

CLAIMS

1. A system for transforming a hydrocarbon-containing inflow gas into outflow gas products, comprising:
- 5 a gas delivery subsystem, a plasma reaction chamber, a microwave subsystem, and an effluent separation and disposal system;
- wherein the gas delivery subsystem:
- i. is in fluid communication with the plasma reaction chamber and directs one or more gases into the plasma reaction chamber, wherein
- 10 the one or more gases comprises the hydrocarbon-containing inflow gas; and
- ii. comprises a delivery conduit and a gas injector,
- a. wherein the delivery conduit is in fluid communication with the gas injector, wherein the delivery conduit delivers the one or more
- 15 gases to the gas injector, and wherein the delivery conduit comprises a feed gas conveying circuit that delivers the hydrocarbon-containing inflow gas into the gas injector, and
- b. wherein the gas injector delivers the one or more gases into the plasma reaction chamber;
- 20 wherein the plasma reaction chamber:
- i. is in fluid communication with the effluent separation and disposal system; and
- ii. is disposed within an elongate reactor tube having a proximal and a distal end, and wherein the elongate reactor tube is dimensionally
- 25 adapted for interaction with the microwave subsystem;
- wherein the microwave subsystem:
- i. directs microwave energy into the plasma reaction chamber to energize the hydrocarbon-containing inflow gas, thereby forming a plasma in the plasma reaction chamber, and wherein the plasma effects the
- 30 transformation of a hydrocarbon in the hydrocarbon-containing inflow gas into the outflow gas products, wherein the outflow gas products comprise acetylene and hydrogen;
- ii. comprises an applicator for directing microwave energy towards the plasma reaction chamber, and wherein the plasma reaction chamber is

disposed in the region of the elongate reactor tube that passes through the applicator and intersects it perpendicularly; and

- iii. further comprises a power supply, a magnetron, and a waveguide, whereby the power supply energizes the magnetron to produce microwave energy, the microwave energy being conveyed by the waveguide to the applicator, and wherein the applicator directs the microwave energy towards the reaction chamber within the elongate reactor tube, thereby forming the plasma in the plasma reaction chamber,

wherein the outflow gas products flow within the plasma reaction chamber towards the distal end of the elongate reactor tube and emerge from the distal end of the elongate reactor tube forming an effluent stream that enters the effluent separation and disposal subsystem, and

wherein the effluent separation and disposal system comprises a short-cycle temperature swing adsorption system adapted for separating the hydrogen from the effluent stream.

2. A system for transforming a hydrocarbon-containing inflow gas into a VCM (vinyl chloride monomer)-containing liquid product, comprising:

a gas delivery subsystem, a plasma reaction chamber, a microwave subsystem, and a VCM reactor and separator subsystem;

wherein the gas delivery subsystem:

- i. is in fluid communication with the plasma reaction chamber and directs one or more gases into the plasma reaction chamber, wherein the one or more gases comprises the hydrocarbon-containing inflow gas; and
- ii. comprises a delivery conduit and a gas injector,
- a. wherein the delivery conduit is in fluid communication with the gas injector, wherein the delivery conduit delivers the one or more gases to the gas injector, and wherein the delivery conduit comprises a feed gas conveying circuit that delivers the hydrocarbon-containing inflow gas into the gas injector, and
- b. wherein the gas injector delivers the one or more gases into the plasma reaction chamber;

wherein the plasma reaction chamber:

- i. is in fluid communication with the effluent separation and disposal system; and
- ii. is disposed within an elongate reactor tube having a proximal and a distal end, and wherein the elongate reactor tube is dimensionally adapted for interaction with the microwave subsystem;

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wherein the microwave subsystem:

- i. directs microwave energy into the plasma reaction chamber to energize the hydrocarbon-containing inflow gas, thereby forming a plasma in the plasma reaction chamber, and wherein the plasma effects the transformation of a hydrocarbon in the hydrocarbon-containing inflow gas into outflow gas products, wherein the outflow gas products comprise acetylene and hydrogen;
- ii. comprises an applicator for directing microwave energy towards the plasma reaction chamber, and wherein the plasma reaction chamber is disposed in the region of the elongate reactor tube that passes through the applicator and intersects it perpendicularly; and
- iii. further comprises a power supply, a magnetron, and a waveguide, whereby the power supply energizes the magnetron to produce microwave energy, the microwave energy being conveyed by the waveguide to the applicator, and wherein the applicator directs the microwave energy towards the reaction chamber within the elongate reactor tube, thereby forming the plasma in the plasma reaction chamber,

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wherein the outflow gas products flow within the plasma reaction chamber towards the distal end of the elongate reactor tube and emerge from the distal end of the elongate reactor tube forming an outflow stream that enters the VCM reactor and separator subsystem, wherein the VCM reactor and separator subsystem comprises a VCM reactor and a plurality of separators;

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- i. wherein the plurality of separators comprise a first separation system, a second separation system and a third separation system;
- ii. wherein the first separation system is in fluid communication with the elongate reactor tube, and is an effluent separator adapted to remove higher acetylenes and aromatics from the outflow stream, producing a

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purified effluent stream to deliver to the VCM reactor, wherein the purified effluent stream comprises acetylene gas; and wherein:

(a) the VCM reactor is in fluid communication with the first separation system and the second separation system;

(b) the VCM reactor receives the purified effluent stream and directs the purified effluent stream across a catalytic bed that reacts the acetylene gas with a stream of hydrogen chloride gas to produce VCM; and

(c) the VCM reactor expels the VCM formed therein in a gaseous VCM-containing effluent stream that is directed into the second separation system;

iii. wherein the second separation system is a condensing system comprising a compressor, a chiller, and a liquid-gas separator, the second separation system being adapted to condense VCM into liquid VCM and separate liquid VCM from the VCM effluent stream, yielding the VCM-containing liquid product and a residual gas stream; and

iv. wherein the residual gas stream is directed into a third separation system in fluid communication with the second separation system, wherein the third separation system processes the residual gas stream to separate purified hydrogen from the residual gas.

3. A system for transforming a hydrocarbon-containing inflow gas into a VCM (vinyl chloride monomer)-containing liquid product, comprising:

a gas delivery subsystem, a plasma reaction chamber, a microwave subsystem, and a VCM reactor and separator subsystem;

wherein the gas delivery subsystem:

i. is in fluid communication with the plasma reaction chamber and directs one or more gases into the plasma reaction chamber, wherein the one or more gases comprises the hydrocarbon-containing inflow gas; and

ii. comprises a delivery conduit and a gas injector,
a. wherein the delivery conduit is in fluid communication with the gas injector, wherein the delivery conduit delivers the one or more gases to the gas injector, and wherein the delivery conduit

comprises a feed gas conveying circuit that delivers the

hydrocarbon-containing inflow gas into the gas injector, and

- b. wherein the gas injector delivers the one or more gases into the plasma reaction chamber;

5 wherein the plasma reaction chamber:

- i. is in fluid communication with the effluent separation and disposal system; and

- ii. is disposed within an elongate reactor tube having a proximal and a distal end, and wherein the elongate reactor tube is dimensionally adapted for interaction with the microwave subsystem;

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wherein the microwave subsystem:

- i. directs microwave energy into the plasma reaction chamber to energize the hydrocarbon-containing inflow gas, thereby forming a plasma in the plasma reaction chamber, and wherein the plasma effects the transformation of a hydrocarbon in the hydrocarbon-containing inflow gas into outflow gas products, wherein the outflow gas products comprise acetylene and hydrogen;

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- ii. comprises an applicator for directing microwave energy towards the plasma reaction chamber, and wherein the plasma reaction chamber is disposed in the region of the elongate reactor tube that passes through the applicator and intersects it perpendicularly; and

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- iii. further comprises a power supply, a magnetron, and a waveguide, whereby the power supply energizes the magnetron to produce microwave energy, the microwave energy being conveyed by the waveguide to the applicator, and wherein the applicator directs the microwave energy towards the reaction chamber within the elongate reactor tube, thereby forming the plasma in the plasma reaction chamber,

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wherein the outflow gas products flow within the plasma reaction chamber towards the distal end of the elongate reactor tube and emerge from the distal end of the elongate reactor tube forming an outflow stream that enters the VCM reactor and separator subsystem, wherein the VCM reactor and separator subsystem comprises a VCM reactor and a plurality of separators;

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- i. wherein the plurality of separators comprises a first separation system, a second separation system and a third separation system;
- ii. wherein the first separation system, in fluid communication with the elongate reactor tube, is an effluent separator adapted to remove higher acetylenes and aromatics from the outflow stream, producing a purified effluent stream comprising acetylene gas and hydrogen;
- iii. wherein the purified effluent stream enters the second separation system in fluid communication with the first separation system;
- iv. wherein the hydrogen is separated from the purified effluent stream, thereby producing a separate hydrogen stream and a concentrated effluent stream comprising acetylene gas;
- v. wherein the concentrated effluent stream is delivered to the VCM reactor in fluid communication with the second separation system; wherein (a) the VCM reactor receives the concentrated effluent stream and directs the concentrated effluent stream across a catalytic bed that reacts the acetylene gas with a stream of hydrogen chloride gas to produce VCM; and (b) the VCM reactor expels the VCM formed therein in a gaseous VCM-containing effluent stream that is directed into the third separation system;
- vi. wherein the third separation system, in fluid communication with the VCM reactor, is a condensing system comprising a compressor, a chiller, and a liquid-gas separator, the third separation system being adapted to condense liquid VCM and separate it from the VCM effluent stream, yielding the liquid VCM product and a residual gas stream.
4. An integrated acetylene-based vitamin synthesis system for synthesizing a vitamin product, comprising:
- a plasma-based hydrocarbon processing system and a vitamin manufacturing system,
- wherein the plasma-based hydrocarbon processing system comprises a gas delivery subsystem, a plasma reaction chamber, a microwave subsystem, and a set of separator subsystems,
- wherein the gas delivery subsystem:
- i. is in fluid communication with the plasma reaction chamber and directs one or more gases into the plasma reaction chamber, wherein

the one or more gases comprises the hydrocarbon-containing inflow gas; and

- ii. comprises a delivery conduit and a gas injector,
 - a. wherein the delivery conduit is in fluid communication with the gas injector, wherein the delivery conduit delivers the one or more gases to the gas injector, and wherein the delivery conduit comprises a feed gas conveying circuit that delivers the hydrocarbon-containing inflow gas into the gas injector, and
 - b. wherein the gas injector delivers the one or more gases into the plasma reaction chamber;

wherein the plasma reaction chamber:

- i. is in fluid communication with the effluent separation and disposal system; and
- ii. is disposed within an elongate reactor tube having a proximal and a distal end, and wherein the elongate reactor tube is dimensionally adapted for interaction with the microwave subsystem;

wherein the microwave subsystem:

- i. directs microwave energy into the plasma reaction chamber to energize the hydrocarbon-containing inflow gas, thereby forming a plasma in the plasma reaction chamber, and wherein the plasma effects the transformation of a hydrocarbon in the hydrocarbon-containing inflow gas into outflow gas products, wherein the outflow gas products comprise acetylene and hydrogen;
- ii. comprises an applicator for directing microwave energy towards the plasma reaction chamber, and wherein the plasma reaction chamber is disposed in the region of the elongate reactor tube that passes through the applicator and intersects it perpendicularly; and
- iii. further comprises a power supply, a magnetron, and a waveguide, whereby the power supply energizes the magnetron to produce microwave energy, the microwave energy being conveyed by the waveguide to the applicator, and wherein the applicator directs the microwave energy towards the reaction chamber within the elongate reactor tube, thereby forming the plasma in the plasma reaction chamber,

wherein the outflow gas products flow within the plasma reaction chamber towards the distal end of the elongate reactor tube and emerge from the distal end of the elongate reactor tube forming an outflow stream that enters the set of separator subsystems;

- 5 i. wherein the set of separator subsystems comprises an effluent separator, an acetylene separator, and a hydrogen separator;
- ii. wherein the effluent separator is in fluid communication with the elongate reactor tube, and is adapted to remove higher acetylenes and aromatics from the outflow stream, producing a purified effluent
- 10 stream comprising acetylene gas and hydrogen;
- iii. wherein the acetylene separator is in fluid communication with the effluent separator, and separates a purified acetylene product from the purified effluent stream, thereby forming a remaining effluent stream, and wherein the acetylene separator is in fluid communication with the
- 15 vitamin manufacturing system and directs at least a portion of the purified acetylene product into the vitamin manufacturing system; and
- iv. wherein acetylene separator is further in fluid communication with the hydrogen separator and directs the remaining effluent stream into the hydrogen separator, wherein the hydrogen separator separates
- 20 hydrogen from the remaining effluent stream, producing a purified hydrogen product;
- v. wherein the hydrogen separator is also in fluid communication with the vitamin manufacturing system and directs at least a portion of the purified hydrogen product into the vitamin manufacturing system; and
- 25 wherein the vitamin manufacturing system comprises a vitamin reaction plant and a controller, whereby the controller regulates entry of the portion of purified acetylene product and the portion of purified hydrogen product into the vitamin reaction plant, and
- wherein the vitamin reaction plant synthesizes the vitamin product using the
- 30 purified acetylene product and/or the purified hydrogen product.

5. An integrated acetylene-based synthesis system for synthesizing acetylene black, comprising:

a plasma-based hydrocarbon processing system and an acetylene-black manufacturing system,

wherein the plasma-based hydrocarbon processing system comprises a gas delivery subsystem, a plasma reaction chamber, a microwave subsystem, and a set of separation and purification subsystems,

wherein the gas delivery subsystem:

- i. is in fluid communication with the plasma reaction chamber and directs one or more gases into the plasma reaction chamber, wherein the one or more gases comprises the hydrocarbon-containing inflow gas; and
- ii. comprises a delivery conduit and a gas injector,

wherein the delivery conduit is in fluid communication with the gas injector, wherein the delivery conduit delivers the one or more gases to the gas injector, and wherein the delivery conduit comprises a feed gas conveying circuit that delivers the hydrocarbon-containing inflow gas into the gas injector, and wherein the gas injector delivers the one or more gases into the plasma reaction chamber;

wherein the plasma reaction chamber:

- i. is in fluid communication with the effluent separation and disposal system; and
- ii. is disposed within an elongate reactor tube having a proximal and a distal end, and wherein the elongate reactor tube is dimensionally adapted for interaction with the microwave subsystem;

wherein the microwave subsystem:

- i. directs microwave energy into the plasma reaction chamber to energize the hydrocarbon-containing inflow gas, thereby forming a plasma in the plasma reaction chamber, and wherein the plasma effects the transformation of a hydrocarbon in the hydrocarbon-containing inflow gas into outflow gas products, wherein the outflow gas products comprise acetylene and hydrogen;
- ii. comprises an applicator for directing microwave energy towards the plasma reaction chamber, and wherein the plasma reaction chamber is disposed in the region of the elongate reactor tube that passes through the applicator and intersects it perpendicularly; and

iii. further comprises a power supply, a magnetron, and a waveguide, whereby the power supply energizes the magnetron to produce microwave energy, the microwave energy being conveyed by the waveguide to the applicator, and wherein the applicator directs the microwave energy towards the reaction chamber within the elongate reactor tube, thereby forming the plasma in the plasma reaction chamber,

wherein the outflow gas products flow within the plasma reaction chamber towards the distal end of the elongate reactor tube and emerge from the distal end of the elongate reactor tube forming an outflow stream that enters the set of separation and purification subsystems;

i. wherein the set of separation and purification subsystems comprises an acetylene separator in fluid communication with the elongate reactor tube, adapted to remove higher acetylenes and aromatics from the outflow stream, producing a purified effluent stream comprising acetylene gas and hydrogen and an offgas stream comprising higher acetylenes and aromatics;

ii. wherein the set of separation and purification subsystems further comprises a hydrogen separator in fluid communication with the elongate reactor tube, wherein the hydrogen separator separates hydrogen as a hydrogen stream from at least one of the outflow stream and the purified effluent stream; and

iii. wherein the set of separation and purification subsystems produces an acetylene-rich feedstock stream; and

an acetylene-black manufacturing system, wherein the acetylene-black manufacturing system comprises an acetylene decomposition reactor in fluid communication with the separation and purification subsystems, and wherein the acetylene decomposition reactor produces acetylene black and hydrogen from the acetylene-rich feedstock stream produced by the separation and purification subsystems.

6. An integrated acetylene-based synthesis system for producing hydrogen, comprising a plasma-based hydrocarbon processing subsystem and an acetylene-black manufacturing subsystem:

- a. wherein the plasma-based hydrocarbon processing subsystem comprises a gas delivery subsystem, a plasma reaction chamber, a microwave subsystem, and a set of separation and purification subsystems,

wherein the gas delivery subsystem:

- 5 i. is in fluid communication with the plasma reaction chamber and directs one or more gases into the plasma reaction chamber, wherein the one or more gases comprises the hydrocarbon-containing inflow gas; and
- ii. comprises a delivery conduit and a gas injector,

10 wherein the delivery conduit is in fluid communication with the gas injector, wherein the delivery conduit delivers the one or more gases to the gas injector, and wherein the delivery conduit comprises a feed gas conveying circuit that delivers the hydrocarbon-containing inflow gas into the gas injector, and wherein the gas injector delivers the one or more gases into the plasma reaction chamber;

15 wherein the plasma reaction chamber:

- i. is in fluid communication with the set of separation and purification subsystems; and
- ii. is disposed within an elongate reactor tube having a proximal and a distal end, and wherein the elongate reactor tube is dimensionally
- 20 adapted for interaction with the microwave subsystem;

wherein the microwave subsystem:

- i. directs microwave energy into the plasma reaction chamber to energize the hydrocarbon-containing inflow gas, thereby forming a plasma in the plasma reaction chamber, and wherein the plasma effects the
- 25 transformation of a hydrocarbon in the hydrocarbon-containing inflow gas into outflow gas products, wherein the outflow gas products comprise acetylene and hydrogen;
- ii. comprises an applicator for directing microwave energy towards the plasma reaction chamber, and wherein the plasma reaction chamber is
- 30 disposed in the region of the elongate reactor tube that passes through the applicator and intersects it perpendicularly; and
- iii. further comprises a power supply, a magnetron, and a waveguide, whereby the power supply energizes the magnetron to produce microwave energy, the microwave energy being conveyed by the

waveguide to the applicator, and wherein the applicator directs the microwave energy towards the reaction chamber within the elongate reactor tube, thereby forming the plasma in the plasma reaction chamber,

5 wherein the outflow gas products flow within the plasma reaction chamber towards the distal end of the elongate reactor tube and emerge from the distal end of the elongate reactor tube forming an outflow stream that enters the set of separation and purification subsystems; wherein the set of separation and purification subsystems:

- 10 i. comprises, in fluid communication with the elongate reactor tube, an effluent separator that removes higher acetylenes and aromatics from the outflow stream, producing (a) a purified effluent stream comprising acetylene gas and hydrogen and (b) an offgas stream comprising higher acetylenes and aromatic impurities;
- 15 ii. further comprises, in fluid communication with the effluent separator, an acetylene separator which produces an acetylene-rich feedstock stream and a remaining effluent stream as separate streams;
- iii. further comprises a hydrogen separator in fluid communication with the acetylene separator, wherein the hydrogen separator separates
- 20 hydrogen as a purified hydrogen stream from the remaining effluent stream,
1. wherein the hydrogen stream is separable into one or more of a recycled hydrogen stream, an integrated hydrogen stream, and an external hydrogen stream,
- 25 2. wherein the external hydrogen stream is isolated from the integrated acetylene-based synthesis system as a first isolated hydrogen stream; and

b. wherein:

- 30 i. the acetylene-black manufacturing system comprises an acetylene decomposition reactor in fluid communication with the set of separation and purification subsystems and wherein:
- ii. the acetylene decomposition reactor produces acetylene black and hydrogen from the acetylene-rich feedstock stream, and

iii. the hydrogen produced by the acetylene decomposition reactor is separable from the integrated acetylene-based synthesis system as a second isolated hydrogen stream.

5 7. The system of any one of claims 1 to 6, wherein the hydrocarbon-containing inflow gas is derived from a mixed gas source.

8. The system of claim 7, wherein the mixed gas source is natural gas.

10 9. The system of claim 7, wherein the mixed gas source is a biogas.

10. The system of any one of claims 1 to 6, wherein the hydrocarbon-containing inflow gas comprises a gas selected from the group consisting of methane, ethane, propane, and butane.

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11. The system of claim 10, wherein the hydrocarbon-containing inflow gas consists essentially of methane.

12. The system of claim 10, wherein the hydrocarbon-containing inflow gas comprises methane.

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13. The system of any one of claims 1 to 6, wherein the delivery conduit comprises an additional gas conveying circuit that delivers an additional gas into the gas injector.

25 14. The system of claim 13, wherein the additional gas is hydrogen.

15. The system of claim 13, wherein the additional gas conveying circuit is an auxiliary gas conveying circuit that delivers an auxiliary gas into the gas injector.

30 16. The system of claim 13, wherein the additional conveying circuit is a recycled gas conveying circuit that delivers a recycled gas into the gas injector.

17. The system of claim 16, wherein the recycled gas comprises hydrogen.

18. The system of claim 16, wherein the recycled gas consists essentially of hydrogen.
19. The system of any one of claims 1 to 6, wherein the delivery conduit delivers each of the one or more gases into the gas injector through a separate pathway.
- 5 20. The system of any one of claims 1 to 6, wherein the gas injector comprises an injector body comprising two or more coaxially arranged and separate gas feeds, a first gas feed conveying the hydrocarbon-containing inflow gas into the plasma reaction chamber through a first set of one or more nozzles, and the second gas feed conveying the additional gas into the plasma reaction chamber through a second set of one or more nozzles.
- 10 21. The system of claim 20, wherein at least one of the one or more nozzles is oriented at an angle to a longitudinal axis of the plasma reaction chamber or at an angle to a transverse axis of the plasma reaction chamber.
- 15 22. The system of claim 20, wherein at least one of the one or more nozzles is oriented at an angle to a longitudinal axis or a transverse axis of the injector body.
- 20 23. The system of claim 20, whereby combined gas flow from the first set of nozzles and the second set of nozzles creates a vortex flow within the plasma reaction chamber.
24. The system of any one of claims 1 to 6, wherein the elongate reactor tube is a quartz tube.
- 25 25. The system of any one of claims 1 to 6, wherein the plasma reaction chamber is disposed approximately at the midportion of the elongate reactor tube.
- 30 26. The system of claim 13, wherein the gas injector conveys the hydrocarbon-containing inflow gas and the additional gas into a proximal portion of the elongate reactor tube, wherein the hydrocarbon-containing inflow gas and the additional gas flow distally therefrom towards the plasma reaction chamber.

27. The system of claim 26, wherein the gas injector is positioned centrally within the proximal portion, and the first set of one or more nozzles and the second set of one or more nozzles are oriented peripherally.
- 5 28. The system of claim 26, wherein the gas injector is positioned peripherally within the proximal portion, and the first set of one or more nozzles and the second set of one or more nozzles are oriented centrally.
- 10 29. The system of any one of claims 1 to 6, wherein the applicator is a single-arm applicator.
30. The system of any one of claims 1 to 6, wherein the magnetron produces L-band microwave energy.
- 15 31. The system of claim 1, wherein the effluent separation and disposal subsystem further comprises a solids filter and a cold trap.
32. The system of claim 1, wherein the effluent separation and disposal subsystem further comprises a regular-cycle adsorption system.
- 20 33. The system of claim 32, wherein the regular-cycle temperature swing adsorption system is adapted for removing higher acetylenes from the effluent stream.
- 25 34. The system of claim 33, wherein the regular-cycle temperature swing adsorption system is positioned upstream from the short-cycle temperature swing adsorption system.
- 30 35. The system of claim 1, wherein the effluent separation and disposal subsystem further comprises an absorption column.
36. The system of claim 35, wherein the absorption column absorbs acetylene.

37. The system of claim 1, wherein the effluent separation and disposal subsystem further comprises a concentrated acid in an amount sufficient to oxidize higher-order hydrocarbons.
- 5 38. The system of claim 1, wherein the effluent separation and disposal subsystem further comprises a catalyst suitable for converting higher-order hydrocarbons into derivative compounds separable from the effluent stream.
- 10 39. The system of claim 1, wherein the effluent separation and disposal subsystem further comprises a condenser.
40. The system of claim 1, wherein the effluent separation and disposal subsystem further comprises a gas separation membrane array.
- 15 41. The system of claim 40, wherein the gas separation membrane array separates hydrogen from the effluent stream.
42. The system of claim 1, wherein the effluent separation and disposal subsystem further comprises a hydrogen separation subsystem.
- 20 43. The system of claim 42, wherein the hydrogen separation subsystem is in fluid communication with the recycled gas conveying circuit and wherein hydrogen collected by the hydrogen separation subsystem is recycled into the recycled gas conveying circuit.
- 25 44. The system of claim 1, wherein the effluent separation and disposal subsystem further comprises an acetylene separation subsystem.
- 30 45. The system of claim 1, further comprising a vacuum subsystem that produces a first reduced pressure environment for the outflow products passing through one or more components of the effluent separation and disposal subsystem.
46. The system of claim 45, wherein the vacuum subsystem produces a second reduced pressure environment within the elongate reactor tube.

47. The system of claim 46, wherein the vacuum subsystem produces a third reduced pressure environment for the gas delivery subsystem.
- 5 48. The system of claim 46, wherein the vacuum subsystem produces a first, second, and third reduced pressure environment.
49. The system of claim 48, wherein the first, second, and third reduced pressure environments are each independently within a range of about 30 to about 120 Torr.
- 10 50. The system of claim 49, wherein at least one of the reduced pressure environments is between 50 to about 100 Torr.
- 15 51. The system of claim 50, wherein at least one of the reduced pressure environments is between about 60 to about 80 Torr.
52. The system of claim 48, wherein the first reduced pressure environment has a pressure that is substantially higher than the pressure in the second reduced pressure environment and/or the third reduced pressure environment.
- 20 53. The system of claim 48, wherein the pressure in the second reduced pressure environment and the third reduced pressure environment is each independently between 120 and 280 Torr.
- 25 54. The system of claim 48, wherein the first, second, and third reduced pressure environments are substantially similar.
55. The system of claim 1, further comprising a cooling subsystem.
- 30 56. The system of claim 55, wherein the cooling subsystem comprises at least one of a water cooling subsystem and a gas cooling subsystem.
57. The system of claim 56, wherein the gas cooling subsystem comprises a nitrogen-based cooling circuit.

58. The system of claim 57, wherein the nitrogen-based cooling circuit comprises one or more enclosures for components of the system, whereby the one or more enclosures are sealed sufficiently to enclose nitrogen gas around the components and exclude oxygen therefrom.
59. The system of claim 1, further comprising a data management and safety subsystem.
60. The system of claim 2, wherein the first separation system comprises a prescrubber or a temperature swing adsorber.
61. The system of claim 2, wherein the VCM reactor comprises a housing enclosing the catalytic bed, and wherein the catalytic bed comprises a plurality of catalyst-containing tubes, each of the catalyst-containing tubes containing a plurality of catalyst pellets.
62. The system of claim 61, wherein each of the catalyst pellets comprises a support with a plurality of catalyst particles affixed to the support or deployed in proximity to the support, and wherein the support is penetrated by a plurality of pores through at least some of which the purified effluent stream and hydrogen chloride gas passes, thereby bringing the acetylene gas and the hydrogen chloride gas in contact with catalyst particles to produce VCM that exits through at least some of the pores to form a VCM-containing effluent stream that emerges from the VCM reactor as the VCM reactor effluent.
63. The system of claim 2, wherein the third separation system comprises a hydrogen separator.
64. The system of claim 2, wherein the hydrogen separator is a membrane separator or a pressure swing adsorber.
65. The system of claim 3, wherein the separate hydrogen stream is recycled to comprise one of the one or more gases that are directed into the plasma reaction chamber.

66. The system of claim 3, wherein the first separation system comprises a prescrubber or a temperature swing adsorber.
- 5 67. The system of claim 3, wherein the VCM reactor comprises a housing enclosing the catalytic bed, and wherein the catalytic bed comprises a plurality of catalyst-containing tubes, each of the catalyst-containing tubes containing a plurality of catalyst pellets.
- 10 68. The system of claim 67, wherein each of the catalyst pellets comprises a support with a plurality of catalyst particles affixed to the support or deployed in proximity to the support, and wherein the support is penetrated by a plurality of pores through at least some of which the concentrated effluent stream and hydrogen chloride gas passes, thereby bringing the acetylene gas and the hydrogen chloride gas in contact with catalyst particles to produce VCM that exits through at least some of the pores to form
15 a VCM-containing effluent stream that emerges from the VCM reactor as the VCM reactor effluent.
- 20 69. The system of claim 3, wherein the second separation system comprises a hydrogen separator.
70. The system of claim 69, wherein the hydrogen separator is a membrane separator or a pressure swing adsorber.
- 25 71. The system of claim 4, wherein the effluent separator comprises a prescrubber or a temperature swing adsorber.
72. The system of claim 4, wherein the acetylene separator comprises an acetylene purification column.
- 30 73. The system of claim 4, wherein the hydrogen separator comprises a membrane separator or a pressure swing adsorber.
- 35 74. The system of claim 4, wherein the vitamin manufacturing system further comprises an acetylene receptacle for storage of an excess amount of the purified acetylene product, and wherein the controller regulates entry of the purified acetylene product

into the acetylene receptacle and regulates release of the purified acetylene product from the acetylene receptacle.

5 75. The system of claim 74, wherein the controller directs purified acetylene product released from the acetylene receptacle to enter the vitamin reaction plant.

10 76. The system of claim 4, wherein the vitamin manufacturing system further comprises a hydrogen receptacle for storage of an excess amount of the purified hydrogen product, and wherein the controller regulates entry of the purified hydrogen product into the hydrogen receptacle and regulates release of the purified hydrogen product from the hydrogen receptacle.

15 77. The system of claim 76, wherein the controller directs purified hydrogen product released from the hydrogen receptacle to enter the vitamin reaction plant.

78. The system of claim 4, wherein the vitamin reaction plant synthesizes the vitamin products using the purified acetylene product.

20 79. The system of claim 4, wherein the vitamin reaction plant synthesizes the vitamin products using the purified acetylene product and the purified hydrogen product.

80. The system of claim 4, wherein the vitamin product is selected from Vitamin A, Vitamin E, β -carotene, or a combination thereof.

25 81. The system of claim 5, wherein the effluent separator comprises a prescrubber or a temperature swing adsorber.

30 82. The system of claim 5, wherein the acetylene separator comprises an acetylene purification column.

83. The system of claim 5, wherein the hydrogen separator comprises a membrane separator or a pressure swing adsorber.

35 84. The system of claim 5, wherein the acetylene-black manufacturing system synthesizes the acetylene black using only the acetylene-rich feedstock stream.

85. The system of claim 5, wherein the acetylene-black manufacturing system synthesizes the acetylene black using the acetylene-rich feedstock stream and the offgas stream.

5 86. The system of claim 5, wherein the acetylene-black manufacturing system synthesizes
the acetylene black using the acetylene-rich feedstock stream and an accelerating
species.

87. A method for processing a hydrocarbon-containing inflow gas to produce outflow gas products, wherein the outflow gas products comprise acetylene and hydrogen, the method comprising the steps of:

injecting the hydrocarbon-containing inflow gas into a plasma reaction chamber;

energizing the hydrocarbon-containing inflow gas in the plasma reaction
15 chamber with microwave energy to create a plasma;

forming outflow gas products in the plasma, wherein the outflow gas products comprise acetylene and hydrogen;

flowing the outflow gas products to exit the plasma reaction chamber; and

removing hydrogen from the outflow gas products by short cycle temperature swing adsorption.

88. A method for transforming a hydrocarbon-containing inflow gas into outflow gas products, comprising:

providing one or more gases, wherein the one or more gases comprises the hydrocarbon-containing inflow gas;

directing the one or more gases into the system of claim 1, wherein the delivery conduit delivers the one or more gases to the gas injector, wherein the gas injector delivers the one or more gases into the plasma reaction chamber.

wherein the microwave subsystem directs microwave energy into the plasma
30 reaction chamber to transform the one or more gases into a plasma and wherein the
plasma effects the transformation of a hydrocarbon in the hydrocarbon-containing
inflow gas into the outflow gas products;

wherein the outflow gas products flow within the plasma reaction chamber towards the distal end of the elongate reactor tube and emerge from the distal end of

the elongate reactor tube forming an effluent stream that enters the effluent separation and disposal subsystem, and

wherein the short-cycle temperature swing adsorption system removes hydrogen from the effluent stream.

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89. A method for producing vinyl chloride monomer, comprising:

providing the system of claim 2,

processing a hydrocarbon-containing inflow gas to produce outflow gas products,

wherein the outflow gas products comprise acetylene and hydrogen, wherein the step

10 of processing comprises the steps of:

injecting the hydrocarbon-containing inflow gas into the plasma reaction chamber;

energizing the hydrocarbon-containing inflow gas in the plasma reaction chamber with microwave energy to create a plasma;

15 forming outflow gas products in the plasma, wherein the outflow gas products comprise acetylene and hydrogen;

flowing the outflow gas products to exit the plasma reaction chamber; and

processing the acetylene thereby produced in the VCM reactor and separator subsystem in fluid communication with the plasma reaction chamber,

20 wherein the VCM reactor combines the acetylene with hydrogen chloride gas to form VCM in the gas by a catalytic reaction within the VCM reactor, and wherein the catalytic reaction proceeds by exposing the acetylene and hydrogen chloride gas to a catalyst within the VCM reactor.

25 90. A method for transforming a hydrocarbon-containing inflow gas into a VCM (vinyl chloride monomer)-containing liquid product, comprising:

providing one or more gases, wherein the one or more gases comprises the hydrocarbon-containing inflow gas;

directing the one or more gases into the system of claim 2,

30 wherein the delivery conduit delivers the one or more gases to the gas injector, wherein the gas injector delivers the one or more gases into the plasma reaction chamber,

wherein the microwave subsystem directs microwave energy into the plasma reaction chamber to transform the one or more gases into a plasma and

wherein the plasma effects the transformation of a hydrocarbon in the hydrocarbon-containing inflow gas into the outflow gas products; wherein the outflow gas products flow within the plasma reaction chamber towards the distal end of the elongate reactor tube and emerge from the distal end of the elongate reactor tube forming an effluent stream that enters the VCM reactor and separator subsystem; and wherein the outflow gas products comprise acetylene and hydrogen, wherein the VCM reactor and separator subsystem is in fluid communication with the elongate reactor tube;

combining acetylene with hydrogen chloride in the VCM reactor to form a VCM-containing gas; and separating the VCM from the VCM-containing gas as a VCM-containing liquid product.

91. A method for processing a hydrocarbon-containing inflow gas into a VCM (vinyl chloride monomer)-containing liquid product, the method comprising the steps of:

injecting the hydrocarbon-containing inflow gas into a plasma reaction chamber;

energizing the hydrocarbon-containing inflow gas in the plasma reaction chamber with microwave energy to create a plasma;

forming outflow gas products in the plasma, wherein the outflow gas products comprise acetylene and hydrogen;

flowing the outflow gas products to exit the plasma reaction chamber and enter a VCM and separator subsystem, wherein the VCM and separator subsystem is in fluid communication with the plasma reaction chamber, wherein the VCM and separator subsystem comprises a VCM reactor, and wherein the outflow gas products comprise acetylene and hydrogen;

combining acetylene with hydrogen chloride in the VCM reactor to form a VCM-containing gas; and separating the VCM from the VCM-containing gas as a VCM-containing liquid product.

92. A method for synthesizing a vitamin product, comprising:

- i. providing the system of claim 4,

- 5 ii. processing a hydrocarbon-containing inflow gas to produce outflow
gas products using the system of claim 4, wherein the outflow gas
products comprise acetylene and hydrogen, wherein the step of
processing comprises the steps of:
- 10 a. injecting the hydrocarbon-containing inflow gas into the plasma
reaction chamber;
- b. energizing the hydrocarbon-containing inflow gas in the plasma
reaction chamber with microwave energy to create a plasma;
- c. forming outflow gas products in the plasma, wherein the
15 outflow gas products comprise acetylene and hydrogen;
- d. flowing the outflow gas products to exit the plasma reaction
chamber;
- iii. separating the outflow gas products into a set of gas streams, the set of
gas streams comprising a first gas stream comprising higher acetylenes
15 and aromatic impurities, a second gas stream comprising purified
acetylene, and a third gas stream comprising purified hydrogen;
- iv. directing the second gas stream comprising purified acetylene into the
vitamin manufacturing system; and
- v. synthesizing the vitamin product from the purified acetylene.
- 20 93. A method for synthesizing acetylene black, comprising:
- i. providing the system of claim 5,
- ii. processing a hydrocarbon-containing inflow gas to produce outflow
gas products using the system of claim 5, wherein the outflow gas products
25 comprise acetylene and hydrogen, wherein the step of processing comprises
the steps of:
- a. injecting the hydrocarbon-containing inflow gas into the
plasma reaction chamber;
- b. energizing the hydrocarbon-containing inflow gas in the plasma
30 reaction chamber with microwave energy to create a plasma;
- c. forming outflow gas products in the plasma, wherein the
outflow gas products comprise acetylene and hydrogen;
- d. flowing the outflow gas products to exit the plasma reaction
chamber;

- iii. separating the outflow gas products into a set of gas streams, the set of gas streams comprising a first gas stream comprising higher acetylenes and aromatic impurities, a second gas stream comprising purified acetylene, and a third gas stream comprising purified hydrogen;
 - 5 iv. directing the second gas stream comprising purified acetylene into the acetylene-black manufacturing system; and
 - v. synthesizing the acetylene black from the purified acetylene.
94. A method for producing hydrogen, comprising:
- 10 a. providing the integrated acetylene-based synthesis system of claim 6,
 - b. processing a hydrocarbon-containing inflow gas to produce outflow gas products using the plasma-based hydrocarbon processing subsystem, wherein the outflow gas products comprise acetylene and hydrogen, wherein the step of processing comprises the steps of:
 - 15 i. injecting the hydrocarbon-containing inflow gas into the plasma reaction chamber;
 - ii. energizing the hydrocarbon-containing inflow gas in the plasma reaction chamber with microwave energy to create a plasma;
 - iii. forming outflow gas products in the plasma, wherein the outflow gas products comprise acetylene and hydrogen;
 - 20 iv. flowing the outflow gas products to exit the plasma reaction chamber;
 - c. separating the outflow gas products into a set of gas streams, the set of gas streams comprising a first gas stream comprising higher acetylenes and aromatic impurities, a second gas stream that is the purified hydrogen stream, and a third gas stream that is the acetylene-rich feedstock stream; wherein the step of separating the outflow products further comprises a substep of effluent separation to remove higher acetylenes from the first gas stream, and a step of acetylene separation to remove purified acetylene from the third gas stream;
 - 25 d. isolating at least a portion of the purified hydrogen stream as a first isolated hydrogen stream;
 - e. directing the acetylene-rich feedstock stream into the acetylene-black manufacturing subsystem and producing hydrogen and acetylene black therefrom; and
 - 30

f. isolating at least a portion of the hydrogen from step e as a second isolated hydrogen stream.

5 95. The method of any one of claims 87 to 94, wherein the hydrocarbon-containing inflow gas is derived from a mixed gas source.

96. The method of claim 95, wherein the mixed gas source is natural gas.

10 97. The method of claim 95, wherein the mixed gas source is a biogas.

98. The method of any one of claims 87 to 94, wherein the hydrocarbon-containing inflow gas comprises a gas selected from the group consisting of methane, ethane, propane, and butane.

15 99. The method of any one of claims 87 to 94, wherein the hydrocarbon-containing inflow gas consists essentially of methane.

20 100. The method of any one of claims 87 to 94, further comprising providing one or more additional gases concomitant with the step of providing the hydrocarbon-containing inflow gas.

101. The method of claim 100, wherein the one or more additional gases are selected from the group consisting of hydrogen, nitrogen, and a recycled gas.

25 102. The method of claim 101, wherein the recycled gas consists essentially of hydrogen.

30 103. The method of any one of claims 87 to 94, further comprising segregating acetylene gas from the outflow gas products following the step of removing hydrogen from the outflow gas products by short cycle temperature swing adsorption.

104. The method of any one of claims 87 to 94, further comprising recycling at least one of the outflow gas products.

105. The method of claim 104, wherein the at least one outflow gas products that is recycled comprises hydrogen.
- 5 106. The method of claim 104, wherein the at least one outflow gas products that is recycled consists essentially of hydrogen.
- 10 107. The method of claim 89, further comprising removing hydrogen from the outflow gas products and segregating acetylene gas from the outflow gas products before the step of processing the acetylene in the VCM reactor.
108. The method of claim 107, further comprising recycling at least one of the outflow gas products.
- 15 109. The method of claim 108, wherein the at least one outflow gas products that is recycled comprises hydrogen.
110. The method of claim 108, wherein the at least one outflow gas products that is recycled consists essentially of hydrogen.
- 20 111. The method of claim 92, wherein the step of separating the outflow products into the set of gas streams further comprises, in any order,
- 25 i. a substep of effluent separation to remove higher acetylenes and aromatic impurities from the first gas stream;
- ii. a substep of acetylene separation to remove purified acetylene from the second gas stream; and
- iii. a substep of hydrogen separation to remove purified hydrogen from the third gas stream.
- 30 112. The method of claim 111, wherein the substep of effluent separation precedes the substep of acetylene separation, and the substep of acetylene separation precedes the substep of hydrogen separation.

113. The method of claim 111, further comprising recycling as a recycled gas a portion of the set of gas streams that remains after the performance of the substeps of effluent separation, acetylene separation, and hydrogen separation.
- 5 114. The method of claim 92, wherein the step of directing is a direct delivery of the purified acetylene into the vitamin manufacturing system.
115. The method of claim 92, wherein the step of directing comprises a diversion to a storage receptacle.
- 10 116. The method of claim 92, wherein the step of directing comprises a commercialization process.
117. The method of claim 92, further comprising a step of directing the third gas stream comprising purified hydrogen into the vitamin manufacturing system.
- 15 118. The method of claim 117, wherein the step of synthesizing the vitamin products from the purified acetylene also uses the purified hydrogen from the third gas stream for synthesis of the vitamin products.
- 20 119. The method of claim 92, further comprising providing one or more additional gases concomitant with the step of providing the hydrocarbon-containing inflow gas.
- 25 120. The method of claim 119, wherein the one or more additional gases are selected from the group consisting of hydrogen, nitrogen, and the recycled gas.
121. The method of claim 120, wherein the recycled gas consists essentially of hydrogen.
- 30 122. The method of claim 92, wherein the vitamin product is selected from Vitamin A, Vitamin E, β -carotene, or a combination thereof.

123. The method of claim 93, wherein the step of separating the outflow products into the set of gas streams further comprises, in any order,
- i. a substep of effluent separation to remove higher acetylenes and aromatic impurities from the first gas stream;
 - 5 ii. a substep of acetylene separation to remove purified acetylene from the second gas stream; and
 - iii. a substep of hydrogen separation to remove purified hydrogen from the third gas stream.
- 10 124. The method of claim 123, further comprising recycling as a recycled gas the purified hydrogen removed from the third gas stream.
125. The method of claim 123, further comprising recycling as a recycled gas a portion of the set of gas streams that remains after the performance of the substeps of effluent separation, acetylene separation, and hydrogen separation.
- 15 126. The method of claim 93, further comprising providing one or more additional gases concomitant with the step of providing the hydrocarbon-containing inflow gas.
- 20 127. The method of claim 126, wherein the one or more additional gases are selected from the group consisting of hydrogen, nitrogen, and the recycled gas.
128. The method of claim 127, wherein the recycled gas consists essentially of hydrogen.
- 25 129. The method of claim 94, further comprising providing one or more additional gases concomitant with the step of providing the hydrocarbon-containing inflow gas.
- 30 130. The method of claim 129, wherein the one or more additional gases are selected from the group consisting of hydrogen, nitrogen, and the recycled gas.
131. The method of claim 130, wherein the recycled gas consists essentially of hydrogen.
- 35

132. The method of claim 130, wherein the recycled gas is obtained by recycling at least a portion of the second gas stream.
- 5 133. The method of claim 94, wherein at least a portion of the first isolated hydrogen stream is isolated for sale, storage, or disposal.
134. The method of claim 94, wherein at least a portion of the first isolated hydrogen stream is used as a feedstock in an integrated process.
- 10 135. The method of claim 94, wherein at least a portion of the second isolated hydrogen stream is isolated for sale, storage, or disposal.
136. A metal-cutting system, comprising:
15 the system of claim 1;
a storage system for containing the outflow gas products produced by the system of claim 1; and
an apparatus for metal-cutting in fluid communication with the storage system, wherein the apparatus draws the outflow gas products from the storage system
20 and ignites them for use in metal cutting.
137. The metal-cutting system of claim 136, wherein the apparatus is an acetylene torch or an oxyacetylene torch.
- 25 138. The metal-cutting system of claim 136, further comprising a hydrogen separation system in fluid communication with the system of claim 1, wherein the outflow gas flows into the hydrogen separation system, wherein the hydrogen separation system separates the outflow gas into two product streams, wherein one product stream is an acetylene-rich gas; and wherein the apparatus
30 for metal cutting uses the acetylene-rich gas stored in the storage system as fuel for metal cutting.