CHEM 163B Prelim II, 11:00 AM – 12:10 PM, March 2, 2016

Name ________________________ SID ________________________ Section ________________________

<table>
<thead>
<tr>
<th>Constants</th>
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<tbody>
<tr>
<td>( R = 8.314 \text{ J/Kmol;} 1 \text{ bar} = 10^5 \text{ Pa;} 1 \text{ atm} = 1.01 \times 10^5 \text{ Pa} )</td>
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1. (20 points) **True or False?**
   a. A change of state from state 1 to state 2 produces a greater increase in entropy when carried out irreversibly than when done reversibly. (TRUE) (FALSE)
   b. For a reversible process in a closed system, \( dq \) is equal to \( TdS \) (TRUE) (FALSE)
   c. For an adiabatic process in a closed system, because \( q = 0 \), \( \Delta S \) must also be zero. (TRUE) (FALSE)
   d. \( U, H, S, A, \) and \( G \) all have the same dimensions. (TRUE) (FALSE)
   e. \( \Delta S_{\text{fusion}} \) and \( \Delta S_{\text{evaporation}} \) are always positive. (TRUE) (FALSE)
   f. For a closed system, \( \Delta S \) can never be negative. (TRUE) (FALSE)
   g. Since \( G = H - TS \), \( dG = dH - TdS \) is applicable to all processes. (TRUE) (FALSE)
   h. \( G \) is an extensive variable and \( \mu \) is an intensive variable. (TRUE) (FALSE)
   i. At equilibrium, \( \Delta G = 0 \) and \( \Delta S = 0 \). (TRUE) (FALSE)
   j. For a chemical reaction involving only ideal gases, the equilibrium constant varies with reaction temperature. (TRUE) (FALSE)

2. (20 pts) Please state the second and third laws of thermodynamics

   **Second law of thermodynamics:**

   **Third law of thermodynamics:**
3. (25 pts). Two adiabatic containers (10 L each) are connected by a valve. Initially, one of them contains 2 mole of an ideal gas, and the other is vacuum. At 300 K, the valve is opened, and the gas is expanded into the other container. Calculate $\Delta U$, $\Delta H$, $\Delta S$, $\Delta A$ and $\Delta G$ involved?

$Q = 0, \quad W = 0. \quad \therefore \Delta U = 0, \quad \Delta T = 0$

$\Delta H = 0$

$\Delta S = nR \ln \frac{V_2}{V_1} = 2 \times 8.314 \ln \frac{20}{10}$

$= 11.52 \text{ (J/K)}$

$\Delta A = \Delta G = -T \Delta S = -300 \times 11.52 = -3457.70 \text{ J}$
4. (15 points) The diagram to the right represents a reversible Carnot cycle for an ideal gas.

a. What is the thermodynamic efficiency of the engine?

\[ \varepsilon = 1 - \frac{T_L}{T_H} = 1 - \frac{303}{673} = 0.55 \]

\[ \varepsilon = \frac{W}{q_H} \]

\[ q_H = \frac{W}{\varepsilon} = \frac{600}{0.55} = 1091.35 \text{ (J)} \]

\[ q_L = q_H - W = 1091.35 - 600 = 491.35 \text{ (J)} \]
5. (20 pts) Using the definition of $G = H - TS$, show that the exact differential, $dG = -SdT + VdP$. Then derive the Gibbs-Helmholtz equation $\left( \frac{\partial G}{\partial T} \right)_p = -\frac{H}{T^2}$.

\[ \left( \frac{\partial G}{\partial T} \right)_p = \frac{1}{T} \left( \frac{\partial G}{\partial T} \right)_p - G \left( \frac{1}{T^2} \right) \]

as $dG = -SdT + VdP$

\[ \frac{\partial G}{\partial T} \bigg|_p = -S \]

\[ \left( \frac{\partial G}{\partial T} \right)_p = -\frac{S}{T} - \frac{G}{T^2} \]

\[ -\frac{S}{T} + \frac{G}{T^2} = -\frac{H}{T^2} \]