Catalytic Conversion of Greenhouse Gases

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Introduction

Indisputably, greenhouse gases emission has been unfavourable to the eco-system (Nabgan *et al.*, 2016). Methane (CH_4) is a reactive trace gas readily available which can be obtained from natural and anthropogenic sources (University of Oxford, 1998). It is the main constituent of natural gas (Zavala-Araiza *et al.*, 2015). CH_4 and carbon dioxide (CO_2) are the main anthropogenic gases present in the atmosphere (Lauder *et al.*, 2013). The increased development of industries and the abundance of non-renewable carbon and H_2 sources have led to the growing reservoir of greenhouse gases. Generally, CH_4 can be transformed into more valuable product such as; syngas (H_2 and CO) using various reforming techniques which include steam, partial oxidation and CO_2 reforming. In fact, CH_4 reforming has become an accepted procedure for producing syngas which is used in the petrochemical industry (Domínguez *et al.*, 2007; Zahedinezhad *et al.*, 2009). Detailed study have been reported using these various techniques viz; steam reforming by Antzara *et al.* (2016), partial oxidation by Jahangiri and Pahlavanzadeh (2012), CO_2 reforming by Foo *et al.* (2012), Osazuwa *et al.* (2017b) and, (Osazuwa and Cheng, 2017). Combination of CH_4 reforming techniques in order to obtain a much improved product have also being reported previously by, Lim *et al.* (2010), Koo *et al.* (2014), (Choudhary and Mondal, 2006). Apart from the fact that the CO_2 reforming of CH_4 reaction consumes greenhouse gases, its products serve as feed for the Fischer-Tropsch synthesis (syngas ratio below 2.0) (Choudhary and Mondal, 2006). The product (H_2) is employed as fuel cells for transmission of clean energy, electricity generation and production systems (Wang *et al.*, 1996; Hosseini and Wahid, 2016). The need to promote a cleaner environment by minimizing global warming cannot be over emphasized. To reiterate this need, over 195 countries signed an agreement in 2015 to take part in a combined attempt to reduce the emission of greenhouse gases. Naturally, CH_4 reforming with CO_2 (greenhouse gases) is an endothermic reaction that occurs at a very slow rate if allowed to progress un-catalysed. Therefore, catalytic reforming of CH_4 with CO_2 is a reaction, which progresses with H_2 and CO formation as products and carbon as unwanted/by products (Pompeo *et al.*, 2009). This carbon deactivates the catalyst; hence, researchers have tried to develop catalysts with improved performance, which minimizes catalyst deactivation from carbon formation on the surface or pore of the catalyst. Noble metal based catalyst was reported to minimize carbon deposition (Hou *et al.*, 2006; Sutthiumporn and Kawi, 2011). However, nickel (Ni) catalyst is more economical (Hirose *et al.*, 2011; Yentekakis *et al.*, 2015). Reports have shown that as a result of the cost of noble metals coupled with the attraction of Ni to carbon, it makes economic sense to enhance the performance of non-noble metal catalyst. Hence, transition metal based catalyst has shown better performance towards syngas production from CH_4 dry reforming (Valderrama *et al.*, 2005; Gallego *et al.*, 2008b; Rivas *et al.*, 2008; Khajeh Talkhoncheh and Haghighi, 2015). Another effective catalyst for CO_2 reforming/ conversion of CH_4 is the perovskite, which requires the introduction of metals into the perovskite matrix. Perovskite possess a structure with superior reduction-oxidation properties that permits very high distribution of metal elements in a reduced system; hence enhancing the activity of the catalyst (Goldwasser *et al.*, 2005b; Moradi *et al.*, 2012). Moreover, the perovskite has a wide selection of A and/or B cations, enabling combinations of varying oxidation state of its elements (Tienthao *et al.*, 2007). Catalytic conversion of greenhouse gases to valuable products can be effectively achieved via CO_2 reforming of CH_4. However, catalyst inhibition (deactivation) due to carbon formation has been outlined as the major setback that inhibits the revolution of CO_2 reforming of CH_4 to a commercial process. Reports available in literature have attempted to analyse ways to enhance catalyst activity, catalyst stability, reduce carbon formed and deactivation of catalyst by varying supports, promoters and combining metals to obtain support on metal oxides and perovskite type catalysts. Furthermore, various modifications have been carried out to alter the kinetic behaviour of these catalysts in order to improve these aforementioned qualities. This paper seeks to outline the various methods that have been employed in the catalytic conversion of greenhouse gases into valuable products. More specifically, the effects of various catalyst type on the overall behaviour (conversion, yield and kinetic) of greenhouse gases (CH_4 and CO_2) have been emphasized in this review paper.

Greenhouse Gases

Greenhouse effect is a natural (regular) occurrence modelled to retain gases in the earth crust at equilibrium. However, disturbances to the environment take place when imbalance exists. These disturbances are as a result of artificial greenhouse effect which enhances the regular greenhouse effect. Artificial greenhouse effect results from burnt fossil fuels, natural gas, coal and petroleum, while the regular greenhouse effect results from confined heat waves released from the sun. As a result of the heat energy, the temperature of the greenhouse gases in the atmosphere is increased. Activities of man such as; deforestation, burning of fossil fuels, coal, oil, industrialization and population increase are responsible for the excess greenhouse gases produced. Components of greenhouse gases are; water vapour, nitrous oxide, ozone, CH_4 and CO_2. CO_2 and CH_4 are readily available in much