

**10.213 Chemical Engineering Thermodynamics
Spring 2002**

Problem Set H

Due Wednesday, April 17, 2002 in lecture

Problem 26

A design for purifying helium consists of an adiabatic process that splits a helium stream containing 30 mole percent methane into two products streams, one containing 97 mole percent helium, and the other 90 mole percent methane. The feed enters at 10 bar and 117 °C; the methane-rich product leaves at 1 bar and 27 °C; the helium-rich product leaves at 50 °C and 15 bar. Moreover, work is produced by the process. Assuming helium an ideal gas with $C_p = (5/2)R$ and methane an ideal gas with $C_p = (9/2)R$, calculate the total entropy change of the process on the basis of 1 mol of feed to confirm that the process does not violate the second law.

Problem 27

For a particular binary liquid solution at constant T and P, the molar enthalpies of mixtures are represented by the equation:

$$H = x_1(a_1 + b_1x_1) + x_2(a_2 + b_2x_2) \text{ where } a_i \text{ and } b_i \text{ are constants.}$$

Since the equation has the form of $H = \sum_{i=1}^n x_i \bar{H}_i$, it might be that $\bar{H}_i = x_i(a_i + b_ix_i)$.

- a) Show whether $\bar{H}_i = x_i(a_i + b_ix_i)$ is valid by using the Gibbs-Duhem equation.
- b) Derive expressions for \bar{H}_1 and \bar{H}_2 based on the definition of a partial molar property.

Problem 28

The heat of mixing data for the n-octanol + n-decane liquid mixture at atmospheric pressure are approximately fit by

$$H = x_1x_2(A + B(x_1 - x_2)) \text{ J/mol}$$

where $A = -12,974 + 51.505 T$ and $B = +8782.8 - 34.129 T$ with T in K and x_1 being the n-octanol mole fraction.

- a) Compute the difference between the partial molar and pure component enthalpies of n-octanol and n-decane at $x_1 = 0.5$ and $T = 300$ K.
- b) Compute the difference between the partial molar and pure component heat capacities of n-octanol and n-decane at $x_1 = 0.5$ and $T = 300$ K.
- c) An $x_1 = 0.2$ solution and an $x_1 = 0.9$ solution are to flow continuously into an isothermal mixer in a mole ratio of 2:1 at 300 K. Will heat have to be added or removed to keep the temperature of the solution leaving the mixer at 300 K? What will be the heat flow per mole of solution leaving the mixer?
- d) Plot H vs. x_1 at 300 K. Show the relationship between the plotted data and your answers in part a) by placing your value for n-octanol at $x_1 = 1.0$ and your value for n-decane at $x_1 = 0.0$.
- e) Using the plot, estimate values for \bar{H}_1^∞ and \bar{H}_2^∞ .

Additional Practice Problem (not to be handed in)

Practice Problem P12

A vessel divided into two parts by a partition, contains 4 mol of N₂ gas at 75 °C and 30 bar on one side and 2.5 mol of Ar gas at 130 °C and 20 bar on the other. If the partition is removed and the gases mix adiabatically and completely, what is the change in entropy? Assume N₂ an ideal gas with C_p = 3.5R and Ar an ideal gas with C_p = 2.5R.

Practice Problem P13

For a ternary solution at T and P, the composition dependence of molar property M is given by:

$$M = x_1M_1 + x_2M_2 + x_3M_3 + x_1x_2x_3C$$

where M₁, M₂, M₃ are the values of M for pure species of 1, 2, and 3, respectively, and C is a parameter independent of composition. Determine expressions for \bar{M}_1 , \bar{M}_2 , and \bar{M}_3 by the

application of the equation: $\bar{M}_i = \left[\frac{\partial(nM)}{\partial n_i} \right]_{P,T,n_{j \neq i}}$. As a partial check of your results, verify

that they satisfy the relationship: $M = \sum_i x_i \bar{M}_i$.