO2018069794. In addition to being used as a feed to a steam cracker, said recovered aliphatic hydrocarbons may also advantageously be fed to other refining processes including hydrocracking, isomerization, hydrotreating, thermal
25 catalytic cracking and fluid catalytic cracking. Further, in addition to being used as a feed to a steam cracker, said recovered aliphatic hydrocarbons may also advantageously be separated into different fractions which each may find a different application, such as diesel, marine fuel, solvent,
30 etc.

Accordingly, the present invention also relates to a process for steam cracking a hydrocarbon feed, wherein the hydrocarbon feed comprises aliphatic hydrocarbons as

recovered in one of the above-described processes for the recovery of aliphatic hydrocarbons. Further, accordingly, the present invention also relates to a process for steam cracking a hydrocarbon feed, comprising the steps of:

- 5 recovering aliphatic hydrocarbons from a liquid hydrocarbon feedstock stream in one of the above-described processes for the recovery of aliphatic hydrocarbons; and steam cracking a hydrocarbon feed which comprises aliphatic hydrocarbons as recovered in the preceding step. In the present
- 10 specification, said phrase "steam cracking a hydrocarbon feed which comprises aliphatic hydrocarbons as recovered in the preceding step" may mean "steam cracking a hydrocarbon feed which comprises at least part of the recovered aliphatic hydrocarbons". The hydrocarbon feed to the steam cracking
- 15 process may also comprise hydrocarbons from another source, other than the present processes for the recovery of aliphatic hydrocarbons. Such other source may be naphtha, hydrowax or a combination thereof.

- Advantageously, in a case wherein the liquid hydrocarbon
- 20 feedstock stream comprises aromatic hydrocarbons, especially polycyclic aromatics, heteroatom containing organic compounds, conjugated aliphatic compounds having two or more carbon-carbon double bonds, or a combination thereof, these have already been removed by the present aliphatic
- 25 hydrocarbons recovery process as described above before feeding recovered hydrocarbons to a steam cracking process. This is particularly advantageous in that said removed compounds, especially polycyclic aromatics, can no longer cause fouling in the preheat, convection and radiant sections
- 30 of a steam cracker and in the downstream heat exchange and/or separation equipment for a steam cracker, for example in transfer line exchangers (TLEs) which are used to rapidly cool the effluent from a steam cracker. When hydrocarbons

condense, they may thermally decompose into a coke layer which may cause fouling. Such fouling is a major factor determining the run length of the cracker. Reducing the amount of fouling results in longer run times without
5 maintenance shutdowns, and improved heat transfer in the exchangers.

The steam cracking may be performed in any known way. The hydrocarbon feed is typically preheated. The feed can be heated using heat exchangers, a furnace or any other
10 combination of heat transfer and/or heating devices. The feed is steam cracked in a cracking zone under cracking conditions to produce at least olefins (including ethylene) and hydrogen. The cracking zone may comprise any cracking system known in the art that is suitable for cracking the feed. The
15 cracking zone may comprise one or more furnaces, each dedicated for a specific feed or fraction of the feed.

The cracking is performed at elevated temperatures, preferably in the range of from 650 to 1000 °C, more preferably of from 700 to 900 °C, most preferably of from 750
20 to 850 °C. Steam is usually added to the cracking zone, acting as a diluent to reduce the hydrocarbon partial pressure and thereby enhance the olefin yield. Steam also reduces the formation and deposition of carbonaceous material or coke in the cracking zone. The cracking occurs in the
25 absence of oxygen. The residence time at the cracking conditions is very short, typically in the order of milliseconds.

From the cracker, a cracker effluent is obtained that may comprise aromatics (as produced in the steam cracking
30 process), olefins, hydrogen, water, carbon dioxide and other hydrocarbon compounds. The specific products obtained depend on the composition of the feed, the hydrocarbon-to-steam ratio, and the cracking temperature and furnace residence

time. The cracked products from the steam cracker are then passed through one or more heat exchangers, often referred to as TLEs ("transfer line exchangers"), to rapidly reduce the temperature of the cracked products. The TLEs preferably cool
5 the cracked products to a temperature in the range of from 400 to 550 °C.

Figures

The present process for the recovery of aliphatic hydrocarbons from a liquid hydrocarbon feedstock stream is
10 further illustrated by Figures 1 and 2.

In the process of Figure 1, a liquid hydrocarbon feedstock stream 1, which comprises aliphatic hydrocarbons (including conjugated aliphatic compounds having two or more carbon-carbon double bonds, which are hereinafter referred to
15 as "dienes"), aromatic hydrocarbons and heteroatom containing organic compounds; a first solvent stream 2 which comprises an organic solvent (for example N-methylpyrrolidone) which is an extraction solvent a) in accordance with the present invention; and a second solvent stream 3 which comprises
20 water which is an optional washing solvent c) in accordance with the present invention, are fed to an extraction column 4. In column 4, liquid hydrocarbon feedstock stream 1 is contacted with first solvent stream 2 (organic solvent), thereby recovering aliphatic hydrocarbons by liquid-liquid
25 extraction of dienes, aromatic hydrocarbons and heteroatom containing organic compounds with the organic solvent. Further, the water in second solvent stream 3 removes organic solvent from the upper part of column 4 by liquid-liquid extraction of organic solvent with water. A stream 5
30 comprising recovered aliphatic hydrocarbons exits column 4 at the top. Further, a stream 6 comprising organic solvent, water, dienes, aromatic hydrocarbons and heteroatom containing organic compounds exits column 4 at the bottom.

Stream 6 and a stream 14 comprising additional water, which is a demixing solvent b) in accordance with the present invention, are combined, are combined, and the combined stream is fed to a decanter 13. In decanter 13, the combined stream is separated into a stream 15 comprising dienes, aromatic hydrocarbons and heteroatom containing organic compounds and a stream 16 comprising organic solvent, water, dienes, aromatic hydrocarbons and heteroatom containing organic compounds.

Further, in the process of Figure 1, stream 16 may be fed to a sorption unit 10 containing a sorption agent removing dienes, aromatic hydrocarbons and heteroatom containing organic compounds. Treated stream 11 from sorption unit 10 comprises organic solvent and water. Stream 16 or treated stream 11 is fed to a distillation column 7, where it is separated into a top stream 8 comprising water and a bottom stream 9 comprising organic solvent. In a case where stream 16 is fed to distillation column 7, top stream 8 additionally comprises dienes, aromatic hydrocarbons and heteroatom containing organic compounds and is fed to a sorption unit 12 containing a sorption agent removing dienes, aromatic hydrocarbons and heteroatom containing organic compounds. Treated stream 17 from sorption unit 12 comprises water, part of which water stream (stream 17a) is sent back to distillation column 7 as a reflux stream whereas the other part (stream 17b) may be recycled via water stream 14 and/or water stream 3. In a case where treated stream 11 is fed to distillation column 7, top stream 8 may be fed to sorption unit 12. If in the latter case, top stream 8 is not fed to sorption unit 12, part of top stream 8 (stream 17a) is sent back to distillation column 7 as a reflux stream whereas the other part (stream 17b) may be recycled via water stream 14

and/or water stream 3. Organic solvent from bottom stream 9 is recycled via organic solvent stream 2.

In the process of Figure 2, a liquid hydrocarbon feedstock stream 1, which comprises aliphatic hydrocarbons (including conjugated aliphatic compounds having two or more carbon-carbon double bonds, which are hereinafter referred to as "dienes"), aromatic hydrocarbons and heteroatom containing organic compounds; and a first solvent stream 2 which comprises an organic solvent (for example N-methylpyrrolidone) which is an extraction solvent a) in accordance with the present invention, are fed to a first extraction column 4a. In column 4a, liquid hydrocarbon feedstock stream 1 is contacted with first solvent stream 2 (organic solvent), thereby recovering aliphatic hydrocarbons by liquid-liquid extraction of dienes, aromatic hydrocarbons and heteroatom containing organic compounds with the organic solvent, resulting in a top stream 5a comprising recovered aliphatic hydrocarbons and organic solvent and a bottom stream 6 comprising organic solvent, dienes, aromatic hydrocarbons and heteroatom containing organic compounds. Stream 5a and a second solvent stream 3 which comprises water, which is an optional washing solvent c) in accordance with the present invention, are fed to a second extraction column 4b. In column 4b, stream 5a is contacted with second solvent stream 3 (water), thereby removing organic solvent by liquid-liquid extraction of organic solvent with water. A stream 5b comprising recovered aliphatic hydrocarbons exits column 4b at the top. Further, a stream 14 comprising organic solvent and water, which water is a demixing solvent b) in accordance with the present invention, exits column 4b at the bottom. Streams 6 and 14 are combined, and the combined stream is fed to a decanter 13. In respect of the treatment in decanter 13 and further, downstream treatments in the

process of Figure 2 reference is made to the above description of the corresponding treatments in the process of Figure 1.

C L A I M S

1. A process for the recovery of aliphatic hydrocarbons from a liquid hydrocarbon feedstock stream comprising aliphatic hydrocarbons, heteroatom containing organic compounds and optionally aromatic hydrocarbons, said process comprising the steps of:

a) contacting at least part of the liquid hydrocarbon feedstock stream with an extraction solvent a) which contains one or more heteroatoms and subjecting the liquid hydrocarbon feedstock stream to liquid-liquid extraction with the extraction solvent a), resulting in a first stream comprising aliphatic hydrocarbons and a second stream comprising extraction solvent a), heteroatom containing organic compounds and optionally aromatic hydrocarbons;

b) mixing at least part of the second stream resulting from step a) with a demixing solvent b) which contains one or more heteroatoms and has a miscibility in heptane which is lower than the miscibility of extraction solvent a) in heptane, and separating the resulting mixture into a first stream comprising heteroatom containing organic compounds and optionally aromatic hydrocarbons and a second stream comprising extraction solvent a), demixing solvent b), heteroatom containing organic compounds and optionally aromatic hydrocarbons;

c) separating at least part of the second stream resulting from step b) into a first stream comprising demixing solvent b), optionally heteroatom containing organic compounds and optionally aromatic hydrocarbons and a second stream comprising extraction solvent a);

d) recycling at least part of the extraction solvent a) from the second stream resulting from step c) to step a); and

e) optionally recycling at least part of the demixing solvent b) from the first stream resulting from step c) to step b),

wherein:

5 (i) before step c), heteroatom containing organic compounds and optionally aromatic hydrocarbons are removed from the second stream resulting from step b) by contacting at least part of that stream with a sorption agent; and/or

10 (ii) after step c), heteroatom containing organic compounds and optionally aromatic hydrocarbons are removed from the first stream resulting from step c), wherein that stream comprises demixing solvent b), heteroatom containing organic compounds and optionally aromatic hydrocarbons, by contacting at least part of that stream with a sorption
15 agent.

2. The process according to claim 1, wherein step c) comprises:

20 separating at least part of the second stream resulting from step b) by distillation into a top stream comprising demixing solvent b), optionally heteroatom containing organic compounds and optionally aromatic hydrocarbons and a bottom stream comprising extraction solvent a), and

wherein:

25 (i) heteroatom containing organic compounds and optionally aromatic hydrocarbons are removed from the second stream resulting from step b) by contacting at least part of that stream with a sorption agent, and at least part of the treated stream resulting from step (i) is fed to step c);
30 and/or

(ii) the top stream resulting from step c) comprises demixing solvent b), heteroatom containing organic compounds and optionally aromatic hydrocarbons, and heteroatom

containing organic compounds and optionally aromatic hydrocarbons are removed from that stream by contacting at least part of that stream with a sorption agent.

5 3. The process according to claim 1 or 2, wherein:

the extraction solvent a) has a $R_{a,heptane}$ of at least 5 MPa^{1/2}, preferably at least 10 MPa^{1/2}, and the demixing solvent b) has a $R_{a,heptane}$ of at least 20 MPa^{1/2}, preferably at least 30 MPa^{1/2}, wherein $R_{a,heptane}$ refers to the Hansen solubility
10 parameter distance with respect to heptane as determined at 25 °C; and

the $R_{a,heptane}$ for the demixing solvent b) is greater than the $R_{a,heptane}$ for extraction solvent a), wherein said difference in $R_{a,heptane}$ for solvents a) and b) is at least 1
15 MPa^{1/2}, preferably at least 5 MPa^{1/2}, more preferably at least 10 MPa^{1/2}, more preferably at least 15 MPa^{1/2}.

4. The process according to any one of claims 1 to 3, wherein the extraction solvent a) comprises ammonia or,
20 preferably, one or more organic solvents selected from the group consisting of diols and triols, including monoethylene glycol (MEG), monopropylene glycol (MPG), any isomer of butanediol and glycerol; glycol ethers, including oligoethylene glycols, including diethylene glycol,
25 triethylene glycol and tetraethylene glycol, and monoalkyl ethers thereof, including diethylene glycol ethyl ether; amides, including N-alkylpyrrolidone, wherein the alkyl group may contain 1 to 8 or 1 to 3 carbon atoms, including N-methylpyrrolidone (NMP), formamide and di- and monoalkyl
30 formamides and acetamides, wherein the alkyl group may contain 1 to 8 or 1 to 3 carbon atoms, including dimethyl formamide (DMF), methyl formamide and dimethyl acetamide; dialkylsulfoxide, wherein the alkyl group may contain 1 to 8

or 1 to 3 carbon atoms, including dimethylsulfoxide (DMSO);
sulfones, including sulfolane; N-formyl morpholine (NFM);
furan ring containing components and derivatives thereof,
including furfural, 2-methyl-furan, furfuryl alcohol and
5 tetrahydrofurfuryl alcohol; hydroxy esters, including
lactates, including methyl and ethyl lactate; trialkyl
phosphates, including triethyl phosphate; phenolic compounds,
including phenol and guaiacol; benzyl alcoholic compounds,
including benzyl alcohol; aminic compounds, including
10 ethylenediamine, monoethanolamine, diethanolamine and
triethanolamine; nitrile compounds, including acetonitrile
and propionitrile; trioxane compounds, including 1,3,5-
trioxane; carbonate compounds, including propylene carbonate
and glycerol carbonate; and cycloalkanone compounds,
15 including dihydrolevoglucosenone.

5. The process according to any one of claims 1 to 4,
wherein the demixing solvent b) comprises one or more
solvents selected from the group consisting of water and the
20 solvents from the group of solvents as defined for extraction
solvent a) in claim 4, and wherein the demixing solvent b)
preferably comprises water.

6. The process according to any one of claims 1 to 5,
25 wherein:

a washing solvent c) is added to step a) resulting in a
first stream comprising aliphatic hydrocarbons and a second
stream comprising washing solvent c), extraction solvent a),
heteroatom containing organic compounds and optionally
30 aromatic hydrocarbons; or

the first stream resulting from step a) comprises
aliphatic hydrocarbons and extraction solvent a), at least
part of which first stream is contacted with a washing

solvent c) and is subjected to liquid-liquid extraction with the washing solvent c), resulting in a first stream comprising aliphatic hydrocarbons and a second stream comprising washing solvent c) and extraction solvent a).

5

7. The process according to claim 6, wherein the washing solvent c) is identical to or different from, preferably identical to, demixing solvent b), and preferably comprises water.

10

8. A process for the recovery of aliphatic hydrocarbons from plastics, wherein at least part of the plastics comprises heteroatom containing organic compounds, said process comprising the steps of:

15

(I) cracking the plastics and recovering a hydrocarbon product comprising aliphatic hydrocarbons, heteroatom containing organic compounds and optionally aromatic hydrocarbons; and

20

(II) subjecting a liquid hydrocarbon feedstock stream, which comprises at least part of the hydrocarbon product obtained in step (I), to the process of any one of claims 1-7.

25

9. Process for steam cracking a hydrocarbon feed, wherein the hydrocarbon feed comprises aliphatic hydrocarbons as recovered in a process according to any one of claims 1-8.

10. Process for steam cracking a hydrocarbon feed, comprising the steps of:

30

recovering aliphatic hydrocarbons from a liquid hydrocarbon feedstock stream in a process according to any one of claims 1-8; and

steam cracking a hydrocarbon feed which comprises aliphatic hydrocarbons as recovered in the preceding step.