

Name _____

Wednesday, April 17th

ECHE 363 – Thermodynamics of Chemical Systems
Midterm #2

Rules:

- 75 minutes total time. Once time is up, put aside answer sheets.
- Be sure to show all work to obtain maximum credit. This includes showing and simplifying any mass/mole, 1st Law, and 2nd Law balances that are needed to solve each problem.
- Closed book and no notes.
- Write your name on every page.
- Please only write on the front side of each page. Ask for additional paper if necessary.

Name _____

For instructor use only:

Problem 1 / 35	
Problem 2 / 35	
Problem 3 / 30	
Total / 100 points	

Name _____

1. (35 points) You are designing a process in which a pure gas at P_1, T_1 is fed to a steady-state adiabatic turbine at molar flow rate \dot{n}_{in} . The turbine exit stream is vapor at P_2, T_2 . The properties of this real gas are well-described by the van der Duval equation of state:

$$P = \frac{1}{v_{\text{m}} - b} \left(RT - \frac{aP}{\sqrt{T}} \right)$$

where a and b are known constants, and $b < v_{\text{m}}$.

The ideal gas heat capacity for this gas is:

$$\frac{C_{\text{p,m}}^{\text{ideal}}}{R} = A + BT$$

where A and B are known constants, and T is in K.

Derive an expression for the power generated by the turbine per mole of gas, $w_{\text{s,m}} = \frac{\dot{W}_{\text{s}}}{\dot{n}_1}$.

Find $w_{\text{s,m}}$ in terms of the following known quantities: $P_1, P_2, T_1, T_2, a, b, A, B, R$.

Name _____

Name _____

Name _____

Name _____

2. (35 points) You need to find the enthalpy of vaporization of a fluid at 500 K. The following equilibrium saturation pressure measurements have been made: (1) the saturation pressure is 0.2 bar at 400 K, and (2) the saturation pressure is 3 bar at 550 K. The following heat capacity data are known for the liquid (L) and vapor (V) phase:

$$c_{p,m}^L = 40 \text{ [J/mol-K]}$$
$$c_{p,m}^V = 30 + 0.05T \text{ [J/mol-K]}$$

You may assume that the vapor phase is an ideal gas in this problem. Note that $\Delta h_m^{\text{vap}} = h_m^V - h_m^L$, where h_m^V and h_m^L are the molar enthalpies of the vapor and liquid phase, respectively.

- a) (15 points) Calculate the enthalpy of vaporization assuming that Δh_m^{vap} is a constant.
- b) (20 points) Calculate Δh_m^{vap} at 500 K, now accounting for the temperature variation of $\Delta h_m^{\text{vap}}(T)$.

Name _____

Name _____

Name _____

Name _____

3. (30 points) You are the Sr. Gatorade Engineer for the Cleveland Guardians and are responsible for ensuring the team has enough blue Gatorade for the season. To achieve this, you have tasked the engineers on your team with developing an expression for the molar volume of a mixture of water (component 1) and Gatorade concentrate (component 2). One of your colleagues has developed the following model for the molar volume of the binary liquid sports drink mixture:

$$v_m = Ax_1 + Bx_2 + Cx_1x_2^2$$

where A , B , and C are known constants.

- a) (10 points) What is the pure species molar volume for Gatorade concentrate (species 2), $v_{m,2}$? Express your answer in terms of known constants A , B , and C .
- b) (20 points) Derive an expression for the partial molar volume of Gatorade concentrate, \bar{V}_2 , in terms of x_1 , as well as the known constants A , B , and C .
- c) **Bonus** (10 extra points, no partial credit) You are skeptical about whether your colleague's proposed model for v_m is consistent with basic thermodynamics. Is the proposed model thermodynamically possible? Justify your evaluation mathematically.

Name _____

Name _____

Name _____