Name ____

Wednesday, April 12th

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.
- There is one bonus question on the exam. This will be graded "all or nothing" (i.e., no partial credit).
- Closed book and no notes.
- Write your name on <u>every page</u>.
- Please <u>only write on the front side of each page</u>. Ask for additional paper if necessary.

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For instructor use only:

Problem 1 / 35	
Problem 2 / 25	
Problem 3 / 40	
Total / 100 points	

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1. (35 points) A mysterious fluid obeys the Renner–renneR equation of state:

$$P(v_{\mathrm{m}} - b) = RT + \frac{aP^2}{T}$$

where the constants are:

$$a = 10^{-7}\ \mathrm{m^3\ K\ /(Pa\ mol)}$$
$$b = 8 \times 10^{-5}\ \mathrm{m^3/mol}$$
$$c_{\mathrm{p,m}}^{\mathrm{ideal}} = 33.5\ \mathrm{J/(mol\,K)}$$

Using the provided property data, calculate the molar entropy change of the fluid for a change from P_1 = 12 bar, T_1 = 300 K to P_2 = 12 bar, T_2 = 400 K.

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2. (25 points) We are interested in the thermodynamic properties of a gas-phase system that contains charged molecules under the influence of an external electrostatic potential. These charged species have a molar charge of α_m. For a system where work can be done through both "PV work" and electrical work, the reversible work is: $dw_{m,rev} = -Pdv_m + \psi d\alpha_m$, where ψ is the potential and α is the charge per mole.

   a) (5 points) Come up with a fundamental equation for du_m for this system.

   b) (10 points) Come up with a fundamental equation for dg_m for this system.

   c) (10 points) Derive a Maxwell Relation equivalent to the partial derivative $\left(\dfrac{\partial s_m}{\partial \alpha_m}\right)_{T,P}$

   d) **Bonus** (10 extra points): Derive a Maxwell Relation equal to the partial derivative $\left(\dfrac{\partial \alpha_m}{\partial v_m}\right)_{s_m,\psi}$. You may need to define a new thermodynamic state function, χ_m.

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3. (40 Points) Two solid phases, α and β, of a pure species exist in equilibrium. It is assumed that the molar volumes of both phases (v_{m}^{α} and v_{m}^{β}) are constant, as are the heat capacities ($c_{\mathrm{p,m}}^{\alpha}$ and $c_{\mathrm{p,m}}^{\beta}$). The enthalpy of the phase change, $\Delta h_{\mathrm{m}}^{\alpha\to\beta} = h_{\mathrm{m}}^{\beta} - h_{\mathrm{m}}^{\alpha}$, is known at T_{o} and is equal to $\Delta h_{\mathrm{m}}^{\alpha\to\beta}(T_{\mathrm{o}})$. Using the measured equilibrium point of (P_{o}, T_{o}) as an integration constant, derive an equation to relate the temperature and pressure of phase equilibrium assuming:

   a) (15 points) The enthalpy of phase change is a constant.

   b) (25 points) The enthalpy of phase change depends on temperature.

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