289ah Catalytic Wet Oxidation of Lactose

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Lactose (milk sugar) is a low value by-product generated in large quantities from the dairy industry, primarily from cheese whey. Only a small amount of cheese whey is further utilized and it accumulates in quantities of about 1.2 million tons annually worldwide, with lactose being approximately 75% of the solid components. As a result, most of the lactose is disposed of in waste water which leads to additional environmental problems. Therefore, it is desirable to minimize this waste, either by converting lactose to smaller organic and inorganic carbon compounds more suitable for disposal or, preferably, to a lactose derivative compound with significant value. Catalytic wet oxidation is capable of meeting both of these objectives and is the subject of the work in this proposal.

Literature results have shown that Pt/Al_2O_3 is capable of degrading glucose to small organic acids. A Mn/Ce mixed metal oxide is capable of further degrading these acids to CO_2 and water. The ability of these catalysts to similarly degrade lactose was investigated together with a Pt/Mn/Ce catalyst for one step degradation. To produce a value added product, bismuth promoted Pd/C catalysts have been shown to selectively convert glucose and lactose to gluconic acid and lactobionic acid, respectively, in a batch reactor. Since a batch reactor would be inefficient for production, the performance of this catalyst under flow conditions was investigated.

Reactivity studies were conducted using a lactose concentration of 0.08 mol/l in water. A plug flow reactor was used with flowrates of 5-35 ml/min liquid and 0.05-1.44 l/min of oxygen. Temperature was varied from 140 to 170°C and pressure was 100 psig. Reactant and product analysis was performed using HPLC.

The Pt/Al_2O_3 catalyst converted all lactose for 17.5 ml/min flow at 170°C, 1.18 l/min O_2, and 4.3 g of catalyst. Although a number of side products were produced, their total concentration was less than 5% of the original lactose concentration. Similar results were obtained for the Mn/Ce catalyst. Lower oxygen feed rates resulted in slightly lower conversions and more side products. For the Pt/Mn/Ce catalyst, complete conversion was obtained at 23 ml/min feed with 1.44 l/min O_2 for 3.3 g of catalyst. Complete conversion was also obtained at lower oxygen flowrates but additional side-product formation was observed. Maximum reaction rates and the apparent activation energy were also determined using low conversion runs.

For selective conversion of lactose to lactobionic acid, the Pd/Bi/C catalyst demonstrated complete conversion for 8.0 g catalyst and 25 ml/min feed. Oxygen flow was varied from 1.18 to 0.08 L/min and had no effect on conversion. However, only the lowest flowrate produced a high selectivity (>90%) to lactobionic acid. Again, maximum reaction rates and the apparent activation energy were determined using low conversion runs.

Thus, Pt/Al_2O_3, Mn/Ce, and Pt/Mn/Ce catalysts are all capable of directly converting lactose to carbon dioxide and water. The presence of Pt does increase the activity slightly but does not appear to be required for complete degradation. A Pd/Bi/C catalyst is capable of converting all lactose with a high selectivity to the desired product of lactobionic acid in a flow reactor.