## A First Course on Kinetics and Reaction Engineering Example 17.3

## **Problem Purpose**

This problem illustrates the concepts of series and series-parallel reaction networks.

## **Problem Statement**

It is conceivable that the oxidation of methane could produce methanol, formaldehyde, carbon monoxide and carbon dioxide. Write a series-parallel reaction network that leads to this set of products.

## **Problem Solution**

The products given in the problem statement are successively more oxidized. Hence, we expect oxygen to appear in parallel (being added in each step) while the carbon-containing species appears in series (becoming more and more oxidized). This leads to the following reaction network.

 $\begin{array}{l} 2 \ CH_4 + O_2 \rightarrow 2 \ CH_3OH \\ \\ 2 \ CH_3OH + O_2 \rightarrow 2 \ HCHO + 2 \ H_2O \\ \\ 2 \ HCHO + O_2 \rightarrow 2 \ CO + 2 \ H_2O \\ \\ 2 \ CO + O_2 \rightarrow 2 \ CO_2 \end{array}$ 

Notice, oxygen is a reactant in every reaction, as would be expected for a parallel network, but at the same time methanol is formed in the first reaction and consumed in the second. Formaldehyde is formed in the second reaction and consumed in the third, CO is formed in the third reaction and consumed in the fourth. Thus while the network looks like a parallel network from the perspective of oxygen, it simultaneously looks like a series network from the perspective of methanol, formaldehyde and CO.

Note that if the problem had not specified a series-parallel reaction network, we could have written the following parallel network that would also describe the observed products.

2 CH<sub>4</sub> + O<sub>2</sub>  $\rightarrow$  2 CH<sub>3</sub>OH CH<sub>4</sub> + O<sub>2</sub>  $\rightarrow$  HCHO + H<sub>2</sub>O 2 CH<sub>4</sub> + 3 O<sub>2</sub>  $\rightarrow$  2 CO + 4 H<sub>2</sub>O CH<sub>4</sub> + 2 O<sub>2</sub>  $\rightarrow$  CO<sub>2</sub> + 2 H<sub>2</sub>O