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BI- And Tri-Metallic Catalysts for Hydrogen Production from Hydrogen Iodide Decomposition

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Abstract : Production of hydrogen from a renewable raw material without any co-synthesis of harmful greenhouse gases is the current need for sustainable energy solutions. The sulfur-iodine (SI) thermochemical cycle, using intermediate chemicals, is an efficient process for producing hydrogen at a much lower temperature than that required for the direct splitting of water. No net byproduct forms in the cycle. Hydrogen iodide (HI) decomposition is a crucial reaction in this cycle, as the product, hydrogen, forms only in this step. It is an endothermic, reversible, and equilibrium-limited reaction. The theoretical equilibrium conversion at 550°C is just a meagre of 24%. There is a growing interest, therefore, in enhancing the HI conversion to near-equilibrium values at lower reaction temperatures and by possibly improving the rate. The reaction is relatively slow without a catalyst, and hence catalytic decomposition of HI has gained much significance. Bi-metallic Ni-Co, Ni-Mn, Co-Mn, and tri-metallic Ni-Co-Mn catalysts over zirconia support were tested for HI decomposition reaction. The catalysts were synthesized via a sol-gel process wherein Ni was 3wt% in all the samples, and Co and Mn had equal weight ratios in the Co-Mn catalyst. Powdered X-ray diffraction and Brunauer-Emmett-Teller surface area characterizations indicated the polycrystalline nature and well-developed mesoporous structure of all the samples. The experiments were performed in a vertical laboratory-scale packed bed reactor made of quartz, and HI (55 wt%) was fed along with nitrogen at a WHSV of 12.9 hr^{-1}. Blank experiments at 500°C for HI decomposition suggested conversion of less than 5%. The activities of all the different catalysts were checked at 550°C, and the highest conversion of 23.9% was obtained with the tri-metallic 3Ni-Co-Mn-ZrO_2 catalyst. The decreasing order of the performance of catalysts could be expressed as: 3Ni-Co-Mn-ZrO_2 > 3Ni-2Co-ZrO_2 > 3Ni-2Mn-ZrO_2 > 2.5Co-2.5Mn-ZrO_2. The tri-metallic catalyst remained active till 360 mins at 550°C without any observable drop in its activity/stability. Among the explored catalyst compositions, the tri-metallic catalyst certainly has a better performance for HI conversion when compared to the bi-metallic ones. Owing to their low costs and ease of preparation, these trimetallic catalysts could be used for large-scale hydrogen production.

Keywords : sulfur-iodine cycle, hydrogen production, hydrogen iodide decomposition, bi-, and tri-metallic catalysts
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