sulfur, and oxygen, the following three independent linear combinations are found:

$$\Delta N_{\mathrm{OC}} + \Delta N_{\mathrm{MC}} + \Delta N_{\mathrm{OCS}} + \Delta N_{\mathrm{MCS}} = 0 \tag{18}$$

$$\Delta N_{\mathrm{acid}} + \Delta N_{\mathrm{OCS}} + \Delta N_{\mathrm{MCS}} = 0 \tag{19}$$

$$\Delta N_{\mathrm{OC}} + \Delta N_{\mathrm{MC}} + 4\Delta N_{\mathrm{acid}} + 4\Delta N_{\mathrm{OCS}} + 4\Delta N_{\mathrm{MCS}} + \Delta N_{\mathrm{water}} = 0 \tag{20}$$

The material balance over hydrogen is dependent of these three equations since the rank $R = 3$. However, since only the two reactions (16) and (17) occur, the following equations, which cannot be obtained from the material balances over the elements, must be satisfied

$$\Delta N_{\mathrm{OC}} + \Delta N_{\mathrm{OCS}} = 0 \tag{21}$$

$$\Delta N_{\mathrm{MC}} + \Delta N_{\mathrm{MCS}} = 0 \tag{22}$$

Thus there are two linear combinations in excess. However, only four of the Equations (18) to (22) are independent equations. Equation (22), for example, can be obtained by combining (18) and (21). Therefore, the number of independent linear combinations in excess, $NLCE = 1$. This means that Equation (15) gives the right number of independent reactions also in this case.

NOTATION

$\Delta N_{al}, \Delta N_{ac} \ldots \Delta N_{\mathrm{OC}}$ etc. = change in number of moles

$NLCE$ = the number of independent linear combinations of ΔN-values, which remain zero during reaction, in excess over those derived from material balances over the elements.

NRX = number of independent reactions

NSP = number of species

R = rank of the elements-by-species matrix

x_i = molar extent of the ith reaction

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Reply to Björnbom's Note

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The case described by Björnbom, where the number of independent reactions exceeds the difference between the numbers of species and the rank of the element-by-species matrix, contains kinetic constraints on ratio of product species. The equality

$$NRX = NSP - NC$$

should be replaced by

$$NRX \leqq NSP - NC$$

as noted by Aris (1963).

In our original paper (1973) we did not consider compositional constraints in cases that did not involve isomeric species. These constraints can, however, easily be added to the program by defining a new variable (for example, CONSTR), which takes on integer values equal in number to the constraints of the type described by Björnbom. This variable would be subtracted from Equation (3) in our original paper.

We wish to thank Dr. Björnbom for bringing this interesting case to our attention.

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Mass Transfer to the Free Interface in a Stirred Vessel

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A turbulent, free interface occurs at the liquid surface with liquid and gas phases in a mechanically stirred vessel. At low stirring speeds in baffled vessels, the interface is not broken by gas entrapment and the turbulence at the interface appears to correspond to the turbulence in the stream generated by the impeller. This note presents an analysis of the mechanism of liquid phase mass transport at this free interface by comparison of the impeller stream turbulence to that for turbulent flow in a circular pipe.

PIPE FLOW

Transition region turbulence in pipe flow appears similar to that for a free interface because both show a penetration model response. Hughmark (1973) has shown that the

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