NORTH CAROLINA STATE UNIVERSITY
Department of Chemistry Name_____

CH 331 Mid-term Examination
Physical Chemistry

Given: $g = 9.81\ m/s^2$
$R = 8.314\ J\ mol^{-1}\ K^{-1} = 0.08206\ L\ atm\ mol^{-1}\ K^{-1}$
$1\ atm = 1.0133 \times 10^5\ Nm^{-2} = 760\ Torr$
$P = P_0 \exp\{-Mgh/RT\}$

$$P_2 = P_1 + \frac{\Delta_{trs}H_m}{\Delta_{trs}V_m}\ln\left(\frac{T_2}{T_1}\right) \quad , \quad \ln\left(\frac{P_2}{P_1}\right) = \frac{\Delta_{trs}H_m}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$$\ln\left(\frac{K_2}{K_1}\right) = \frac{\Delta H_m}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$$\Delta S = -R\sum_{i=1}^{N} x_i \ln x_i \quad \textit{where } N \textit{ is the number of components}$$

$$\Pi = cRT \quad , \quad \rho = mgh \quad , \quad P = \rho gh \quad , \quad DT_{fus} = K_f m \quad , \quad K_f = \frac{RT_{fus}^2 M}{1000\Delta H_{fus}}$$

Please answer all questions.

1. A. Assuming that Ar gas is ideal calculate its density at 10 atm and 200 K (5 points):

$\rho(gL^{-1})$ = _____

B. Calculate the molar internal energy of argon gas at 200 K (3 points).

C. Calculate the molar heat capacity at constant pressure of argon gas at 200 K (2 points).

2. Calculate the pressure 15000 m below the surface of the ocean at 10 ^{o}C assuming that water has a density of 1.0 x 10^{3} gL^{-1} (5 points).

P(bars) = _____

3. Oxygen, nitrogen, carbon dioxide and argon gases are placed in an insulated vessel with volume V with a gas tight seal dividing the vessel into four equal volumes. The initial pressures of all four gases is 1 atm. The seal is removed reversibly and the four gases are allowed to come to equilibrium (15 points).

a. Calculate the entropy of mixing.
b. Calculate the entropy change associated with the volume change as argon is expanded from the initial to the final volume (system only).
c. Calculate the entropy change associated with the volume change as oxygen is expanded from the initial to the final volume (system only).
d. Calculate the entropy change associated with the volume change as nitrogen is expanded from the initial to the final volume (system only).
e. Calculate the entropy change associated with the volume change as carbon dioxide is expanded from the initial to the final volume (system only).
f. What can you say about the two methods for calculating the entropy (mixing vs. expansion)?

4. An ideal gas is initially at 1.0 atm and 400 K. Its volume is initially 10 L and the gas is compressed to 0.2 L under the following conditions (15 points):

(1.) $P_{external}$ = 500.0 atm
(2.) $P_{external}$ = constant (single-step)
(3.) $P_{external} = P_{gas}$ (reversible compression)

For each of the above conditions calculate ΔU, q, and w, for the gas.

	q(J)	w(J)	ΔU(J)
(1.)	_____	_____	_____
(2.)	_____	_____	_____
(3.)	_____	_____	_____

5. A. Calculate the thermodynamic efficiency of a steam turbine operating at 600 K with an exhaust temperature of 300 K (3 points).

   B. How much work would be derived for every kJ of heat expelled into the environment by this engine (2 points)?

6. The standard enthalpy of the reaction N_2 (g) + 3 H_2 (g) $\rightarrow$ 2 NH_3 (g) is – 92.2 kJ/mol of ammonia and the third law entropies of H_2, N_2, and NH_3 at 298 K are given in the table below. Assuming that the entropy and enthalpy are independent of temperature calculate the Gibb's free energy at 240 K. The enthalpy of vaporization of ammonia is $\Delta_{vap}H^o$ = 23.3 kJ/mol and T_b = 239.7 K. (20 points).

Substance	C_p (J/mol-K)	S^o (J/mol-K)
NH_3 (aq)	75.3	111.3
NH_3 (g)	35.4	192.4
H_2 (g)	27.3	130.6
N_2 (g)	29.1	191.6

7. A. What is the total pressure above a solution of ethanol ($x_{ethanol}$ = 0.6) and methanol as it begins to boil? ($P_{ethanol}$* = 58 torr and $P_{methanol}$* = 159 torr) (5 points)

P_{total} = _____

B. Calculate the mole fraction of ethanol in the vapor phase under the conditions above. (5 points)

$y_{ethanol}$ = _____

8. How do trees transport water?
   A. If they do it by hydrostatic pressure determine the tallest tree that can grow at 1 atm of pressure by calculated the height of a column of water that can be supported at 1 atm (5 points).

   B. Determine the height of water supported by the osmotic pressure at 298 K in a tree where the electrolyte concentration is 0.4 M (5 points).

8. Using the data given below calculate the boiling point of water on the top of Mt. Kilimanjaro where the atmospheric pressure is P = 0.5 bar. (15 points)

T_{fus} = 273.15 K $\Delta_{fus}H$ = 6.0 kJ/mol
T_{vap} = 373.15 K $\Delta_{vap}H$ = 40.65 kJ/mol
ρ_{ice} = 0.917 gm/cm^3 ρ_{water} = 1.000 gm/cm^3
Triple point T = 273.16 K P = 0.006 bar
Critical point T_c = 647.3 K P_c = 218 bar