Law I \[ \Delta U = q + w \]
\[ U = U(T, V) \]
\[ dU = \left( \frac{\partial U}{\partial T} \right)_V dT + \left( \frac{\partial U}{\partial V} \right)_T dV \]

Law II: \[ dS = \frac{q_{nw}}{T} \]
\[ S = S(T, V) \]
\[ dS = \left( \frac{\partial S}{\partial T} \right)_V dT \]
\[ = \left( \frac{\partial S}{\partial V} \right)_T dV \]

Comb I, II: \[ dU = T dS - P dV \]
\[ H = U + P V; \quad A = U - T S \]
\[ G = H - T S; \quad dG = -S dT + V dP \]

Thermodynamic Equation of State
\[ \left( \frac{\partial H}{\partial P} \right)_T = V - T \left( \frac{\partial V}{\partial T} \right)_P \]
\[ \left( \frac{\partial S}{\partial T} \right)_V = C_p; \quad \left( \frac{\partial S}{\partial P} \right)_T = - \left( \frac{\partial V}{\partial T} \right)_P ; \]
\[ \mu_A = \mu_A^* + RT \ln \frac{P_A}{P_o} \]

Dalton's Law
\[ P_A = \chi_A P_{tot}; \quad P_T = \sum_A P_A; \quad G = \sum n_i \mu_i \]
\[ \Delta G_{mix} = RT \sum n_i \ln \left( \frac{P_i}{P_o} \right) \]

Raoult/Dalton Law
\[ n_i (Z - \chi) = n_i (y - Z) \]

Lever Rule

Calculus Identities:
\[ \Delta Z = \int \left( \frac{\partial Z}{\partial y} \right)_x \, dx \]

Cyclic rule:
\[ \frac{d(zy)}{dx} = \frac{d(yz)}{dx} = -1 \]
\[ \frac{dy}{dx} \frac{d(xz)}{dy} + y \frac{d(zx)}{dy} = -1 \]
\[ \frac{dx}{dz} = \frac{dy}{dz} \frac{dx}{dy}; \quad \frac{\partial x}{\partial z} = \frac{\partial y}{\partial z} \frac{\partial x}{\partial y} \]

\[ \beta = \frac{1}{V} \left( \frac{\partial V}{\partial T} \right)_P \]
\[ \kappa = \frac{-1}{V} \left( \frac{\partial V}{\partial P} \right)_T \]

vdW Gas EoS: \[ P = \frac{RT}{V_m - b} - \frac{a}{V_m^2} \]

\[ \Delta H_{rxn}^o = \sum_i v_i \Delta H_f^o (i) \]
\[ \Delta S_{rxn}^o = \sum_i v_i S_f^o (i) \]
\[ dn_i = n_i - n_i^{init} = v_i dX \]
\[ \Delta C_{P,rxn} = \sum_i v_i C_{P,m} (i) \]
\[ \Delta H^o = \Delta H_{rxn}^o \, dX \]
\[ \Delta G_{rxn} = \Delta G_{rxn}^o + RT \ln Q_p = RT \ln \frac{Q_p}{K_p} \]
\[ \Delta E = \Delta E^o - \frac{RT}{v_i F} \ln Q_p \quad \text{Nernst Eqn.} \]
\[ Q_p = \prod_{i=1}^N \left( \frac{P_i}{P_o} \right)^{v_i} @ Eq \quad Q_p = K_p \]
\[ K_p = \left( \frac{P}{P_o} \right)^{\Delta v} K_x = \left( \frac{c_o RT}{P_o} \right)^{\Delta v} K_c \]
\[ \ln \left( \frac{K_p (T_2)}{K_p (T_1)} \right) = - \frac{\Delta H_{rxn}^o}{R} \left( \frac{1}{T_2} - \frac{1}{T_1} \right) \quad \text{Van't Hoff Eqn :} \]
\[ \ln \left( \frac{P_2}{P_1} \right) = - \frac{\Delta H_{rxn}^{sup}}{R} \left( \frac{1}{T_2} - \frac{1}{T_1} \right) \quad \text{Clausius-Clapeyron} \]
\[ \left( \frac{\partial P}{\partial T} \right)_{\Delta H} = \frac{\Delta S}{\Delta V} \quad \text{Clapeyron} \]

Constants:
\[ R = 8.3 J / mol \cdot K \]
\[ R = 0.082 L \cdot atm / mol \cdot K \]
\[ R \cdot 300 = 2.5 \, kJ / mol \]
\[ 1 \text{bar} = 10^5 \, Pa \]
\[ T(K) = T(C) + 273.15 \]
More equations of state and Maxwell relations:
\[ dU = TdS - PdV \quad \left( \frac{\partial U}{\partial V} \right)_T = T \left( \frac{\partial P}{\partial T} \right)_V - P \quad \left( \frac{\partial S}{\partial V} \right)_T = \left( \frac{\partial P}{\partial T} \right)_V \quad \left( \frac{\partial S}{\partial T} \right)_P = \frac{C_p}{T} \]
\[ \frac{\Delta S_{\alpha,\beta}}{\Delta V_{\alpha,\beta}} = \frac{dP}{dT} \]

Useful equations for non-ideal gases:
\[ z = \frac{PV}{RT} \quad \ln \gamma = \int_0^P \frac{\{z - 1\}}{P'} dP' \]

Mixtures:
\[ P_A = \chi_A P_A^* \]
\[ P_A = \chi_A K_A^* \]

Use this page for additional space if you need it. Be sure to write out clearly the equation you are using, in a compact form if possible, before substituting in numbers to obtain a numerical result.

Show your work throughout; clearly show what equations you are using, and always show units for computed quantities.

The mean is often quite low on my exams. If you are having difficulty, don’t freak out. Many parts of problems can be done independently, so if you get stuck, see if you can do another section. The questions are not arranged in order of difficulty. Show your work throughout, always write down the equations you are using before substituting in numerical values and always show units for computed quantities. Show the analytical results of derivatives and integrals before substituting numbers. You do not need to compute the final number if you do not want to but show where the numbers you are given can be used.

Name ____________________________

Student ID __________________