

In-Depth Experimental Study on Thermochemical Conversion of Furan in Molten Alkali Carbonates

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ABSTRACT: Furan is a typical heterocyclic compound in pyrolytic tar and has a strong tendency of coke deposition in thermochemical conversion, leading to catalyst deactivation for tar upgrading. The present study proposed a promising method for furan cracking and reforming using molten alkali carbonates ($\text{Li}_2\text{CO}_3\text{-Na}_2\text{CO}_3\text{-K}_2\text{CO}_3$). The results showed that a little gas was generated in the conversion process and CO dominated the gas species. In comparison to the experiment under salt-free conditions, the decarbonylation of furan in molten salt conversion was strengthened and oxygen could be removed as H_2O into the liquid products. Under the catalysis of alkali metal cations, the conversion of furan to aromatic compounds was promoted at each temperature. Moreover, excess CO_2 enhanced the reverse water–gas reaction, resulting in the consumption of H_2 and the increase of CO in gaseous products. In addition, coke produced in molten salts was of higher reactivity and could hardly affect the stability of the molten salt system. On the basis of the good thermal conversion behavior as well as anticoking performance of molten carbonates, these findings offer a new way for the proper reforming and upgrading of furan through molten salt thermal treatment.

1. INTRODUCTION

China has a large population, with 40% living in small towns and counties, in which residents produce 150 million tons of domestic garbage every year.¹ Currently, the landfill is the main disposal treatment of rural domestic waste. However, the traditional landfill technology is facing long-term environmental risks as a result of taking up much of the land resources. Recently, incineration has become one of the main techniques of domestic garbage treatment in large and medium cities of China for fast waste to energy.² Nevertheless, domestic wastes produced in small counties and towns are scattered, for which the collection and transportation of these domestic wastes for large-scale centralized incineration are with great difficulty. Therefore, searching for a suitable disposal technology for rural domestic wastes has become one of the key issues for the social environmental protection of China.^{3–5} Relatively, pyrolysis technology that can be applied in a small scale is feasible for the fast thermal treatment of domestic waste in towns. After pyrolysis, domestic wastes are flexibly converted into useful gas, tar, and char, with the potential of high-value-added utilization.^{6–8}

The further utilization of domestic waste pyrolysis products is of great significance to the economy of pyrolysis technology.⁹ Among the pyrolysis products, tar is a multi-component mixture of different compounds, including acids, phenols, ketones, aromatics, heterocyclic compounds, etc.¹⁰ Generally, there are a lot of oxygen-containing components in pyrolytic tar of domestic waste, and the high oxygen contents limit sufficient utilization of tar.¹¹ Converting tar into liquid fuels or chemicals is a potential technique for high-value utilization of tar, during which the homogenization and upgrading (especially the removal of oxygen) of tar are key

issues for effective application of this technique. As for tar upgrading, catalysts are extensively applied in converting complex tar into value-added products by many researchers around the world.^{12–15} Nevertheless, it is widely reported that coke is proposed to form in the catalytic stimulation of tar decomposition/cracking, and catalysts are easy to deactivate as a result of the deposition of coke.¹⁶

Furan is a typical heterocyclic compound in tar.¹⁷ As a result of the existence of the furan ring, furan has a strong tendency of coke deposition in thermochemical conversion. Efforts have been made to clarify the mechanism of furan thermal conversion to cut down the negative effect of furan on high-value application of tar. The work by Hu et al.¹⁸ found that the pathway of furan thermal conversion differed in water and methanol. Furan could barely make its way to benzofuran because its polymerization dominated with water as the solvent. In contrast, the polymerization of furan was suppressed using methanol as the solvent, and benzofuran formation was enhanced substantially. These results provide a valuable direction for furan conversion by changing the reaction system. In addition, research by Cheng and Huber¹⁹ confirmed that furan reacted with olefins to form aromatics and water catalyzed by HZSM-5 (Zeolite Socony Mobile-5, a zeolite catalyst). However, the polymerization and carbon deposition of a little furan would block the micropore in the

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