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DECOMPOSITION OF POLYCHLORINATED BIPHENYLS (PCB's) IN A RADIO-FREQUENCY GLOW DISCHARGE PLASMA

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A study was made on the decomposition of PCB's in a radio-frequency glow discharge plasma. When PCB's were decomposed in a plasma of oxygen at a few Torr, they were completely decomposed to gaseous products: carbon monoxide, carbon dioxide, water, hydrogen chloride, chlorine, and chlorine dioxide. Hazardous compounds such as phosgene and vinyl chloride were not detected by a GC-MS analysis.

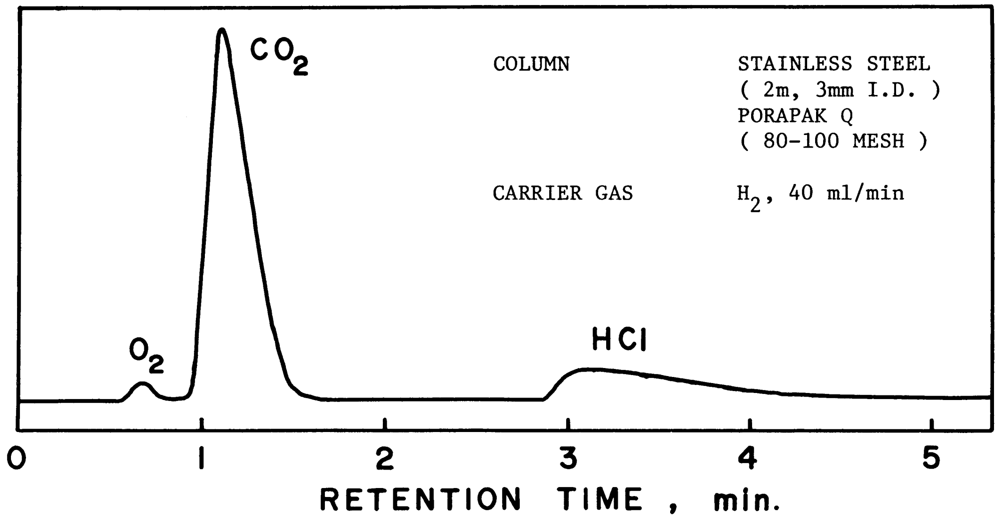
For the decomposition of PCB's, methods by using pyrolysis,[1, 2] radiolysis,[3-6] and photolysis[7] have been reported. In this study, it was examined whether PCB's could be decomposed in a low temperature plasma. It was found that PCB's were decomposed completely with high efficiency into gaseous products in an oxygen glow plasma. A detailed analysis of the reaction products was performed.

Samples of PCB's used were KC-200 and KC-500. The pressure and the flow rate of oxygen were 1.8 Torr and 3.15×10^{-5} mole/sec, respectively. One tenth gram of PCB's was put in a ceramic boat and was decomposed in a radio-frequency glow discharge plasma which was generated by a radio-frequency generator with a maximum power of 50 watts. The inner diameter of the pyrex discharge tube was 10 mm. The products were trapped in a liquid nitrogen cooled trap and were analysed with a Shimadzu 6APTF gas chromatograph with a thermal conductivity detector. A confirmation of products was done by using a Hitachi 063 gas chromatograph-mass spectrometer. For these analyses, 2 m stainless steel column packed with porapak Q(80-100 mesh) was used.

When PCB's were subjected to a plasma of oxygen, they were quickly decomposed into gaseous products in only 5 minutes. The temporal brownish liquid and solid products on the wall of the discharge tube were also decomposed easily within 10 minutes. The gaseous products were trapped in a dry-ice acetone cooled trap and a liquid nitrogen cooled trap. The only product found in the dry-ice acetone cooled trap was water. The products in the liquid nitrogen cooled trap were analysed by the gas chromatograph and the gas chromatograph-mass spectrometer. The gas chromatogram for KC-500 is shown in Fig. 1. The major products are carbon dioxide and hydrogen chloride. No carbon compounds other than carbon dioxide were detected. Roughly 40% of carbon content in PCB's is converted to carbon dioxide. The rest (60%) should be converted to carbon monoxide which can not be trapped by a liquid nitrogen cooled trap. A small amount of ozone, which was detected as an oxygen peak in Fig. 1, was also the gaseous product from a glow discharge of oxygen.

Chlorine and chlorine dioxide, which were not detected by the gas chromatograph owing to their high reactivities, were confirmed as reaction products by separate experiments. The quantitative analyses of chlorine and chlorides were done by using the Mohr method and the redox titration methods[8,9] after the gaseous products were dissolved into the sodium hydroxide solution or the potassium iodide and sodium bicarbonate solution. The yields (%) of hydrogen chloride, chlorine, and chlorine dioxide for KC-500 and KC-200 with respect to chlorine contained in PCB's were 65, 34, 1 and 82, 16, 1, respectively.

Fig. 1. Gas chromatogram of gaseous products from the decomposition of KC-500



In summary, it was found that PCB's were decomposed completely into gaseous products with a very high efficiency in a low temperature plasma ($\lesssim 200^{\circ}C$). The quantity of oxygen consumed was only a few times of the stoichiometric oxygen demand for the perfect oxidation of PCB's. This high efficiency suggests that the direct decomposition of PCB's by high-energy electrons in a plasma (an order of 10^4 to 10^5 K [10]) was one of the major decomposition mechanisms of PCB's as well as the addition reaction of an oxygen atom to PCB which is followed by the decomposition of an adduct. If a high-power radio-frequency generator was used and PCB's were feeded continuously into a plasma, we think the present method could be technically applicable for the decomposition of PCB's.

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