Chapter

Introductory Chapter: Olefins - Past, Now and Future

Reza Davarnejad

1. Introduction

The previous book published by the same publisher illustrates some findings (until that date) on the alkenes molecular structure (synthesis and application) [1]; now, the current book will try to show some new techniques on the alkenes separation and purification although some industrial aspects will also be considered. Therefore, alkenes (olefins) quality, their separation and purification techniques, and economic and environmental aspects of their production will be studied.

2. Various techniques in olefins production

Alkenes (olefins) play an important role in the human life and their consumption is increasing. Most industries produce the olefins through steam cracking (SC) of hydrocarbons, while few of them are investing in alternative technologies and feedstocks. These technologies have been encouraged due to the abundance of cheap propane, ethane, and methane from shale and stranded gases. From the economic point of view, methane is an interesting starting material if products can be produced from it [2]. According to the literature, the future for proven technologies such as Fischer-Tropsch synthesis (FTS) or methanol to gasoline is vague. Therefore, some industries tried to produce light olefins by the catalytic dehydrogenation of propane. Ethylene and propylene are the main olefins, with a production rate of 1.5×10^8 t/yr and 8×10^7 t/yr, respectively [3]. These are expected to increase with the increasing global population combined with rising living standards [4]. In fact, the light olefins and their derivatives are the modern life basis. The olefin production traditionally depends on natural gas processing products or crude oil fractions based on steam cracking technology. In this process, hydrocarbons that primarily originate from fossil resources are cracked at elevated temperatures in tubular reactors suspended in a gas-fired furnace. However, this process has wieldy been applied and optimized, but its economical issue is challengeable. Furthermore, alternative and more sustainable processes and feedstocks would be required to fulfill the future demand for the chemicals. The methane supply has enormously increased since 2008 and its price has considerably dropped [5, 6]. Therefore, shale gas has been bolded as an interesting cost-competitive feedstock for valorizing methane in the form of olefins and higher hydrocarbons. Moreover, the abundance of cheap ethane from the shale gas has enabled cheap low-olefin production through the steam cracking and has had a proper impact on olefin market of some countries (such as the USA) [7–9]. Ethane steam crackers were found to add around 1×10^7 t of ethylene capacity in 2020 in the USA. The steam cracking of hydrocarbons would be the main technique in the light olefin production. Therefore, lighter feedstocks developed on-purpose of higher olefins and even propylene production [7, 10]. Petrochemical producers can skip the refining step and reduce their production costs by using the recent process [11].

Since the use of coal as a feedstock is discouraged from the environmental aspects, a lot of researchers and engineers are trying to explore alternative eco-friend production techniques. However, energy and chemicals production is an important issue for the world's future, but environmental concerns on the various techniques should be noted. According to the literature, each of these alternative olefin production approaches benefits from the abundance of propane, ethane, and methane from shale gas and stranded gas although the relevance of each approach to lighter feedstock utilization in the steam cracking of hydrocarbons results in reducing the production of important coproducts. Ethylene and propylene would mainly be produced by the steam cracking of hydrocarbons. Not only the steam cracking of hydrocarbons is the most important process in the petrochemical industries but also is the most energy-intensive process. In fact, it is a leading technology for light olefin production. In this process, a hydrocarbon feedstock is mixed with steam and cracked at elevated temperatures in a tubular reactor. The feedstock is from light alkanes (such as ethane and propane) to complex mixtures (such as naphtha) and gas oils [12]. The global propylene and crude C_4 production capacity (for the production of ethylene in steam crackers) has an impact by feed shifting from naphtha to light feeds. However, the steam cracking feedstock makes a shift to ethane low price feedstocks, but shipping and transport *via* pipes of ethane also provided several advantages such as local low ethane prices. On the other hand, the crude oil large availability caused producers of ethylene (such as ExxonMobil) to shift to this process, as well [2]. However, some ethylene producers located in India, Brazil, Canada, and several European countries are going to import ethane but some companies (in China) mainly depend on naphtha cracking. This can limit their competitiveness in the world because the other companies [in Iran (Asaluyeh county)] are producing various olefins from natural gas that is a cheap source in some countries having huge natural gas resources.

Finally, several technologies such as the catalytic dehydrogenation of light alkanes, oxidative coupling of methane (OCM), and syngas-based routes such as the Fischer-Tropsch synthesis (FTS) and methanol synthesis followed by methanol to olefins (MTO) have recently been paid attention [13–16]. According to the literature, FTS is not a selective technique for the light olefin production due to producing a considerable amount of the other hydrocarbons, which can be used as fuel. This process is improving with catalyst design. OCM as an alternative process should be modified in terms of the reactor because of the strong exothermicity of its reaction. However, it seems that steam cracking still is a predominant process for the olefin production (with a mainly lighter feedstock) but a lot of researchers are studying alternative technologies to remove some bottlenecks in the process efficiency and CO_2 footprint.

Author details

Reza Davarnejad
Faculty of Engineering, Department of Chemical Engineering, Arak University, Arak, Iran

*Address all correspondence to: davarnejad.usm.ac@gmail.com

References

[1] Davarnejad R, Sajjadi B. Alkenes. 1st ed. Croatia: Intechopen; 2018. pp. 1-170

[2] Amghizar I, Vandewalle LA, Van Geem KM, Marin GB. New trends in olefin production. Engineering. 2017;**3**:171-178

[3] Zimmermann H, Walzl R. Ethylene. In: Ullmann's Encyclopedia of Industrial Chemistry. Weinheim: Wiley-VCH Verlag GmbH and Co. KGaA; 2009

[4] BP Statistical Review of World Energy, BP Technical Report. London: BP Plc; 2013

[5] United States Energy Information Administration. Annual Energy Outlook 2015 with Projections to 2040. Washington DC: United States Energy Information Administration; 2015

[6] Sattler JJ, Ruiz-Martinez J, Santillan-Jimenez E, Weckhuysen BM. Catalytic dehydrogenation of light alkanes on metals and metal oxides. Chemical Reviews. 2014;**114**: 10613-10653

[7] Bruijnincx PC, Weckhuysen BM. Shale gas revolution: An opportunity for the production of biobased chemicals? Angewandte Chemie (International Ed. in English). 2013;**52**:11980-11987

[8] Siirola JJ. The impact of shale gas in the chemical industry. AICHE Journal. 2014;**60**:810-819

[9] Yang CJ. US shale gas versus China's coal as chemical feedstock. Environmental Science & Technology. 2015;**49**:9501-9502

[10] Ding J, Hua W. Game changers of the C3 value chain: Gas, coal, and biotechnologies. Chemical Engineering and Technology. 2013;**36**:83-90

[11] Available from: http://news.ihsmarkit.com/press-release/new-exxonmobil-and-saudi-aramco-technologies-produce-ethylene-directly-crude-oil-cutti

[12] Van Geem KM, Reyniers MF, Marin GB. Challenges of modeling steam cracking of heavy feedstocks. Oil & Gas Science and Technology—Revue IFP Energies Nouvelles. 2008;**63**:79-94

[13] Al-Salem S, Lettieri P, Baeyens J. Recycling and recovery routes of plastic solid waste (PSW): A review. Waste Management. 2009;**29**:2625-2643

[14] Al-Salem S, Lettieri P, Baeyens J. The valorization of plastic solid waste (PSW) by primary to quaternary routes: From re-use to energy and chemicals. Progress in Energy and Combustion Science. 2010;**36**:103-129

[15] Bridgwater AV. Review of fast pyrolysis of biomass and product upgrading. Biomass & Bioenergy. 2012;**38**:68-94

[16] Putro JN, Soetaredjo FE, Lin SY, Ju YH, Ismadji S. Pretreatment and conversion of lignocellulose biomass into valuable chemicals. RSC Advances. 2016;**6**:46834-46852