Decomposition of Benzene, Toluene and Xylene using an Atmospheric Corona Discharge

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1. Introduction

Recently, various kinds of VOCs (volatile organic compounds) contained in exhaust gas, which are emitted from factories, automobiles etc., cause major environmental issues. These VOCs, such as benzene, toluene, and xylene, are harmful to the human body and the environment.

2. Experimental apparatus and conditions

- **Electrode**
  - A multi-needle electrode, which consists of thirteen stainless-steel needles (5 mm length and 4 mm diameter) and a plane electrode made of stainless steel (80 mm diameter), are placed in a cylindrical discharge chamber.
  - The distance between the multi-needle electrode and the plane electrode is fixed at 10 mm.
- **Discharge chamber**
  - The cylindrical discharge chamber is made of stainless steel, with 100 mm inner diameter and 500 mm height.
- **Applied voltage**
  - A positive DC high voltage 20–28 kV is applied to the multi-needle electrode, generating a streamer corona discharge.
- **Gas condition**
  - Nitrogen-oxygen mixture is used as a background gas, and the mixture ratio is N₂/O₂ = 90/10%.
  - Initial gas pressure in the chamber is 1013 hPa (atmospheric pressure), and initial concentrations of benzene, toluene and xylene are 300 ppm.
- **Concentration measurement**
  - Concentrations of benzene, toluene, xylenes, and by-products are measured by a Fourier Transform Infrared Spectrophotometer (Shimadzu, FTIR-8900) equipped with a gas cell (Infrared Analyzer, B844), which has optical path length of 10 m.
- **Measurement of voltage and current**
  - Applied voltage is measured by a high-voltage probe (Tektronix P6015A).
  - Discharge current is calculated by voltage drop across a ten microfarad interelectrode (1 µF), which connected between the plane electrode and the earth.

3. Experimental results and discussion

3.1 Infrared spectrum (C₆H₆ and C₆H₅(CH₃)₂)

- The infrared spectrum of benzene (C₆H₆) and xylene (C₆H₅(CH₃)₂) are measured by a Fourier Transform Infrared Spectrophotometer.
- The infrared peaks of benzene (C₆H₆) and xylene (C₆H₅(CH₃)₂) are observed at 2850 cm⁻¹, 1590 cm⁻¹, and 1460 cm⁻¹, respectively.

3.2 Concentration variations of benzene, toluene, xylene and by-products

- The concentration of benzene, toluene, and xylene decreases with the increase of input energy.
- CO, CO₂, and HCOOH are major products from benzene, toluene, and xylene in the corona discharge.
- CO₂ is a gaseous product, and CO and HCOOH are intermediate products.

3.3 Mass balance for carbon atoms

- In benzene decomposition, the total number of carbon atoms, which is presented as the top line of stacked graph, decreases monotonously with the increase of input energy, and then becomes constant.
- In toluene and xylene decomposition, the total number of carbon atoms decreases with the increase of input energy, once tends to increase, and then becomes constant.

- It is likely that gaseous unknown by-products containing carbon atoms exist in toluene and xylene decomposition.

3.4 Decomposition processes of benzene, toluene and xylene

- Benzene, toluene and xylene are chiefly converted to CO₂ via CO and HCOOH by the atmospheric DC corona discharge.
- Toluene and xylene are converted to CO₂ via HCHO, PAN, CH₂COOH and unknown products by the atmospheric DC corona discharge.

4. Conclusions

Decomposition processes of benzene, toluene and xylene in nitrogen-oxygen mixture gas in an atmospheric DC corona discharge are investigated.

- CO, CO₂, HCOOH, C₆H₆, and HCN are produced from benzene, toluene and xylene in the atmospheric DC corona discharge.
- HCHO, PAN and CH₂COOH are found to be intermediate products from toluene and xylene.
- Concentrations of benzene, toluene and xylene decrease monotonously with the increase of input energy.
- In benzene decomposition, the total number of carbon atoms, which is presented as the top line of stacked graph, decreases with the increase of input energy, and then becomes constant.
- In toluene and xylene decomposition, the total number of carbon atoms decreases with the increase of input energy, once tends to increase, and then becomes constant.
- Benzene, toluene and xylene are chiefly converted to CO₂ via CO and HCOOH by the atmospheric DC corona discharge.