Advancing PET Waste Chemical Recycling for Terephthalic Acid Recovery

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Chemical recycling presents a promising solution to tackle the pressing environmental issues posed by plastic waste. This study delves into the hydrothermal chemical recycling of polyethylene terephthalate (PET) waste, a common material found in bottles and textiles. The objective is to improve the recovery of its valuable monomer, terephthalic acid (TPA), in a more environmentally friendly way through: isothermal acid hydrolysis or fast neutral hydrolysis.

In the isothermal acid hydrolysis experiments, a range of acid catalysts were employed to assess their impact on TPA yield. Notably, the use of TPA as a catalyst at 200 °C resulted in TPA yield of 98% after 2 h. Zinc iodide, benzoic acid, and acetic acid also yielded TPA levels surpassing 80%. We note a consistent trend wherein TPA yields increase with decreasing pH for aliphatic carboxylic acids and nitric acid, regardless of the catalyst added. However, this pattern does not hold true for zinc iodide, ionic liquids, and sulfuric acid.

We discovered fast neutral hydrolysis—a rapid non-isothermal heating process. By manipulating heating rates (ranging from 3 to 12 ˚C/sec), reaction times (spanning 15 seconds to 3 minutes), and PET/water mass ratios (ranging from 1/2 to 1/10), TPA yields as high as 90% were achieved. However, it is noteworthy that excessive severities led to TPA decomposition, underscoring the pivotal role of temperature and time in optimizing TPA production. Fast neutral hydrolysis had the lowest environmental energy impact (448 °C·min) in contrast to isothermal acid hydrolysis (10^4 °C·min).

Moreover, a kinetic analysis model was developed to predict TPA yield and conversion under varying conditions, accounting for autocatalysis, heating rate, and physical factors influencing PET throughout the hydrolysis process. This model exhibited accuracy and reliability, providing valuable insights into the optimization of the chemical recycling workflow.