

PROCESS FOR PRODUCING OLEFINS BY STEAM CRACKING BY UPGRADING A PYROLYSIS GAS

5 TECHNICAL FIELD

The present invention is in the field of the recycling of plastics and/or tyres and/or solid recovered fuels (SRFs). The present invention is aimed at maximizing the production of olefins constituting polymers of plastic and/or of tyres and/or of SRF via a steam cracking unit by virtue of upgrading the light pyrolysis gases, thus making
10 possible a significant increase in olefin yield and a reduction in the environmental impact.

PRIOR ART

Plastics obtained from collection and sorting channels or recycled tyres or else solid
15 recovered fuels (SRFs) may undergo a pyrolysis step in order to upgrade them. Pyrolysis consists in heating, with or without a catalyst, a feedstock containing plastic and/or recycled tyres and/or else SRFs in the absence of oxygen, leading to the formation of three main products: a hydrocarbon phase liquid at ambient temperature and also referred to as pyrolysis oil, a light gas phase also referred to as pyrolysis
20 gas, and a solid residue also referred to as char.

The liquid hydrocarbon phase – the pyrolysis oil – is generally upgraded as feedstock of a steam cracking unit in order to (re)create olefins, the latter being constituent monomers of certain polymers. Pyrolysis oils have impurities in contents that are often high and incompatible with the steam cracking units or the units located
25 downstream of the steam cracking units, in particular the polymerization processes and the selective hydrogenation processes, which often necessitates purification steps upstream of the steam cracking step, for example via at least one hydrotreatment step.

As for the light gas phase obtained from the pyrolysis, it is generally used (recycled)
30 as fuel for providing the energy needed for the pyrolysis reaction. Such processes

are described, for example, in WO2005/087897, WO2018/000050, US2018/0010050, US2018/0142164, WO2014/006273 or US2015/0080624.

Another way to upgrade the light gas phase is to send it, optionally after a pretreatment for removing in particular H₂S, directly to a steam cracking unit in order to increase the olefin yield. Such processes are described, for example, in WO2016142808, WO2016142809 or WO2018069794. However, none of the documents describes the removal of the CO and of the CO₂ prior to introduction into the steam cracker.

However, the act of sending this light gas phase to a steam cracking unit comes up against two constraints:

- the first is that it is often necessary to purify this light gas phase (by desulfurization, dechlorination, denitrogenation) before sending it into a steam cracking unit in order to preserve stable and substantial alteration-free operation of the steam cracking unit. While the majority of the impurities (chlorine, sulfur, nitrogen, metals, and the like) can be treated upstream of the steam cracking step by hydrotreatment (HDT) processes, the CO and CO₂ present in the light gas phase also have to be removed, since on the one hand the presence of CO has a negative (inhibitory) impact on the activity of the catalysts employed in units located downstream of the steam cracker and on the other hand the presence of CO₂ can cause the formation of ice crystals in the cold train of the steam cracker.
- the second is that it is advantageous to keep open the possibility of using at least a portion of the light gas phase obtained from the pyrolysis for providing the energy needed for the pyrolysis reaction, in order to reduce the energy dependence as well as the carbon footprint of the production site.

The present invention makes it possible to respond to these two constraints above simultaneously, by introducing a step of compressing the pyrolysis light gas phase so as to condense at least the C₃+ hydrocarbons, and then separate them from the non-condensable gases (mainly H₂, CO, CO₂, C₁ and C₂). The condensed stream containing the C₃+ hydrocarbons is advantageously sent to a purification unit (HDT) so as to meet the specifications required for being used as feedstock for a steam

cracking unit. Alternatively, if the condensed stream rich in C3+ hydrocarbons is of satisfactory quality, it may be directly sent, optionally with another hydrocarbon feedstock, into a steam cracking unit.

As for the light products contained in the non-condensable gases, these are advantageously used as fuel for providing the energy needed for operating the pyrolysis unit, for example. In the context of the invention, the conditions of the compression step can be adjusted as a function of the energy requirements of the pyrolysis unit in order to produce more or less of non-condensable light products.

10 SUMMARY OF THE INVENTION

More precisely, the invention relates to a process for producing olefins from a feedstock containing plastic and/or tyres and/or solid recovered fuels, said process comprising the following steps:

- 15 (a) performing a step of pyrolysis of a feedstock containing plastic and/or tyres and/or solid recovered fuels in a pyrolysis unit so as to recover at least a first gaseous effluent containing a mixture of H₂, CO, CO₂ and hydrocarbons comprising C1 to C6 hydrocarbons, and a first liquid effluent containing predominantly C7+ hydrocarbons;
- 20 (b) compressing and then cooling said first gaseous effluent obtained from step a), and then separating said compressed and cooled first gaseous effluent in a separation unit so as to obtain a second liquid effluent containing predominantly C3+ hydrocarbons and a residual second gaseous effluent concentrated in H₂, CO and CO₂;
- 25 (c) introducing said second liquid effluent into a steam cracking unit in the presence of steam so as to produce olefins.

According to a variant, said first liquid effluent is introduced into said steam cracking unit of step c).

- 30 According to a variant, in step b) at least a portion of the first liquid effluent is introduced into said separation unit, as a mixture or not as a mixture with said compressed first gaseous effluent, and then the mixture is separated so as to obtain an intermediate

liquid effluent and said residual second gaseous effluent concentrated in H_2 , CO and CO_2 , and then said intermediate liquid effluent is separated in a second separation unit so as to obtain said second liquid effluent containing predominantly C_3+ hydrocarbons and a residual third gaseous effluent concentrated in H_2 , CO and CO_2 .

- 5 According to a variant, a step of purification of said second liquid effluent obtained from step b) is performed in a purification unit upstream of the steam cracking unit of step c).

According to a variant, a step of purification of said first liquid effluent obtained from step a) is performed in a purification unit upstream of the steam cracking unit of step
10 c).

According to a variant, step b) is performed such that during the separation(s) the pressure is between 0.5 and 2.5 MPa relative, preferably between 1.0 and 1.5 MPa relative, and the temperature is between 20 and 55°C, preferably between 30 and 45°C.

- 15 According to a variant, the purification step comprises a step of pretreating said second liquid effluent obtained from step b) and/or said first liquid effluent obtained from step a), said pretreatment step being implemented upstream of step c), and comprises an adsorption step and/or a filtration step and/or a centrifugation step and/or a decantation step and/or an electrostatic separation step and/or a step of
20 washing with an aqueous solution and/or a gas stripping step.

According to a variant, the purification step comprises a hydrotreatment step implemented in a hydrotreatment reaction section, employing at least one fixed-bed reactor having n catalytic beds, n being an integer greater than or equal to 1, each comprising at least one hydrotreatment catalyst, said hydrotreatment reaction section
25 being fed with said optionally pretreated second liquid effluent obtained from step b) and/or said optionally pretreated first liquid effluent obtained from step a) and a gas stream comprising hydrogen, said hydrotreatment reaction section being implemented at an average temperature of between 150 and 430°C, a hydrogen partial pressure of between 1.0 and 10.0 MPa abs. and an hourly space velocity of between 0.1 and 10.0
30 h^{-1} in order to obtain a purified second liquid effluent and/or a purified first liquid effluent.

According to a variant, said hydrotreatment catalyst comprises a support chosen from alumina, silica, silica-aluminas, magnesia, clays and mixtures thereof and a hydro-

dehydrogenating function comprising either at least one element from group VIII and at least one element from group VIB, or at least one element from group VIII.

According to a variant, the hydrotreatment step is followed by a washing/separation step, fed with said optionally pretreated, purified second liquid effluent, and/or said
5 optionally pretreated, purified first liquid effluent, and an aqueous solution in order to obtain at least a gaseous effluent, an aqueous effluent and said washed and purified second liquid effluent and/or said washed and purified first liquid effluent.

According to a variant, said optionally pretreated and/or washed, purified second liquid effluent, and/or said optionally pretreated and/or washed, purified first liquid effluent, is
10 subjected to at least one fractionation step in a fractionating unit in order to obtain at least one gas stream and at least one liquid stream of C₃+ hydrocarbons.

According to a variant, the fractionating unit comprises a depentanizer column from which a liquid C₃-C₄ hydrocarbon stream and a liquid stream of C₅+ hydrocarbons are withdrawn.

15 According to a variant, at least one of the liquid streams obtained from the fractionation step is at least in part sent into the steam cracking unit of step c).

According to a variant, the steam cracking step c) is carried out in at least one pyrolysis furnace at a temperature of between 700 and 900°C and at a pressure of between 0.05 and 0.3 MPa relative in the presence of steam.

20 According to a variant, in the steam cracking step c), the residence time of the hydrocarbon compounds is less than or equal to 1.0 second and the amount of water introduced, in the form of steam, is between 0.3 and 3.0 kg of water per kg of hydrocarbon compounds at the inlet of the steam cracking step c).

According to a variant, the feedstock consists of plastic and/or tyres and/or solid
25 recovered fuels.

In the remainder of the text, the term "pyrolysis oil" is understood to mean an oil resulting from the pyrolysis of plastics and/or of tyres and/or of SRFs, unless otherwise indicated.

In the remainder of the text, the term "pyrolysis gas" is understood to mean a gas
30 resulting from the pyrolysis of plastics and/or of tyres and/or of SRFs, unless otherwise indicated.

According to the present invention, the expressions "of between ... and ..." and "between ... and ..." are equivalent and mean that the limit values of the interval are included in the described range of values. Should this not be the case and should the limit values not be included in the range described, such a clarification will be provided by the present invention.

In the present description, the term "comprise" is synonymous with (means the same thing as) "include" and "contain", and is inclusive or open-ended and does not exclude other elements which are not mentioned. It is understood that the term "comprise" includes the exclusive and closed term "consist".

Within the meaning of the present invention, the various parameter ranges for a given step, such as the pressure ranges and the temperature ranges, can be used alone or in combination. For example, for the purposes of the present invention, a range of preferred pressure values can be combined with a range of preferred temperature values.

Hereinafter, particular and/or preferred embodiments of the invention may be described. They can be employed separately or combined together, without limitation of combination when this is technically feasible.

Hereinafter, groups of chemical elements are given according to the CAS classification (CRC Handbook of Chemistry and Physics, published by CRC Press, editor in chief D.R. Lide, 81st edition, 2000-2001). For example, group VIII (or VIIIB) according to the CAS classification corresponds to the metals of columns 8, 9 and 10 according to the new IUPAC classification.

The content of metals is measured by X-ray fluorescence.

DETAILED DESCRIPTION

The feedstock

Plastic waste is generally a mixture of several polymers. The feedstock used in the process according to the invention may comprise, alone or as a mixture, (low and/or high density) polyethylene, polypropylene, polyethylene terephthalate, polyvinyl chloride and polystyrene. Furthermore, depending on the applications, the plastics may contain, in addition to polymers, other compounds, such as plasticizers,

pigments, dyes or also residues of polymerization catalysts. Plastic waste may additionally contain, in a minor amount, biomass originating, for example, from household waste.

5 With regard to tyres, these are mainly constituted of rubbers, for their elastic property (mixture of elastomers of the type of crosslinked synthetic and natural rubbers, with the addition of adjuvants of the type of silica, resin, sulfur, zinc oxide, carbon black, and the like), and of textile and metal fibres, for their reinforcing property.

10 Solid recovered fuels (SRFs), also called refuse-derived fuel (RDF), are solid non-hazardous wastes prepared with a view to energy recovery, whether they originate from household and similar waste, from waste from economic activities or from waste from construction and demolition. SRFs are generally a mixture of any combustible waste, such as used tyres, food by-products (fats, animal meal, and the like), viscose and wood waste, light fractions resulting from shredders (for example from used vehicles, electrical and electronic equipment (WEEE), household and commercial
15 waste, residues from the recycling of various types of waste, including certain municipal wastes, plastic waste, textiles or wood, *inter alia*. SRFs generally contain plastic waste.

The feedstock used in the process according to the invention contains plastic and/or tyres and/or SRFs. Preferably, the feedstock consists of plastic and/or tyres and/or
20 SRFs. In the case of a mixture of plastics, of tyres and/or of SRFs, this mixture may be made in any proportion.

Pyrolysis step a)

According to step a) of the process according to the invention, a step of pyrolysis of a feedstock containing plastic and/or tyres and/or SRFs in a pyrolysis unit is performed
25 so as to recover at least a first gaseous effluent containing a mixture of H₂, CO, CO₂ and hydrocarbons comprising C1 to C6 hydrocarbons, also called pyrolysis gas, and a first liquid effluent containing predominantly C7+ hydrocarbons (i.e. having a content of C7+ hydrocarbons of greater than or equal to 50% by weight relative to the mass of the liquid effluent), also called pyrolysis oil.

The step of pyrolysis of the feedstock containing plastic and/or tyres and/or SRFs can be performed via a thermal or catalytic pyrolysis treatment or else be prepared by hydropyrolysis (pyrolysis in the presence of a catalyst and of hydrogen).

5 The pyrolysis step is generally performed at a temperature of between 250°C and 750°C. The pyrolysis step can be carried out under conditions that are more or less severe.

The low-severity pyrolysis step is performed at a temperature of between 250°C and 450°C, preferably of between 275°C and 425°C, and particularly preferably of between 300°C and 400°C. The low-severity pyrolysis step produces pyrolysis oils
10 rich in mono- and diolefins as well as a significant amount of aromatics, and which may include chlorine compounds.

The high-severity pyrolysis step is performed at a temperature of between 450°C and 750°C, preferably of between 500°C and 700°C, and particularly preferably of between 550°C and 650°C. The high-severity pyrolysis step produces pyrolysis oils
15 rich in aromatics, and which may include chlorine compounds.

The pyrolysis unit can comprise one or more reactors configured to convert the feedstock into gas-phase and liquid-phase products (for example simultaneously).

The reactor(s) can contain one or more beds of inert materials or of pyrolysis catalysts comprising sand, zeolite or combinations thereof. Generally, the pyrolysis
20 catalyst is capable of transferring heat to the components subjected to the pyrolysis process in the pyrolysis unit.

The pyrolysis unit can comprise one or more items of equipment, for example one or more heated extruders, a heated rotary kiln, heated tank-type reactors, empty heated containers, closed heated surfaces where the feedstock flows along the wall,
25 containers surrounded by furnaces or furnaces or other items of equipment that provide a heated surface.

In one or more embodiments of the pyrolysis unit, a purge gas is used in all or part of the pyrolysis stage(s) in order to improve the cracking of the plastics, produce products of value, provide a feed for the steam cracking, or combinations thereof.

30 The purge gas may comprise hydrogen (H₂), nitrogen (N₂), steam, product gases, or combinations thereof.

The pyrolysis step makes it possible to produce at least a first gaseous effluent containing a mixture of H₂, CO, CO₂ and hydrocarbons comprising C1 to C6 hydrocarbons, also called pyrolysis gas, and a first liquid effluent containing predominantly C7+ hydrocarbons, also called pyrolysis oil.

- 5 Said first liquid effluent containing predominantly C7+ hydrocarbons is a pyrolysis oil, advantageously in liquid form at ambient temperature. The pyrolysis oil comprises in particular a mixture of hydrocarbon compounds, especially paraffins (n-paraffins and isoparaffins), olefins (mono- and/or diolefins), naphthenes and aromatics. At least 80% by weight of these hydrocarbon compounds preferably have a boiling point of
10 less than 700°C, and with preference of less than 550°C. In particular, depending on the origin of the feedstock treated by the pyrolysis unit, the pyrolysis oil can comprise up to 70% by weight of paraffins, up to 90% by weight of naphthenes, up to 90% by weight of olefins and up to 90% by weight of aromatics, it being understood that the sum of the paraffins, of the naphthenes, of the olefins and of the aromatics is equal to
15 100% by weight of the hydrocarbon compounds.

Said first liquid effluent contains predominantly C7+ hydrocarbons, that is to say a content of C7+ hydrocarbons of greater than or equal to 50% by weight relative to the mass of said first liquid effluent.

- The pyrolysis oil can comprise diolefins. The content of diolefins is commonly
20 determined indirectly as the maleic anhydride value (MAV). The method is based on the Diels-Alder addition reaction between the conjugated diolefins and the maleic anhydride. The method for the determination of the MAV is described in C. López-García *et al.*, Near Infrared Monitoring of Low Conjugated Diolefins Content in Hydrotreated FCC Gasoline Streams, Oil & Gas Science and Technology – Rev. IFP,
25 Vol. 62 (2007), No. 1, pp. 57-68. The MAV is expressed in mg of maleic anhydride having reacted with 1 g of sample (mg/g). The MAV varies between 5 and 100 mg/g in the pyrolysis oils.

- The density of the pyrolysis oil, measured at 15°C according to the ASTM D4052 method, is generally of between 0.75 g/cm³ and 0.99 g/cm³, preferably of between
30 0.75 g/cm³ and 0.95 g/cm³.

The pyrolysis oil additionally can comprise, and usually comprises, impurities, such as metals, in particular iron, silicon or halogen compounds, in particular chlorine compounds. These impurities can be present in the pyrolysis oil at high contents, for example up to 500 ppm by weight or else 700 ppm by weight, indeed even 1000 ppm by weight, and even 5000 ppm by weight, of halogen elements (in particular chlorine but also bromine, fluorine or iodine) contributed by halogen compounds, and generally between 1 and 1000 ppm by weight or between 1 and 700 ppm by weight or else between 1 and 500 ppm by weight of halogen elements. The pyrolysis oil can contain up to 500 ppm by weight or else 700 ppm by weight, indeed even 1000 ppm by weight and even 5000 ppm by weight of chlorine element contributed by chlorine compounds, and generally between 1 and 1000 ppm by weight or between 1 and 700 ppm by weight or else between 1 and 500 ppm by weight of chlorine element.

The oil can comprise up to 200 ppm by weight, indeed even 1500 ppm by weight, of metal or semi-metal elements, and generally between 1 and 200 ppm by weight or between 1 and 1500 ppm by weight of metal or semi-metal elements. Alkali metals, alkaline-earth metals, transition metals, post-transition metals and metalloids can be put into the same category as contaminants of metal nature, referred to as metals or metal or semi-metal elements. In particular, the metals or metal or semi-metal elements comprise silicon, iron or both of these elements. The pyrolysis oil can in particular comprise up to 200 ppm by weight or also 1000 ppm by weight of silicon, and generally between 1 and 200 ppm by weight or between 1 and 1000 ppm by weight or also between 1 and 500 ppm by weight of silicon. The pyrolysis oil can in particular comprise up to 50 ppm by weight or also 100 ppm by weight of iron, and generally between 1 and 50 ppm by weight or between 1 and 100 ppm by weight of iron. The pyrolysis oil can also comprise phosphorus, sodium, calcium, potassium and magnesium.

The pyrolysis oil can also comprise other impurities, such as heteroelements contributed in particular by sulfur compounds, oxygen compounds and/or nitrogen compounds, at contents generally of less than 40 000 ppm by weight of heteroelements and preferably of less than 15 500 ppm by weight of heteroelements, and generally between 1 and 40 000 ppm by weight or between 1 and 15 500 ppm by weight of heteroelements.

The sulfur compounds are generally present in a content of less than 15 000 ppm by weight and preferably of less than 10 000 ppm by weight, and generally between 1 and 15 000 ppm by weight or between 1 and 10 000 ppm by weight of sulfur compounds.

- 5 The oxygen compounds are generally present in a content of less than 15 000 ppm by weight and preferably of less than 10 000 ppm by weight, and generally between 1 and 15 000 ppm by weight or between 1 and 10 000 ppm by weight of oxygen compounds.

- 10 The nitrogen compounds are generally present in a content of less than 10 000 ppm by weight and preferably of less than 5000 ppm by weight, and generally between 1 and 10 000 ppm by weight or between 1 and 5000 ppm by weight of nitrogen compounds.

- 15 The contents of sulfur, oxygen and/or nitrogen compounds often depend on the origin of the feedstock treated. Thus, tyre pyrolysis oils generally contain more heteroelements than plastic pyrolysis oils, in particular sulfur compounds.

The pyrolysis oil can also comprise other impurities, such as heavy metals, for example mercury, arsenic, zinc and lead, for example up to 100 ppb by weight or else 200 ppb by weight of mercury or of arsenic, and generally between 1 and 200 ppb by weight or between 1 and 100 ppb by weight of heavy metals.

- 20 As for said first gaseous effluent obtained from the pyrolysis, also called pyrolysis gas, this contains a mixture of H_2 , CO, CO_2 and hydrocarbons comprising C1 to C6 hydrocarbons. It may also contain halogens (in particular in the form of chlorine compounds), water, sulfur and nitrogen.

- 25 Said first gaseous effluent generally contains hydrocarbons comprising C1 to C6 hydrocarbons at a content of at least 20% by volume, preferably at least 30% by volume and particularly preferably at least 40% by volume, relative to the total volume of said first gaseous effluent.

- 30 Said first gaseous effluent generally contains CO and CO_2 at a content of at least 1% by volume, generally at least 2% by volume and often at least 3% by volume, relative to the total volume of said first gaseous effluent.

Said first gaseous effluent obtained from the pyrolysis can contain halogens, in particular chlorine, depending on the nature of the feedstock pyrolysed. Said first gaseous effluent obtained from the pyrolysis generally contains halogens and in particular chlorine at a content of greater than 25 ppm by weight, generally greater than 50 ppm by weight, and often greater than 70 ppm by weight, relative to the total weight of said first gaseous effluent.

Step b) of compressing, cooling and separating the pyrolysis gas

The treatment of said first gaseous effluent according to the invention during step b) is carried out so as to condense the C3+ hydrocarbons contained in the first gaseous effluent in a liquid phase (also called condensate), while the compounds H₂, CO, CO₂, and the light C1 to C2 hydrocarbons are separated in a non-condensable gas stream.

It is specifically the condensation of the C3+ hydrocarbons of the pyrolysis gas which makes it possible to increase the yield of olefins during the steam cracking step, while at the same time limiting in particular the presence of CO and of CO₂ in the condensate in order to limit the deactivation of the catalysts of the purification steps when they are present but also the deactivation of the catalysts that are possibly employed in the units downstream of the steam cracker for the treatment ("polishing") of the products formed by the steam cracker. This step b) thus makes it possible to selectively extract the upgradable compounds (C3+ hydrocarbons, in particular C3 to C6 hydrocarbons) for the steam cracker.

The remaining gas stream is non-condensable and can be used for providing the energy needed for the operation of the pyrolysis step.

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Thus, during step b) of the process according to the invention, said first gaseous effluent obtained from step a) is compressed and then cooled, and then said compressed and cooled first gaseous effluent is separated in a separation unit so as to obtain a second liquid effluent containing predominantly C3+ hydrocarbons, in particular C3 to C6 hydrocarbons, and a residual second gaseous effluent concentrated in H₂, CO and CO₂.

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Step b) is carried out in such a manner that during the separation the relative pressure is between 0.5 and 2.5 MPa relative (5 and 25 bar relative or barg) and the temperature is between 20 and 55°C. Preferably, the pressure is between 1.0 and 1.5 MPa relative,
 5 and the temperature is between 30 and 45°C, or even between 35 and 40°C.

The compression of said first gaseous effluent is generally carried out in at least one compressor. The cooling of said first gaseous effluent is generally carried out by a heat exchanger.

The separation can advantageously be implemented by any method known to a
 10 person skilled in the art, such as, for example, the combination of one or more separator(s) (drum(s)) and/or one or more stripping columns, it being possible for this or these separator(s) (drum(s)) and/or columns to be optionally fed with a stripping gas, for example a hydrogen-rich gas stream. Preferably, the separation is carried out in a separator drum.

15 Step b) makes it possible to obtain a second liquid effluent containing predominantly C3+ hydrocarbons and a residual second gaseous effluent containing H₂, CO, CO₂, and light C1 to C2 hydrocarbons.

A second liquid effluent containing "predominantly C3+ hydrocarbons" is understood to mean a liquid effluent having a content of C3+ hydrocarbons of greater than or
 20 equal to 50% by weight, relative to the weight of said second liquid effluent.

Said second liquid effluent containing predominantly C3+-C6 hydrocarbons is low in CO and CO₂. The expression "low in CO and CO₂" is understood to mean a content of CO and CO₂ of less than or equal to 5000 ppm, preferably less than or equal to 3000 ppm by weight relative to the weight of said second liquid effluent.

25 Specifically, following the sequence of compression, cooling and separation of step b), the CO and CO₂ (and the H₂) are present concentrated in said residual second gaseous effluent. This makes it possible to recover said second liquid effluent having a content of CO and CO₂ that is acceptable for being sent into steam cracking step c) or into a purification step upstream of steam cracking step c).

According to another embodiment, at least a portion of the first liquid effluent obtained from pyrolysis step a) can be introduced into said separation unit, as a mixture or not as a mixture with said compressed first gaseous effluent. More particularly, the process according to the invention can comprise a step b) in which at least a portion of the first liquid effluent is introduced into said separation unit, as a mixture or not as a mixture with said compressed first gaseous effluent, and then the mixture is separated so as to obtain an intermediate liquid effluent and said residual second gaseous effluent concentrated in H₂, CO and CO₂, and then said intermediate liquid effluent is separated in a second separation unit so as to obtain said second liquid effluent containing predominantly C₃+ hydrocarbons and a residual third gaseous effluent concentrated in H₂, CO and CO₂.

This embodiment makes it possible to further extract organic components from the first gaseous effluent in the liquid phase obtained from the separation. The components recovered comprise C₃ hydrocarbons (for example propane, propylene) and hydrocarbons having higher boiling points, but may also include C₂ hydrocarbons (for example ethylene, ethane) as valuable petrochemical raw materials. Furthermore, this embodiment aims to maximize the recovery of organic chlorine compounds and other impurities in order to clean the first gaseous effluent and concentrate the impurities in the liquid phase in order to be further purified in a purification step. Bringing the first gaseous effluent into contact with the first liquid effluent at elevated pressure reduces the partial pressure of the vapour in the liquid from the separation, thus entraining the heaviest organic components of the vapour phase of the first gaseous effluent in the liquid phase, creating a "sponge" effect. There are several options for sending all or part of the first liquid effluent to the separation:

- the first liquid effluent obtained from step a) is sent directly into the separation unit
- the first liquid effluent obtained from step a) is mixed with the compressed first gaseous effluent upstream or downstream of the cooling thereof and the mixture is sent to the separation unit.

In this embodiment, the separation of the mixture can advantageously be implemented by any method known to a person skilled in the art, such as for example

a separator drum or an absorbent column in which the first liquid effluent is introduced at the top and the first gaseous effluent is introduced at the bottom.

The gas phase obtained from the separation of the mixture, the residual second gaseous effluent, has a lower content of impurities than the first gaseous effluent, thus enabling easier use as fuel, whether for the pyrolysis unit or for an external application, or else as feedstock for the steam cracker.

The liquid recovered from the separation of the mixture, the intermediate liquid effluent, is then treated in a second separation unit in order to produce said second liquid effluent and a residual third gaseous effluent. This separation step makes it possible to further remove light components such as H_2 , CO and/or CO_2 from the intermediate liquid effluent, generally to a content of at most 1000 ppm, often less than 100 ppm, but preferably less than 10 ppm by weight of light components. Removal of these components prevents them from finding their way either into the steam cracking unit or into the purification unit.

The separation of the intermediate liquid effluent can advantageously be implemented by any method known to a person skilled in the art, such as for example by distillation (for example using a plate distillation column or a packed distillation column), the combination of one or more separator drums, a pervaporation membrane, or any combination of these.

The separation of the intermediate liquid effluent can be carried out in the same pressure and temperature ranges as the separation of the mixture. The pressure and temperature conditions can be identical or different. When a distillation column is used as second separation unit, the separation temperature can be between 80 and 150°C at the bottom of the column, and the pressure can be between 1 and 1.5 MPa.

Said residual third gaseous effluent is concentrated with the light components which may include CO, CO_2 , methane, but also comprises certain light hydrocarbon components, in particular ethylene and heavier hydrocarbon compounds. Said residual third gaseous effluent can be recycled and mixed with the first gaseous effluent upstream of the compression or cooling thereof, such that a portion of the light hydrocarbon components can be recovered in the liquid phase from the separation of the mixture. Optionally, said residual third gaseous effluent can also be mixed with the residual second gaseous effluent or the fuel of the pyrolysis unit in

order to use its energy content as fuel either for the pyrolysis unit or for an external application.

Steam cracking step c)

According to step c) of the process according to the invention, said second liquid effluent (condensate) is introduced into a steam cracking unit in the presence of
5 steam so as to obtain olefins.

Advantageously, said first liquid effluent containing predominantly C7+ hydrocarbons (pyrolysis oil) is also introduced into said steam cracking unit of step c), as a mixture or not as a mixture with said second liquid effluent (condensate).

Said second liquid effluent (condensate) can represent between 0.5% and 10% by
10 weight relative to the total weight of the mixture of feedstocks introduced into the steam cracking step.

Said steam cracking step c) is advantageously carried out in at least one pyrolysis furnace at a temperature of between 700 and 900°C, preferably between 750 and 850°C, and at a pressure of between 0.05 and 0.3 MPa relative in the presence of
15 steam. The residence time of the hydrocarbon compounds is generally less than or equal to 1.0 second (denoted s), preferably between 0.1 and 0.5 s. Advantageously, steam is introduced upstream of the steam cracking step c). The amount of water introduced, in the form of steam, is advantageously between 0.3 and 3.0 kg of water per kg of hydrocarbon compounds at the inlet of the steam cracking step.

20 The steam cracking step can be carried out in a plurality of pyrolysis furnaces in parallel, so as to adapt the operating conditions to the various streams feeding the steam cracking step, and also to manage the tube decoking times. A furnace comprises one or more tubes arranged in parallel. A furnace can also denote a group of furnaces operating in parallel. For example, a furnace may be dedicated to
25 cracking the middle distillates cut.

The effluents from the various steam cracking furnaces are generally recombined before separation for the purpose of constituting an effluent. It is understood that the steam cracking step includes the steam cracking furnaces but also the substeps

associated with the steam cracking that are well known to a person skilled in the art.

These substeps may notably include heat exchangers, columns and catalytic reactors and recycling to the furnaces. A column generally makes it possible to fractionate the effluent for the purpose of recovering at least a light fraction

5 comprising hydrogen and compounds having from 2 to 5 carbon atoms, and a fraction comprising pyrolysis petrol, and optionally a heavier fraction. Columns make it possible to separate the various constituents of the fractionation light fraction in order to recover at least a cut rich in ethylene (C2 cut) and a cut rich in propylene (C3 cut) and optionally a cut rich in butenes (C4 cut). The catalytic reactors make it
10 possible in particular to carry out hydrogenations of the C2, C3, and even C4, cuts and of the pyrolysis petrol. The saturated compounds, in particular the saturated compounds having from 2 to 4 carbon atoms, are advantageously recycled to the steam cracking furnaces so as to increase the overall yields of olefins.

This steam cracking step c) makes it possible to obtain at least one effluent

15 containing olefins comprising 2, 3 and/or 4 carbon atoms (i.e. C2, C3 and/or C4 olefins), in satisfactory contents, in particular greater than or equal to 30% by weight of total olefins comprising 2, 3 and 4 carbon atoms relative to the weight of the steam cracking effluent under consideration. Said C2, C3 and C4 olefins can subsequently be advantageously used as polyolefin monomers.

20 According to one embodiment, when said second liquid effluent (condensate) and/or said first liquid effluent (pyrolysis oil) do not meet the specifications (in particular in terms of chlorine) at the inlet of the steam cracking unit, these specifications can be achieved by dilution at the inlet of the steam cracking unit with a feedstock not comprising or comprising very little chlorine, for example a petroleum feedstock. The
25 petroleum feedstock is preferably chosen from naphtha, kerosene, gas oil, or mixtures of such feedstocks.

According to another embodiment, said second liquid effluent (condensate) and/or said first liquid effluent (pyrolysis oil) not meeting the specifications (in particular in terms of chlorine) at the inlet of the steam cracking unit may undergo at least one
30 purification step before being introduced into the steam cracking step c).

Purification step(s) upstream of the steam cracking step (optional)

Said second liquid effluent obtained from step b) (condensate) may contain contents of impurities that are excessively high with respect to the specifications of the steam cracking unit. These impurities are in particular halogen compounds, notably chlorine-based compounds, but also diolefins, olefins, metals, in particular iron, silicon, or else heteroelements such as sulfur, oxygen and nitrogen.

Steam cracking units require very high feedstock purities, notably low contents of chlorine, diolefins, olefins and metals and sulfur. The specification of the chlorine content at the inlet of a steam cracking unit is typically 3 ppm by weight at most, preferably 1 ppm by weight at most.

Said second liquid effluent obtained from step b) (condensate) may thus undergo at least one purification step in a purification unit upstream of the steam cracking unit in order to achieve the specifications required for the steam cracking step c).

The same applies for said first liquid effluent containing predominantly C7+ hydrocarbons and obtained from step a) (pyrolysis oil), which may in particular comprise halogen compounds, notably chlorine-based compounds, but also diolefins, olefins, metals, in particular iron, silicon, or else heteroelements such as sulfur, oxygen and nitrogen, and insoluble materials.

Said first liquid effluent obtained from step a) (pyrolysis oil) may thus also undergo at least one purification step in a purification unit upstream of the steam cracking unit in order to achieve the specifications required for the steam cracking step c).

The purification step may comprise a hydrotreatment step, optionally preceded by a pretreatment and/or optionally followed by a washing/separation step.

According to a variant, only said second liquid effluent undergoes at least one purification step in a purification unit upstream of the steam cracking unit c).

According to another variant, only said first liquid effluent undergoes at least one purification step in a purification unit upstream of the steam cracking unit c).

According to yet another variant, which is preferred, said second liquid effluent and said first liquid effluent undergo at least one purification step in a purification unit upstream of the steam cracking unit, preferably in the same purification unit. Thus, said second liquid effluent (condensate) can be sent, as a mixture or not as a mixture, with said first liquid effluent (pyrolysis oil) into a hydrotreatment step, followed by a washing/separation step.

According to yet another variant, said second liquid effluent and said first liquid effluent may undergo several purification steps, some of them alone and others jointly. Thus, said first liquid effluent (pyrolysis oil) may, for example, undergo a pretreatment, then be sent with said second liquid effluent (condensate) into a hydrotreatment step, followed by a washing/separation step, or else directly into the steam cracking step c).

Pretreatment (optional)

One route for removing the impurities contained in said second effluent and/or in said first liquid effluent is to carry out a pretreatment, generally carried out after the pyrolysis step, and upstream of a hydrotreatment step if one is present.

According to a variant, this optional pretreatment step makes it possible to reduce the amount of contaminants and of solid particles. This optional pretreatment step makes possible in particular the removal of sediments which can be formed as a result of the unstable nature of the pyrolysis oils and/or of a problem of compatibility between two different feedstocks.

Said optional pretreatment step can be implemented by any method known to a person skilled in the art which makes it possible to reduce the amount of contaminants. It can in particular comprise an adsorption step and/or a filtration step and/or a centrifugation step and/or a decantation step and/or an electrostatic separation step and/or a step of washing with an aqueous solution and/or a gas stripping step.

The optional pretreatment step is advantageously implemented at a temperature of between 20 and 400°C, preferably between 40 and 350°C, and at a pressure between 0.15 and 10.0 MPa abs., preferably between 0.2 and 7.0 MPa abs.

According to a variant, said optional pretreatment step is implemented in an adsorption section operated in the presence of at least one adsorbent. The adsorbent can be chosen from a zeolite, activated carbon, a clay, a silica or an alumina.

Advantageously, said adsorbent comprises less than 1% by weight of metal elements and is preferably devoid of metal elements. The term "metal elements of the adsorbent" should be understood as meaning the elements from groups 6 to 10 of the Periodic Table of the Elements (new IUPAC classification).

According to another variant, said optional pretreatment step is implemented in a section for washing with an aqueous solution, for example water, or an acidic or basic solution. This washing section can comprise items of equipment which make it possible to bring the pyrolysis oil and/or the condensate into contact with the aqueous solution and to separate the phases so as to obtain, on the one hand, the pretreated feedstock and, on the other hand, the aqueous solution comprising impurities. These items of equipment can include, for example, a stirred reactor, a settler, a mixer-settler and/or a cocurrent or countercurrent washing column.

According to another variant, said optional pretreatment step is implemented by filtration. The filtration step makes it possible to remove the inorganic solids, sediments and/or fines contained in the pyrolysis oil and/or the condensate, in particular the metals, metal oxides and metal chlorides. Use is generally made of a filter, the size (for example the diameter or equivalent diameter) of the pores of which is less than 25 μm , preferably less than or equal to 10 μm , even more preferably less than or equal to 5 μm . Use may also be made of a series of filters with different pore sizes, in particular a series of filters having pore sizes decreasing in the direction of the circulation of the feedstock. These filtering media are well known for industrial uses. Cartridge filters or self-cleaning filters are suitable, for example.

According to another variant, said optional pretreatment step is carried out by centrifugation, decantation or else by electrostatic separation.

According to another variant, said optional pretreatment step is implemented by gas stripping, thus reducing the content of oxygen in the feedstock. The gas extraction can remove the oxygen (O_2) which may be dissolved in the pyrolysis oil and/or the condensate, thus reducing the probability of formation of free radicals resulting in

polymerization in the downstream steps. The process generally involves bringing the pyrolysis oil and/or the condensate into contact with an extraction gas (for example H_2 , N_2 or a mixture of these), thus transferring at least a portion of the dissolved oxygen of the feedstock to the extraction gas, followed by the separation of the extraction gas from the pyrolysis oil and/or the condensate. Any dissolved H_2 remaining in the pyrolysis oil and/or the condensate after the gas extraction step is not a problem, given the hydrotreatment step generally carried out downstream.

Said optional pretreatment step generally comprises one or more, preferably more, treatments described above.

- 10 Said optional pretreatment step thus makes it possible to obtain said pretreated second effluent and/or said pretreated first liquid effluent which can then feed the hydrotreatment step or be sent into the steam cracking step c), optionally after having carried out a fractionating step.

Hydrotreatment step (optional)

- 15 Another route for removing the impurities contained in said second liquid effluent and/or in said first liquid effluent is to carry out a step of hydrotreatment in the presence of a catalyst.

Thus, the purification step can comprise a hydrotreatment step implemented in a hydrotreatment reaction section, employing at least one fixed-bed reactor having n catalytic beds, n being an integer greater than or equal to 1, each comprising at least one hydrotreatment catalyst, said hydrotreatment reaction section being fed with said optionally pretreated second liquid effluent obtained from step b) and/or said optionally pretreated first liquid effluent obtained from step a) and a gas stream comprising hydrogen, said hydrotreatment reaction section being implemented at an average temperature of between 150 and 430°C, a hydrogen partial pressure of between 1.0 and 10.0 MPa abs. and an hourly space velocity of between 0.1 and 10.0 h^{-1} in order to obtain a purified second liquid effluent and/or a purified first liquid effluent.

- Advantageously, the hydrotreatment step implements hydrotreatment reactions well known to a person skilled in the art and more particularly hydrotreatment reactions

such as hydrodemetallization, hydrogenation of aromatics, hydrodesulfurization and hydrodenitrogenation and also hydrogenation of olefins (mono- and diolefins) and of halogen compounds (in particular chlorine compounds).

Said hydrotreatment reaction section is advantageously implemented at an average
 5 hydrotreatment temperature (or WABT as defined below) between 150 and 430°C, preferably between 280 and 380°C, at a hydrogen partial pressure between 1.0 and 10.0 MPa abs. and at an hourly space velocity (HSV) between 0.1 and 10.0 h⁻¹, preferably between 0.1 and 5.0 h⁻¹, preferentially between 0.2 and 2.0 h⁻¹, with preference between 0.2 and 1 h⁻¹. The hydrogen coverage is advantageously of
 10 between 50 and 1000 Nm³ of hydrogen per m³ of feedstock feeding the hydrotreatment step, and preferably between 50 and 500 Nm³ of hydrogen per m³ of feedstock and with preference between 100 and 300 Nm³ of hydrogen per m³ of feedstock.

The "average temperature" of a reaction section corresponds to the weight-average
 15 bed temperature (WABT), which is well known to a person skilled in the art. The average temperature is advantageously determined as a function of the catalytic systems, of the items of equipment, of the configuration of these, that are used. The average temperature (or WABT) is calculated in the following way:

$$WABT = (T_{inlet} + T_{outlet})/2$$

20 with T_{inlet}: the temperature of the effluent at the inlet of the reaction section, and T_{outlet}: the temperature of the effluent at the outlet of the reaction section.

The hourly space velocity (HSV) is defined here as the ratio of the hourly flow rate by volume of the optionally pretreated feedstock to the volume of catalyst(s).

The hydrogen coverage is defined as the ratio of the volume flow rate of hydrogen
 25 taken under normal temperature and pressure conditions relative to the volume flow rate of optionally pretreated feedstock, without taking into account any recycled fraction, at 15°C (in normal m³, written as Nm³, of H₂ per m³ of feedstock).

Preferably, the process according to the invention comprises a hydrotreatment step implemented in a hydrotreatment reaction section, employing at least one fixed-bed
 30 reactor having n catalytic beds, n being an integer greater than or equal to 1,

preferably between 1 and 10, with preference between 2 and 5, each comprising at least one hydrotreatment catalyst.

Said hydrotreatment reaction section is fed at least with said second liquid effluent obtained from step b) and/or said first liquid effluent obtained from step a), and a
 5 gaseous stream comprising hydrogen, advantageously at the first catalytic bed of the first reactor in operation. An injection of at least a portion of the feedstock and/or at least a portion of hydrogen between the various catalytic beds is also possible.

The hydrotreatment reaction section employing at least one fixed-bed reactor can operate with gas and liquid downflow or upflow.

10 The gas stream comprising hydrogen, which feeds the hydrotreatment reaction section, can consist of a supply of hydrogen and/or of recycled hydrogen. The gas stream comprising hydrogen may be derived from a fossil source or from a renewable source, for example derived from the gasification of plastic waste, or produced by electrolysis.

15 Preferably, an additional gas stream comprising hydrogen is advantageously introduced at the inlet of each reactor, in particular operating in series, and/or at the inlet of each catalytic bed starting from the second catalytic bed of the reaction section. These additional gas streams are also referred to as cooling streams. They make it possible to control the temperature in the reactor in which the reactions
 20 carried out are generally highly exothermic.

Preferably, the hydrotreatment step can employ, upstream of the hydrotreatment catalyst(s), at least one guard bed containing adsorbents of alumina, silica, silica-alumina, zeolite and/or activated carbon type optionally containing metals from group VIB and/or VIII. Use may also be made of a series of guard beds with particles of
 25 different diameters, in particular a series of guard beds having diameters decreasing in the direction of the circulation of the feedstock (also referred to as "grading").

Advantageously, said hydrotreatment catalyst comprises a support, preferably a mineral support, and a hydro-dehydrogenating function.

According to a variant, the hydro-dehydrogenating function comprises in particular at
 30 least one element from group VIII, preferably chosen from nickel and cobalt, and at

least one element from group VIB, preferably chosen from molybdenum and tungsten. According to this variant, the total content, expressed as oxides, of the metal elements from groups VIB and VIII is preferably between 1% and 40% by weight, preferentially from 5% to 30% by weight, relative to the total weight of the catalyst. When the metal is cobalt or nickel, the metal content is expressed as CoO and NiO respectively. When the metal is molybdenum or tungsten, the metal content is expressed as MoO₃ and WO₃ respectively. The ratio by weight, expressed as metal oxide, of the metal (or metals) from group VIB relative to the metal (or to the metals) from group VIII is preferably between 1 and 20 and with preference between 2 and 10.

According to this variant, the reaction section of said hydrotreatment step comprises, for example, a hydrotreatment catalyst comprising between 0.5% and 12% by weight of nickel, preferably between 0.9% and 10% by weight of nickel (expressed as nickel oxide NiO relative to the weight of said catalyst), and between 1% and 30% by weight of molybdenum, preferably between 3% and 20% by weight of molybdenum (expressed as molybdenum oxide MoO₃ relative to the weight of said catalyst), on a preferably mineral support, preferably on an alumina support.

According to another variant, the hydro-dehydrogenating function comprises, and preferably consists of, at least one element from group VIII, preferably nickel. According to this variant, the content of nickel oxides is preferably between 1% and 50% by weight, preferably between 10% and 30% by weight, relative to the weight of said catalyst. This type of catalyst is preferably used in its reduced form, on a preferably mineral support, preferably on an alumina support.

According to another aspect of the invention, the hydrotreatment catalyst as described above additionally comprises one or more organic compounds containing oxygen and/or nitrogen and/or sulfur. Such a catalyst is often denoted by the term "additivated catalyst". Generally, the organic compound is chosen from a compound comprising one or more chemical functions chosen from a carboxylic, alcohol, thiol, thioether, sulfone, sulfoxide, ether, aldehyde, ketone, ester, carbonate, amine, nitrile, imide, oxime, urea and amide function or compounds including a furan ring or sugars.

The support for said hydrotreatment catalyst is preferably chosen from alumina, silica, silica-aluminas, magnesia, clays and mixtures thereof. Said support can include dopant compounds, in particular oxides chosen from boron oxide, especially boron trioxide, zirconia, ceria, titanium oxide, phosphorus pentoxide and a mixture of these oxides. Preferably, said hydrotreatment catalyst comprises an alumina support, optionally doped with phosphorus and optionally boron. When phosphorus pentoxide P_2O_5 is present, its concentration is less than 10% by weight, relative to the weight of the alumina, and advantageously at least 0.001% by weight, relative to the total weight of the alumina. When boron trioxide B_2O_3 is present, its concentration is less than 10% by weight, relative to the weight of the alumina, and advantageously at least 0.001%, relative to the total weight of the alumina. The alumina used can, for example, be a γ (gamma) or η (eta) alumina.

Said hydrotreatment catalyst is for example in the form of extrudates or in the form of beads.

The preparation of the catalyst for the hydrotreatment step is known and generally comprises a step of impregnation of the metals from group VIII and from group VIB when present, and optionally of the phosphorus and/or boron on the support, followed by drying, and then optionally calcining. The catalyst can also be a catalyst used in its reduced form, thus involving a reduction step in its preparation.

Before being used in a step of the process, the catalysts are generally subjected to sulfidation in order to form the active species. Depending on the content of sulfur compounds in the initial feedstock to be treated, a stream containing a sulfiding agent can be injected upstream of the optional pretreatment step or of the hydrotreatment step, preferably upstream of the hydrotreatment step, in order to ensure a sufficient amount of sulfur to form the active species of the catalyst (in sulfide form). This activation or sulfidation step is carried out by methods well known to a person skilled in the art, and advantageously under a sulfo-reductive atmosphere in the presence of hydrogen and hydrogen sulfide. The sulfiding agents are preferably H_2S gas, elemental sulfur, CS_2 , mercaptans, sulfides and/or polysulfides, hydrocarbon cuts having a boiling point of less than $400^\circ C$ containing sulfur compounds or any other sulfur-containing compound used for the activation of hydrocarbon feedstocks with a view to sulfiding the catalyst. Said sulfur-containing compounds are advantageously

chosen from alkyl disulfides, such as, for example, dimethyl disulfide (DMDS), alkyl sulfides, such as, for example, dimethyl sulfide, thiols, such as, for example, n-butyl mercaptan (or 1-butanethiol), and polysulfide compounds of tert-nonyl polysulfide type. The catalyst can also be sulfided by the sulfur contained in the feedstock to be desulfurized. Preferably, the catalyst is sulfided *in situ* in the presence of a sulfiding agent and of a hydrocarbon feedstock. Very preferably, the catalyst is sulfided *in situ* in the presence of the feedstock additivated with dimethyl disulfide. The sulfiding agent can be injected continuously.

According to a variant, the hydrotreated second liquid effluent and/or the first liquid effluent can be supplemented with a conventional petroleum feedstock or a feedstock obtained from the conversion of biomass, which is then co-treated in the pretreatment and/or the hydrotreatment step.

The conventional petroleum feedstock can advantageously be a cut or a mixture of cuts of naphtha or gas oil type.

The feedstock obtained from the conversion of biomass can advantageously be chosen from plant oils, oils from algae or algal oils, fish oils, waste food oils, and fats of plant or animal origin, or mixtures of such feedstocks. Said plant oils can advantageously be crude or refined, completely or partly, and obtained from plants chosen from rapeseed, sunflower, soybean, palm, olive, coconut, coconut kernel, castor oil plant, cotton plant, peanut oil, linseed oil and sea kale oil, and all the oils obtained, for example, from sunflower or rapeseed by genetic modification or hybridization, this list not being limiting. Said animal fats are advantageously chosen from blubber and fats composed of residues from the food industry or obtained from the catering industries. Frying oils, various animal oils, such as fish oils, tallow or lard, can also be used. The feedstock obtained from the conversion of biomass can also advantageously be chosen from methyl esters of fatty acids of plant and/or animal origin or also methyl esters of fatty acids of waste food plant oils.

The feedstock obtained from the conversion of biomass can also be chosen from feedstocks originating from thermal or catalytic biomass conversion processes, such as oils which are produced from biomass, in particular from lignocellulosic biomass, with various liquefaction methods, such as hydrothermal liquefaction or pyrolysis.

The term "biomass" refers to a material derived from recently living organisms, which

includes plants, animals and by-products thereof. The term "lignocellulosic biomass" denotes biomass derived from plants or from by-products thereof. The lignocellulosic biomass is composed of carbohydrate polymers (cellulose, hemicellulose) and of an aromatic polymer (lignin).

- 5 The feedstock obtained from the conversion of biomass can also advantageously be chosen from feedstocks obtained from the papermaking industry.

After the hydrotreatment step, a purified second liquid effluent and/or a purified first liquid effluent are obtained.

Washing/separation step

- 10 According to a variant, the hydrotreatment step can be followed by a washing/separation step, fed with said optionally pretreated, purified second liquid effluent, and/or said optionally pretreated, purified first liquid effluent, and an aqueous solution in order to obtain at least a gaseous effluent, an aqueous effluent and said washed and purified second liquid effluent and/or said washed and purified first liquid
15 effluent.

- This washing/separation step in particular makes it possible to remove the ammonium chloride salts which form by reaction between the chloride ions, released by hydrogenation of the chlorine compounds in HCl form notably during the
20 hydrotreatment step followed by dissolution in the water, and the ammonium ions, generated by hydrogenation of the nitrogen compounds in the form of NH_3 during the hydrotreatment step and/or provided by injection of an amine followed by dissolution in the water, and thus to limit the risks of clogging, in particular in the transfer lines and/or in the sections of the process of the invention and/or the transfer lines to the
25 steam cracker, due to the precipitation of the ammonium chloride salts. This step also makes it possible to remove the hydrochloric acid formed by the reaction of the hydrogen ions and the halide ions released by hydrogenation of the halogen compounds during the hydrotreatment step which dissolve in the aqueous solution. When H_2S is present in the hydrotreated effluent obtained from the hydrotreatment
30 step, the washing/separation step also makes it possible to remove ammonium sulfide ($(\text{NH}_4)_2\text{S}$) salts which form by reaction between H_2S obtained from the

hydrodesulfurization of the sulfur compounds and NH_3 by dissolving them in the aqueous solution.

The washing/separation step is advantageously carried out at a temperature of between 50 and 450°C, preferentially between 100 and 440°C, preferably between 200 and 420°C. It is important to operate in this temperature range (and therefore not to cool the effluent of the hydrotreatment too much) at the risk of clogging in the lines due to the precipitation of the ammonium chloride salts. Advantageously, the washing/separation step is carried out at a pressure close to that employed in the hydrotreatment step, preferably between 1.0 and 10.0 MPa abs., so as to facilitate the recycling of hydrogen.

The aqueous solution may be water. It can also be a basic aqueous solution (by adding NaOH for example). The use of a basic solution makes it possible to neutralize the hydrogen halides and any dissolved salts.

The washing/separation step can advantageously be carried out in common or separate items of washing and separation equipment, these items of equipment being well known (separator drums which can be operated at various pressures and temperatures, pumps, heat exchangers, washing columns, and the like).

Advantageously, the washing/separation step comprises an injection of an aqueous solution, preferably an injection of water, into the hydrotreated effluent, upstream of the washing/separation section, so as to dissolve at least some and preferably all of the hydrogen halides (HCl in particular) and any salts present.

In one optional embodiment of the invention, the washing/separation step comprises the injection of an aqueous solution into the hydrotreated effluent, followed by the washing/separation section advantageously comprising a separation phase for obtaining at least one aqueous effluent loaded with hydrogen halides (HCl in particular) and any dissolved salts present, a washed hydrotreated effluent and a partially washed gaseous effluent. Said aqueous effluent and the washed hydrotreated effluent can then be separated in a decanting vessel in order to obtain said washed hydrotreated effluent and said aqueous effluent. Said partially washed gaseous effluent can, in parallel, be introduced into a washing column where it circulates countercurrentwise to an aqueous stream, preferably of the same nature

as the aqueous solution injected into the hydrotreated effluent, which makes it possible to remove at least some and preferably all of the hydrochloric acid contained in the partially washed gaseous effluent and to thus obtain said gaseous effluent, preferably essentially comprising hydrogen, and an acidic aqueous stream. Said aqueous effluent obtained from the decanting vessel may optionally be mixed with said acidic aqueous stream, and be used, optionally as a mixture with said acidic aqueous stream, in a water recycling circuit to feed the washing/separation step with said aqueous solution upstream of the washing/separation section and/or with said aqueous stream in the washing column. Said water recycling circuit can comprise a supply of water and/or of a basic solution and/or a bleed making it possible to discharge the impurities.

According to one embodiment, and as a function of the content of chlorine compounds in said second liquid effluent and/or first liquid effluent, a stream containing a nitrogen compound such as ammonia or an amine, for example monoethanolamine, diethanolamine and/or monodiethanolamine can be injected upstream of the hydrotreatment step so as to ensure a sufficient amount of ammonium ions for combining the chloride ions formed during the hydrotreatment step in the form of ammonium chloride salts, thus making it possible to limit the formation of hydrochloric acid and thus to limit the corrosion downstream of the separation section.

Said gaseous effluent obtained on conclusion of the washing/separation step advantageously comprises hydrogen, preferably comprises at least 60% by volume, preferably at least 70% by volume, of hydrogen. Said gaseous effluent obtained on conclusion of the washing/separation step contains very little chlorine, generally at a content of less than 3 ppm by weight of chlorine, which enables it to be sent into a refining unit requiring hydrogen. According to one embodiment, said gaseous effluent can at least partly be recycled to the hydrotreatment step, the recycling system possibly comprising a purification section (for example for adsorption of heavy metals such as mercury).

The aqueous effluent obtained on conclusion of the washing/separation step advantageously comprises ammonium salts and/or hydrochloric acid.

A portion of said washed and purified second liquid effluent and/or of said washed and purified first liquid effluent can be recycled upstream of the hydrotreatment step, which makes it possible, on the one hand, to dilute the impurities and, on the other hand, to control the temperature in the hydrotreatment step in which reactions
 5 involved can be highly exothermic. Diluting the impurities makes it possible to limit undesirable reactions such as the polymerization of diolefins (formation of gum) and/or the formation of coke.

According to another embodiment, which is preferred, said washed and purified second liquid effluent and/or said washed and purified first liquid effluent is/are sent
 10 partially, and preferably completely, directly to the inlet of a steam cracking unit.

Fractionation step (optional)

According to one embodiment, said optionally pretreated and/or washed, purified second liquid effluent, and/or said optionally pretreated and/or washed, purified first liquid effluent, is subjected to at least one fractionation step in a fractionating unit
 15 upstream of the steam cracking step in order to obtain at least one gas stream and at least one liquid stream of C₃+ hydrocarbons, for example a naphtha cut and at least one middle distillates cut.

The term "naphtha cut" is understood to mean a hydrocarbon cut comprising compounds having a boiling point generally of less than or equal to 175°C, in
 20 particular between 80 and 175°C.

The term "middle distillates cut" is understood to mean a hydrocarbon cut comprising compounds having a boiling point generally of greater than 175°C. The heavy cut may include middle distillates such as a diesel cut and/or a kerosene cut. It may also comprise heavier compounds.

25 According to the destination or the use of the cuts obtained from the fractionation step, a person skilled in the art will adjust the cut points in the stripping and/or distillation operations. For example, it may be necessary to adjust the final point of the naphtha cut to 150, 175 or 200°C, or even 250°C.

The fractionation step makes it possible in particular to remove the gases dissolved
 30 in the liquid hydrocarbon effluent, for example ammonia, hydrogen sulfide and light C₁ to C₂ hydrocarbons.

The fractionation step is advantageously carried out at a pressure of less than or equal to 1.0 MPa abs., preferably between 0.1 and 1.0 MPa abs.

According to one embodiment, the fractionation step can be carried out in a section advantageously comprising at least one stripping column equipped with a reflux circuit comprising a reflux drum. Said optionally pretreated and/or washed, purified second liquid effluent and/or said optionally pretreated and/or washed, purified first liquid effluent may optionally be heated before entering the stripping column. Thus, the lightest compounds are entrained at the column top and into the reflux circuit comprising a reflux drum in which a gas/liquid separation takes place. The gas phase which comprises the light C1 to C2 hydrocarbons is withdrawn from the reflux drum as a gas stream. The naphtha cut is advantageously withdrawn from the reflux drum as a liquid stream. The middle distillates cut is advantageously withdrawn from the bottom of the stripping column.

According to another embodiment, the fractionation step can be carried out in a section comprising one or more separator drums. Advantageously, at least one "low-pressure, low-temperature" separator drum will be used in order to remove the gases dissolved in said optionally pretreated and/or washed, purified second liquid effluent and/or said optionally pretreated and/or washed, purified first liquid effluent.

According to other embodiments, the fractionation step can employ a stripping column followed by a distillation column or solely a distillation column.

According to yet another embodiment, the fractionation step may be carried out in a depentanizer column from which, in addition to the gas stream, a C3-C4 liquid stream and a C5+ liquid stream are withdrawn.

At least one of the liquid streams obtained by the fractionation step (naphtha cut, middle distillates cut, C3-C4 liquid stream or C5+ liquid stream) can be sent, in whole or in part, to the steam cracking step, on conclusion of which olefins may be (re)formed in order to participate in the formation of polymers.

According to another variant, a portion of the liquid C3-C4 stream may be sent into the steam cracking step, while another portion may be used as a fuel gas for providing a portion of the energy needed for the operation for example of the pyrolysis unit. Separating a liquid C3-C4 stream which can be sent into the steam

cracker or into the pyrolysis unit thus makes it possible to adjust the energy requirements of the pyrolysis unit.

The gas or liquid fraction(s) obtained from the fractionation step can be subjected to additional purification operation(s), for example washing with amines, water or sodium hydroxide.

Alternatively, a portion of at least one of the liquid streams obtained by the fractionation step is optionally recycled into at least one of the steps of the process (for example pretreatment or hydrotreatment) and/or sent to a unit for storing fuel, for example a unit for storing naphtha, a unit for storing middle distillates, obtained from conventional petroleum feedstocks.

Advantageously, the purification step(s) enable(s) the hydrogenation of at least 80%, and preferably of all, of the olefins (mono- and diolefins), but also the conversion, at least partly, of other impurities present in the feedstock, such as the aromatic compounds, metal compounds, sulfur compounds, nitrogen compounds, halogen compounds (in particular chlorine compounds), oxygen compounds.

Preferably, the nitrogen content at the outlet of the purification step is less than 10 ppm by weight.

Preferably, the sulfur content at the outlet of the purification step is less than 10 ppm by weight.

Preferably, the oxygen content at the outlet of the purification step is less than 10 ppm by weight.

Preferably, the metal content at the outlet of the purification step is less than 10 ppm by weight and with preference less than 2 ppm by weight, and the silicon content is less than 5 ppm by weight.

Preferably, the halogen (in particular chlorine) content at the outlet of the purification step is less than 3 ppm by weight.

The contents are given as relative concentrations by weight, percentages (%) by weight, part(s) per million (ppm) by weight or part(s) per billion (ppb) by weight, relative to the total weight of the stream under consideration.

Hydrocracking step (optional)

According to a variant, the process of the invention can comprise a hydrocracking step carried out either directly after the hydrotreatment step, or after the fractionation step on the middle distillates cut. The compounds having a boiling point of greater than 175°C contain, relative to lighter compounds, more naphthenic, naphthenic-aromatic and aromatic compounds, thus leading to a higher C/H ratio. This high ratio is a cause of coking in the steam cracker, thus requiring steam cracking furnaces dedicated to this cut. When it is desired to minimize the yield of these heavy compounds (middle distillates cut) and to maximize the yield of light compounds (naphtha cut), these compounds can be at least partly converted into light compounds by hydrocracking, a cut generally favoured for a steam cracking unit.

Thus, the process of the invention can comprise a hydrocracking step implemented in a hydrocracking reaction section, employing at least one fixed-bed reactor having n catalytic beds, n being an integer greater than or equal to 1, each comprising at least one hydrocracking catalyst, said hydrocracking reaction section being fed with said hydrotreated effluent and/or with the middle distillates cut obtained from the fractionation step and a gas stream comprising hydrogen, said hydrocracking reaction section being implemented at an average temperature of between 250 and 450°C, a hydrogen partial pressure of between 1.5 and 20.0 MPa abs. and an hourly space velocity of between 0.1 and 10.0 h⁻¹, to obtain a hydrocracked effluent which is sent into the fractionation step, and then preferably into the steam cracking step c).

Thus, said hydrocracking reaction section is advantageously implemented at an average temperature of between 250 and 480°C, preferably between 320 and 450°C, at a hydrogen partial pressure of between 1.5 and 20.0 MPa abs., preferably between 2 and 18.0 MPa abs., and at an hourly space velocity (HSV) of between 0.1 and 10.0 h⁻¹, preferably between 0.1 and 5.0 h⁻¹, preferentially between 0.2 and 4 h⁻¹. The hydrogen coverage in the hydrocracking step is advantageously between 80 and 2000 Nm³ of hydrogen per m³ of feedstock which feeds the hydrocracking step, and preferably between 200 and 1800 Nm³ of hydrogen per m³ of feedstock which feeds the hydrocracking step. The definitions of the average temperature (WABT), of the HSV and of the hydrogen coverage correspond to those described above.

The hydrotreatment step and the hydrocracking step can advantageously be carried out in the same reactor or in different reactors. When they are carried out in the same reactor, the reactor comprises several catalytic beds, the first catalytic beds

comprising the hydrotreatment catalyst(s) and the following catalytic beds comprising the hydrocracking catalyst(s).

The hydrocracking step can be carried out in one or two steps. When it is carried out in two steps, a separation of the effluent obtained from the first hydrocracking step is carried out, making it possible to obtain a heavy cut (unreacted middle distillates cut), which cut is introduced into the second hydrocracking step comprising a dedicated second hydrocracking reaction section different from the first hydrocracking reaction section. This configuration is particularly suitable when it is desired to produce only a naphtha cut. The preferred operating conditions and the catalysts used in the second hydrocracking step are those described for the first hydrocracking step. The operating conditions and catalysts used in the two hydrocracking steps can be identical or different.

The hydrocracking catalyst(s) used in the hydrocracking step(s) are conventional hydrocracking catalysts known to a person skilled in the art, of bifunctional type combining an acid function with a hydro-dehydrogenating function and optionally at least one binding matrix. The acid function is contributed by supports of high surface area (generally 150 to 800 m²/g) exhibiting a surface acidity, such as halogenated (in particular chlorinated or fluorinated) aluminas, combinations of boron and aluminium oxides, amorphous silica-aluminas and zeolites. The hydro-dehydrogenating function is contributed by at least one metal from group VIB of the Periodic Table and/or at least one metal from group VIII. Hydro-dehydrogenating functions of NiMo, NiMoW or NiW type are preferred.

LIST OF FIGURES

The particulars of the elements referenced in Figures 1 to 3 makes possible a better understanding of the invention, without the latter being limited to the specific embodiments illustrated in Figures 1 to 3. The various embodiments presented can be used alone or in combination with one another, without limitation of combination.

Figure 1 represents the diagram of a general embodiment of the process of the present invention.

A feedstock containing plastics and/or tyres and/or SRFs (1) is pyrolysed in a thermal or catalytic pyrolysis unit (U1) leading to the production of at least a first gaseous effluent (2) (pyrolysis gas) containing a mixture of H_2 , CO, CO_2 and hydrocarbons comprising C1 to C6 hydrocarbons, and a first liquid effluent containing

5 predominantly C7+ hydrocarbons (3) (pyrolysis oil).

Said first gaseous effluent (2) containing a mixture of H_2 , CO, CO_2 and hydrocarbons comprising C1 to C6 hydrocarbons is then compressed (K1) and then cooled (E1) in order to make possible the recovery, in a separator drum (D1), of a second liquid effluent (4) (condensate) containing predominantly C3 to C6 hydrocarbons and little

10 CO and CO_2 , and of a residual second gaseous effluent (8) concentrated in H_2 , CO and CO_2 (non-condensable gas stream).

As indicated in Figure 1, a solid stream (10) containing carbon ("char") is also withdrawn from the pyrolysis unit.

15 Said second liquid effluent (4) containing predominantly C3 to C6 hydrocarbons is advantageously sent into a purification unit (U2) employed for purifying said second liquid effluent (4) in order to achieve the specifications of a feedstock that can be treated in the steam cracking unit (3). When the purification unit is a hydrotreatment unit, hydrogen (5) is injected.

20 Said first liquid effluent containing predominantly C7+ hydrocarbons (3) is advantageously also introduced into the purification unit (U2).

The hydrotreatment unit may be followed by a washing/separation unit making it possible in particular to remove the chlorine (in HCl form and salts) (not shown).

Said second gaseous effluent (8) obtained from the separator drum (D1), which is

25 rich in H_2 , CO and CO_2 , can be sent, in whole or in part, to the pyrolysis unit in order to provide the energy needed for the process or to be exported and upgraded as fuel (9) in another installation.

Downstream of the hydrotreatment section or of the chlorine removal section, a separation unit (not shown in Figure 1) may be present and configured for separating

30 the "non-condensable" compounds (H_2 , CO, CO_2 , H_2S) and recover a stream of C3+ hydrocarbons. According to a preferred embodiment, the separation unit is a

stabilization unit (depentanizer) from which a liquid hydrocarbon stream rich in C5+ compounds (7) is withdrawn at the bottom of the column and a non-condensable gas stream and a cut containing C3-C4 hydrocarbons (6) are withdrawn at the top of the column after condensation of the top gas.

- 5 As shown in Figure 1, all or some of the hydrocarbon stream (6), optionally after a purification step (for example washing with amines, water or sodium hydroxide), is sent to the steam cracking unit (U3). As shown in the figure, the hydrocarbon stream (6) can be separated into two portions, one portion is used as fuel gas for providing a portion of the energy needed for the operation of the pyrolysis unit (U1) and the other
- 10 portion is sent to the steam cracking unit (U3) producing a mixture of C3-C4 olefins (e.g. propylene, butylene, butadiene).

According to the preferred embodiment of Figure 1, there is sharing of the steam cracking unit (U3) which is configured for treating the stream of C5+ hydrocarbons (7) and the hydrocarbon stream (6) containing C3-C4 hydrocarbons as a mixture.

- 15 Figure 2 represents the diagram of another specific embodiment of the process of the present invention which is based on the diagram of Figure 1 and in which said second liquid effluent (4) (condensate) obtained from the separator drum (D1) is sent, optionally after a chlorine removal step, into the steam cracking unit (U3)
- 20 without having undergone treatment in the purification unit U2. This mode of operation is applicable in particular for treating the condensate by coprocessing with another feedstock the specifications of which are compatible with those of a steam cracker feedstock.

- 25 Figure 3 represents the diagram of another specific embodiment of the process of the present invention which is based on the diagram of Figure 1 and in which at least a portion of the first liquid effluent (11) is introduced into a separation unit (D1), for example an absorbent column or a separator drum. The first liquid effluent (11) can also be mixed with the compressed first gaseous effluent (2) upstream or
- 30 downstream of the cooling thereof and the mixture is sent to the separation unit (D1) (dotted-line arrows).

The separation unit (D1) makes it possible to obtain an intermediate liquid effluent (11') and the residual second gaseous effluent (8) concentrated in H₂, CO and CO₂ which

is recycled into the pyrolysis unit (U1) in order to provide the energy needed for the process.

The intermediate liquid effluent (11'), enriched in light (in particular C2) hydrocarbon compounds by the "sponge" effect, is introduced into the second separation unit (D2) so as to obtain said second liquid effluent (4) containing predominantly C3+ (and a portion of the C2) hydrocarbons and a residual third gaseous effluent (12) concentrated in H₂, CO and CO₂.

Said residual third gaseous effluent (12) is concentrated with the light components which may include CO, CO₂, methane, but also comprises certain light hydrocarbon components, in particular ethylene and heavier hydrocarbon compounds. Said residual third gaseous effluent (12) is preferably recycled and mixed with the first gaseous effluent (2) upstream of the compression or cooling thereof, such that a portion of the light hydrocarbon components can be recovered in the liquid phase from the separation unit (D1).

Only the main steps, with the main streams, are shown in the figures, so as to allow a better understanding of the invention. It is clearly understood that all the items of equipment required for the operation are present (drums, pumps, exchangers, furnaces, columns, and the like), even if not represented.

EXAMPLES

Example 1

The example is based on the embodiment illustrated in Figure 1.

A feedstock of plastic waste originating from a sorting channel is thermally pyrolysed at a temperature of 470°C in the absence of oxygen in the unit U1. Said first liquid effluent (C7+) of the pyrolysate (3) resulting from the pyrolysis reaction is sent to a purification unit (U2) in order to saturate the olefins and diolefins and remove the undesired impurities in the steam cracking unit (U3), namely silicon, nitrogen, sulfur, chlorine, and metals (Si, P, K, Na, Hg, As, etc.). Said first gaseous effluent (2) rich in CO/CO₂, withdrawn from the pyrolysis unit U1, is then compressed and then cooled, and sent into a separator drum operating at a pressure of 1.1 MPa relative (11 barg) and at a temperature of 40°C, thus making it possible to separate a second liquid effluent (4) rich in hydrocarbons (C3+) and depleted in CO/CO₂ from a second

gaseous effluent rich in H_2 , CO and CO_2 (8) which is used to provide the energy needed for the pyrolysis reaction (U1). Said second liquid effluent (4) (condensate) obtained from the drum D1, having an acceptable content of CO and CO_2 , is sent into the unit U2 in order to reduce the content of impurities of Si, N, metals and in particular chlorine, which is still too high with respect to the specification of the steam cracking unit (U3). The stream 4 is then treated as a mixture with the pyrolysate (3) in the purification unit (U2) in order to achieve the specifications required at the inlet of the steam cracker (U3).

Table 1 indicates the pressure, temperature and flow rate of the streams 2, 4 and 8.

In the example below (Table 2), said first liquid effluent (3) represents 70% by weight of the plastic feedstock introduced to the pyrolysis unit (U1), while said second liquid effluent (4) represents 8% by weight of the plastic feedstock introduced to the pyrolysis unit (U1). Thus, by recombining the two streams (3) and (4), the material yield goes from 70% to 78%, i.e. an increase of around 11%. This increase in yield remains the same at the outlet of the purification unit (U2) and therefore at the inlet of the steam cracking unit (U3), provided that all the hydrocarbon streams produced by the purification unit (U2) are sent into the steam cracking unit (U3). Thus, this implies that, if the purification step carried out in the purification unit U2 is followed by a step of stabilization (removal of the non-condensable gases), all of the liquid effluents containing hydrocarbons obtained from the stabilization step are sent to the steam cracking unit (U3) which makes it possible to increase the olefin yield.

Table 1

	Stream 2	Stream 4	Stream 8
Pressure, barg	0.5	11	11
Temperature	30	40	40
Flow rate, kg/h	20	8	12
Composition, wt.%			
CO+CO ₂	4	0.3	6.4
C ₂ - and H ₂	11	2.7	16.6
C ₃	35	25	41
C ₄	40	52	32
C ₅ +	10	20	4

Table 2

	Stream 1	Stream 4	Stream 3	Streams 4 + 3
Flow rate, kg/h	100	8	70	78 (+11%)

Example 2

Example 2 is based on the embodiment illustrated in Figure 3.

Example 2 is carried out under the same pyrolysis conditions and with the same plastic feedstock of Example 1.

In this example, the entirety of said first liquid effluent (C7+) (11) recovered from the pyrolysis unit (U1) is sent with the compressed and then cooled first gaseous effluent (2) to the top of an absorbent column (D1) operating at 12 barg and at 40°C. Before being brought into contact, the first gaseous effluent (2) is compressed and cooled as in Example 1 and then introduced at the bottom of the absorbent column (D1).

Recovered from the absorption column (D1) are an intermediate liquid effluent (11') rich in hydrocarbons (C3+) and depleted in CO/CO₂ and a residual second gaseous effluent rich in H₂, CO and CO₂ (8) which is used to provide the energy needed for the pyrolysis reaction (U1). Said intermediate liquid effluent (11') is sent into a separation unit (D2) which is a distillation column.

Recovered from the separation unit (D2) are a residual third gaseous effluent (12) which is entirely recycled to the compressor (K1) and a second liquid effluent (4) which is introduced into the purification unit (U2). The stream (4) is then treated as a mixture with the pyrolysate (3) in the purification unit (U2) in order to achieve the specifications required at the inlet of the steam cracker (U3).

Table 3 indicates the operating conditions under which the bringing into contact/mixing in the separation unit (D1) is carried out between the first liquid effluent (11), representing 70% by weight of the streams recovered from the unit U1, with the first gaseous effluent (2), representing 20% by weight of the streams collected from the unit U1. This table also indicates the composition of the streams (2), (11), (4), (8) and (12) and also their content of impurities (chloromethane).

Table 4 indicates the flow rates of the streams (1), (4) and (8).

Table 3

	Stream 2	Stream 11	Stream 4	Stream 8	Stream 12
Pressure, barg	0.5	12	11	12	10.8
Temperature, °C	30	30	90	40	40
Flow rate, kg/h	20	70	87.6	2.4	3.4
Composition, wt.%					
CO+CO ₂	4	< 0.1	< 0.005	33	8
C1 and H ₂	2	< 0.1	< 0.1	17	2
C2	9	< 0.1	1	36	43
C3	35	< 0.1	7	7	32
C4	40	1	10	3	13
C5+	10	99	82	4	2
Impurities, ppm by weight					
Chloromethane	50	< 1	11	5	31

Table 4

	Stream 1	Stream 4	Stream 8
Flow rate, kg/hr	100	87.6	2.4

As shown in Tables 3 and 4, the stream (4) recovered from the separation unit (D2) represents approximately 87% by weight of the feedstock treated in the unit U1. The stream (4) has a low content of CO+CO₂ (less than 50 ppm) and essentially few light C1 hydrocarbons, but comprises a portion of the upgradable C2 hydrocarbons. This therefore improves the olefin production yield when the stream (4) is treated in the purification unit (U2) and the effluent is steam cracked in the unit U3.

The second gaseous effluent (8), the flow rate of which is reduced to 2.4%, has a reduced content of organic chlorides, such as chloromethane, from 50 ppm initially to 5 ppm. The stream (8) is therefore smaller in quantity and has a lower impurity content, which enables easy upgrading, for example as a fuel gas.

CLAIMS

1. Process for producing olefins from a feedstock containing plastic and/or tyres and/or solid recovered fuels, said process comprising the following steps:
 - 5 (a) performing a step of pyrolysis of a feedstock containing plastic and/or tyres and/or solid recovered fuels in a pyrolysis unit so as to recover at least a first gaseous effluent (2) containing a mixture of H₂, CO, CO₂ and hydrocarbons comprising C1 to C6 hydrocarbons, and a first liquid effluent (3) containing predominantly C7+ hydrocarbons;
 - 10 (b) compressing and then cooling said first gaseous effluent (2) obtained from step a), and then separating said compressed and cooled first gaseous effluent in a separation unit so as to obtain a second liquid effluent (4) containing predominantly C3+ hydrocarbons and a residual second gaseous effluent (8) concentrated in H₂, CO and CO₂;
 - 15 (c) introducing said second liquid effluent (4) into a steam cracking unit in the presence of steam so as to produce olefins.
2. Process according to the preceding claim, wherein said first liquid effluent (3) is introduced into said steam cracking unit of step c).
3. Process according to one of the preceding claims, wherein in step b) at least a
 - 20 portion of the first liquid effluent (11) is introduced into said separation unit, as a mixture or not as a mixture with said compressed first gaseous effluent (2), and then the mixture is separated so as to obtain an intermediate liquid effluent (11') and said residual second gaseous effluent (8) concentrated in H₂, CO and CO₂, and then said intermediate liquid effluent (11') is separated in a second separation
 - 25 unit so as to obtain said second liquid effluent (4) containing predominantly C3+ hydrocarbons and a residual third gaseous effluent (12) concentrated in H₂, CO and CO₂.
4. Process according to one of the preceding claims, wherein a step of purification of said second liquid effluent (4) obtained from step b) is performed in a purification
 - 30 unit upstream of the steam cracking unit of step c).

5. Process according to one of the preceding claims, wherein a step of purification of said first liquid effluent (3) obtained from step a) is performed in a purification unit upstream of the steam cracking unit of step c).
6. Process according to one of the preceding claims, wherein step b) is performed
5 such that during the separation(s) the pressure is between 0.5 and 2.5 MPa relative, preferably between 1.0 and 1.5 MPa relative, and the temperature is between 20 and 55°C, preferably between 30 and 45°C.
7. Process according to one of Claims 4 to 6, wherein the purification step comprises
10 a step of pretreating said second liquid effluent (4) obtained from step b) and/or said first liquid effluent (3) obtained from step a), said pretreatment step being implemented upstream of step c), and comprises an adsorption step and/or a filtration step and/or a centrifugation step and/or a decantation step and/or an electrostatic separation step and/or a step of washing with an aqueous solution and/or a gas stripping step.
- 15 8. Process according to one of Claims 4 to 7, wherein the purification step comprises a hydrotreatment step implemented in a hydrotreatment reaction section, employing at least one fixed-bed reactor having n catalytic beds, n being an integer greater than or equal to 1, each comprising at least one hydrotreatment catalyst, said hydrotreatment reaction section being fed with said optionally pretreated
20 second liquid effluent obtained from step b) and/or said optionally pretreated first liquid effluent obtained from step a) and a gas stream comprising hydrogen, said hydrotreatment reaction section being implemented at an average temperature of between 150 and 430°C, a hydrogen partial pressure of between 1.0 and 10.0 MPa abs. and an hourly space velocity of between 0.1 and 10.0 h⁻¹ in order to obtain a
25 purified second liquid effluent and/or a purified first liquid effluent.
9. Process according to the preceding claim, wherein said hydrotreatment catalyst comprises a support chosen from alumina, silica, silica-aluminas, magnesia, clays and mixtures thereof and a hydro-dehydrogenating function comprising either at least one element from group VIII and at least one element from group VIB, or at
30 least one element from group VIII.
10. Process according to either of Claims 8 and 9, wherein the hydrotreatment step is followed by a washing/separation step, fed with said optionally pretreated, purified

second liquid effluent, and/or said optionally pretreated, purified first liquid effluent, and an aqueous solution in order to obtain at least a gaseous effluent, an aqueous effluent and said washed and purified second liquid effluent and/or said washed and purified first liquid effluent.

- 5 11. Process according to one of Claims 4 to 10, wherein said optionally pretreated and/or washed, purified second liquid effluent, and/or said optionally pretreated and/or washed, purified first liquid effluent, is subjected to at least one fractionation step in a fractionating unit in order to obtain at least one gas stream and at least one liquid stream of C₃+ hydrocarbons.
- 10 12. Process according to the preceding claim, wherein the separation unit comprises a depentanizer column from which a liquid C₃-C₄ hydrocarbon stream and a liquid stream of C₅+ hydrocarbons are withdrawn.
13. Process according to Claims 11 and 12, wherein at least one of the liquid streams obtained from the fractionation step is at least in part sent into the steam cracking unit of step c).
- 15 14. Process according to one of the preceding claims, wherein the steam cracking step c) is carried out in at least one pyrolysis furnace at a temperature of between 700 and 900°C and at a pressure of between 0.05 and 0.3 MPa relative in the presence of steam.
- 20 15. Process according to one of the preceding claims, wherein, in the steam cracking step c), the residence time of the hydrocarbon compounds is less than or equal to 1.0 second and the amount of water introduced, in the form of steam, is between 0.3 and 3.0 kg of water per kg of hydrocarbon compounds at the inlet of the steam cracking step c).
- 25 16. Process according to one of the preceding claims, wherein the feedstock consists of plastic and/or tyres and/or solid recovered fuels.