however, such methods are minimally effective and result in a significant overall loss of halogen.

[0009] The prior art oxychlorination process first removes the water from HCl (a costly step) and then reacts the HCl with oxygen and hydrocarbon directly. Oxychlorination processes rely on the separation of HCl from the unreacted alkanes and higher hydrocarbon products by using water absorption, and subsequent recovery of anhydrous HCl from the aqueous hydrochloric acid. U.S. Pat. No. 2,220,570 discloses a process and apparatus for the absorption of HCl in water where the heat of absorption is dissipated by contacting the HCl gas with ambient air, and also by the vaporization of water. A process for producing aqueous hydrochloric acid with a concentration of at least 35.5 wt% by absorbing gaseous HCl in water is disclosed in U.S. Pat. No. 4,488,884. U.S. Pat. No. 3,779,870 teaches a process for the recovery of anhydrous HCl gas by extractive distillation using a chloride salt. U.S. Pat. No. 4,259,309 teaches a method for producing gaseous HCl from dilute aqueous HCl using an amine together with an inert water-immiscible solvent.

[0010] Although researchers have made some progress in the search for more efficient CH bond activation pathways for converting natural gas and other hydrocarbon feedstocks into fuels and other products, there remains a tremendous need for a continuous, economically viable, and more efficient process.

SUMMARY ~~OF THE INVENTION~~

[0011] In one ~~aspect~~embodiment of the ~~invention~~present disclosure, a continuous process for converting methane, natural gas, and other hydrocarbon feedstocks into one or more higher hydrocarbons or olefins is provided. In one embodiment of the ~~invention~~present disclosure, the process includes the steps of alkane halogenation, "reproportionation" of polyhalogenated compounds to increase the amount of monohalides that are formed, oligomerization (C-C coupling) of alkyl halides (and optionally, olefins) to form higher carbon number products, separation of products from hydrogen halide, continuous regeneration of halogen, and separation and recovery of molecular halogen from water.

[0012] The ~~invention~~present disclosure exploits the discovery that, following consumption of substantially all of the molecular halogen in an alkane halogenation reactor, polyhalogenated hydrocarbons that are formed can be reacted with unhalogenated alkanes to improve the overall yield of monohalides, which react in later process steps more efficiently -- and form more desirable products -- than polyhalogenated species. After the initial alkane halogenation reaction, which consumes substantially all of the molecular halogen, additional halogenation is accomplished by transfer of halogen from polyhalogenated alkanes to unhalogenated alkanes, thereby reducing carbon loss and coke formation. For example, dibromomethane can be

reproportionated with methane to form methyl bromide, and dibromomethane can be reproportionated with ethane or propane to form ethyl bromide and ethylene and/or propyl bromide and propylene. Although not bound by theory, it is believed that, in some embodiments, monohalide enrichment also proceeds via olefin formation followed by reaction with polyhalogenated alkanes. In some embodiments, reproportionation is facilitated by a catalyst.

[0013] The ~~invention~~present disclosure provides a number of unique subprocesses, improvements, and advantages, including reproportionation of polyhalides; recovery of halogen released during the requisite coke burn off; continuous regeneration of molecular halogen through the reaction of hydrogen halide and oxygen over a catalyst (allowing the overall process to operate continuously); and use of carefully selected anti-corrosion materials to address the inherently corrosive nature of the halogen-based process (allowing the process to be practiced commercially); and use of appropriate, reliable catalysts for long-term halogen generation. The bromination reactor can be operated adiabatically and over a wide temperature range. Carbon dioxide and water are easily tolerated, as are trace hydrocarbon impurities. Carbon loss due to coke formation is minimized by design by preferentially reacting monohalides over a coupling catalyst such as a zeolite or other reactive metal-oxygen material. Complete recovery of halogen for reuse is also an important advantage of the ~~invention~~present disclosure.

[0013a] In an aspect, there is provided a method comprising: providing a halogen stream; providing a first alkane stream; reacting at least a portion of the halogen stream with at least a portion of the first alkane stream to form a halogenated stream, wherein the halogenated stream comprises alkyl monohalides, alkyl polyhalides, and a hydrogen halide; providing a second alkane stream; reacting at least a portion of the second alkane stream with at least a portion of the alkyl polyhalides to create at least some additional alkyl monohalides; and contacting at least some of the alkyl monohalides and at least some of the additional alkyl monohalides with a catalyst to form a product stream that comprises higher hydrocarbons and hydrogen halide.

[0013b] In another aspect, there is provided a system for forming hydrocarbons comprising: a halogenation reactor, wherein the halogenation reactor receives a quantity of halide and a first quantity of alkane and produces a halogenated product, the halogenated product comprising an alkyl monohalide product and an alkyl polyhalide product; a reproportionation reactor, wherein the reproportionation reactor receives the halogenated product and a second quantity of alkane and produces at least some additional alkyl

monohalide product and a quantity of hydrogen halide; and an oligomerization reactor comprising a catalyst, wherein the oligomerization reactor receives the alkyl monohalide product and the additional alkyl monohalide product and produces a quantity of hydrocarbon product and a second quantity of hydrogen halide.

[0013c] In yet another aspect, there is provided a method comprising: providing an alkyl halide stream comprising alkyl monohalides, alkyl polyhalides, and a hydrogen halide; providing a first alkane stream; reacting at least a portion of the first alkane stream with at least a portion of the alkyl halide stream to create at least some additional alkyl monohalides; contacting at least some of the alkyl monohalides and at least some of the additional alkyl monohalides with a catalyst to form a product stream that comprises higher hydrocarbons, hydrogen halide, and any unreacted portion of the first alkane stream; separating the unreacted portion of the first alkane stream from the product stream; providing a halogen stream; and reacting at least some of the unreacted portion of the first alkane stream separated from the product stream with the halogen to form the alkyl halide stream.

[0014] These discoveries, integrated into an overall process, are the basis for the invention and offer a true advance for such applications as the conversion of natural gas to liquid fuels (including gasoline and gasoline additives) and chemicals (including aromatics, such as benzene, xylene, and toluene, and light olefins, such as ethylene and propylene).

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIG. 1 is a schematic view of one embodiment of a continuous process for converting methane or natural gas into hydrocarbon chemicals according to the invention;

[0016] FIG. 2 is a schematic view of one embodiment of a continuous process for converting methane or natural gas into hydrocarbon fuels according to the invention;

[0017] FIG. 3 is a schematic view of a subprocess for reproportionating polyhalides according to an alternate embodiment of the invention;

[0018] FIG. 4 is a schematic view of one embodiment of a monobromide separation column, for use in the practice of the invention;

[0019] FIG. 5 is a schematic view of one embodiment of an extractive distillation system, for use in the practice of the invention