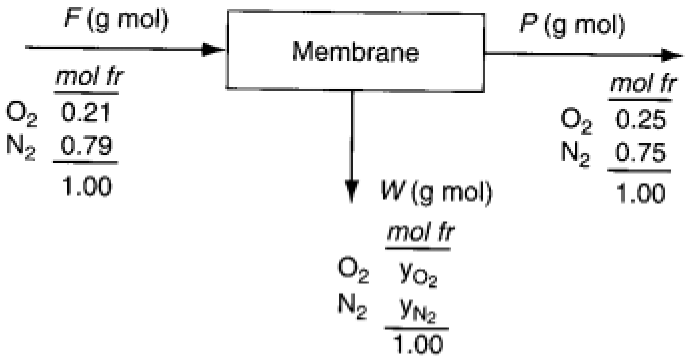
Lecture 11

Example 6

Figure below illustrates a nanoporous membrane that is used in the separation of nitrogen and oxygen from air. What is the composition of the waste stream if the waste stream amounts to 80% of the input stream?



Solution

Basis: 100 g mol of F

<u>Tatal mole balance:</u>

Input = output

F = P + W

100 = P + 0.8 (100)

P = 20 mol

<u>O_2 mol balance</u>

Input = output

0.21(F) = 0.25(P) + y_{O2} (W)

0.21(100) = 0.25(20) + y_{O2} (80)

y_{O2} = 0.2

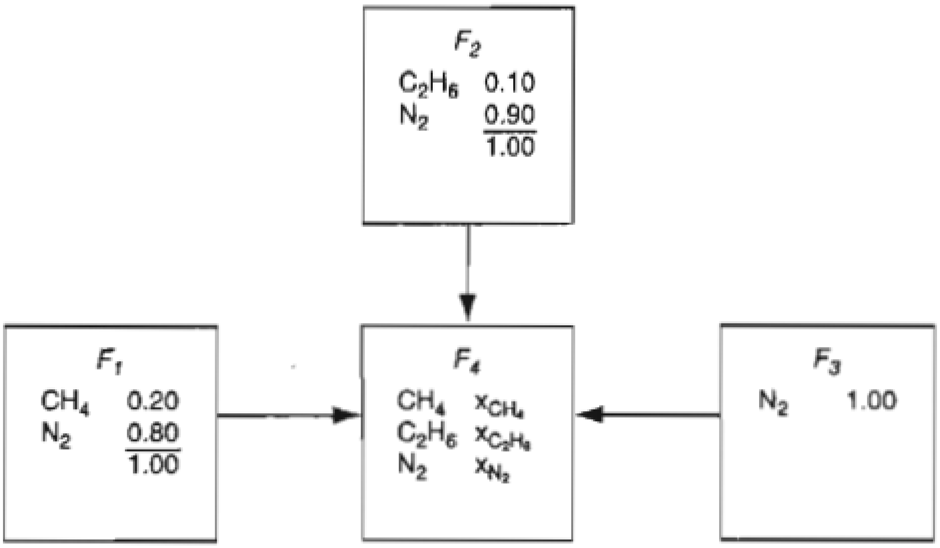
$y_{N2} = 1 - 0.2$

$y_{N2} = 0.8$

Example 7

A cylinder containing CH_4, C_2H_6, and N_2 has to be prepared containing a CH_4 to C_2H_6 mole ratio of 1.5 to 1. Available to prepare the mixture are (1) a cylinder containing a mixture of 80% N_2 and 20% CH_4, (2) a cylinder containing a mixture of 90% N_2 and 10% C_2H_6, and (3) a cylinder containing pure N_2. What is the number of degrees of freedom, i.e., the number of independent specifications that must be made, so that you can determine the respective contributions from each cylinder to get the desired composition in the cylinder with the three components?

Solution



Do you count seven unknowns—three values of x_i and four values of F_i? How many independent equations can be written?

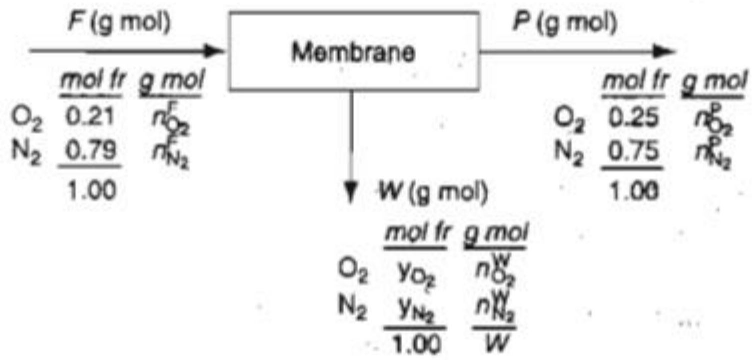
Three material balances: CH_4, C_2H_6, and N_2
One specified ratio: moles of CH_4 to C_2H_6 equal 1.5 or $(x_{CH_4}/x_{C_2H_6}) = 1.5$
One summation of mole fractions: $\Sigma x_i^{F_4} = 1$

Thus, there are seven minus five equals two degrees of freedom. If you pick a basis, such as $F_4 = 1$, one other value has to be specified to solve the problem to calculate composition of F_4. Keep in mind that you must be careful in making any specifications to maintain only independent equations. Avoid transforming one or more independent equations in a set such that the resulting set contains redundant (dependent) equations. Did you notice in the problem formulation that the $\sum x_i = 1$ equations for F_1, F_2, and F_3 were redundant because of the way the specification of the mole fractions was made?

Example 8

Membranes represent a relatively new technology for the separation of gases. One use that has attracted attention is the separation of nitrogen and oxygen from air. Figure E8.2a illustrates a nanoporous membrane that is made by coating a very thin layer of polymer on a porous graphite supporting layer.

What is the composition of the waste stream if the waste stream amounts to 80% of the input stream?



Solution

Basis: 100 g mol = F

A degree of freedom analysis that includes all of the variables comes next.

Number of variables: 9

F, P, W and 6 n_i

Number of equations: 9

Specifications: $n^F_{O_2} = 0.21(100) = 21$

$n^F_{N_2} = 0.79(100) = 79$

$y^P_{O_2} = n^P_{O_2}/P = 0.25 \qquad n^P_{O_2} = 0.25P$

$y^P_{N_2} = n^P_{N_2}/P = 0.75 \qquad n^P_{N_2} = 0.75P$

$W = 0.80(100) = 80$

Material balances: O_2 and N_2

Implicit equations: $\Sigma n_i^W = W$ or $\Sigma y_i^W = 1$

The problem has zero degrees of freedom

	In	*Out*		*In*	*Out*
O_2:	0.21 (100)	$= 0.25P + y^W_{O_2}(80)$	or	0.21 (100)	$= 0.25P + n^W_{O_2}$
N_2:	0.79 (100)	$= 0.75P + y^W_{N_2}(80)$	or	0.79 (100)	$= 0.75P + n^W_{N_2}$
	1.00	$= y^W_{O_2} + y^W_{N_2}$	or	80	$= n^W_{O_2} + n^W_{N_2}$

The solution of these equations is $n^W_{O_2} = 16$ and $n^W_{N_2} = 64$, or $y^W_{O_2} = 0.20$ and $y^W_{N_2} = 0.80$, and $P = 20$ g mol.

Problems

1. Strawberries contain about 15 wt% solids and 85 wt% water. To make strawberry jam, crushed strawberries and sugar are mixed in a 45:55 mass ratio, and the mixture is heated to evaporate water until the residue contains one-third water by mass. Calculate how many pounds of strawberries are needed to make a pound of jam.
2. Three hundred gallons of a mixture containing 75.0 wt% ethanol (ethyl alcohol) and 25% water (mixture specific gravity 0.877) and a quantity of a 40.0 wt% ethanol–60% water mixture (SG 0.952) are blended to produce a mixture containing 60.0 wt% ethanol. Calculate the required volume of the 40% mixture (V_{40}).