NORTH CAROLINA STATE UNIVERSITY
Department of Chemistry Name________________________________

CH 331 Practice Mid-term
Physical Chemistry

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

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

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

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

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

Please answer all questions.

1. Assuming that $N_2$ gas is ideal calculate its density at 1 atm and $100^oC$:

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

2. Calculate the pressure 15 m below the surface of a lake at $20^oC$, noting that water has a density of $1.0 \times 10^3\ gL^{-1}$:

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

2. An ideal gas is initially at 1.00 atm and 350 K. Its volume is initially 7.5 L and the gas expands to 22.2 L under the following conditions:

(1.) $P_{external} = 0$
(2.) $P_{external} = 0.333$ atm
(3.) $P_{external} = P_{gas}$ (reversible expansion)

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

| | ΔU(J) | q(J) | w(J) |
|---|---|---|---|
| (1.) | ___________ | ____________ | _____________ |
| (2.) | ___________ | ____________ | _____________ |
| (3.) | ___________ | ____________ | _____________ |

3. A worker at the patent office opens a sealed envelope and reads a new patent disclosure form. The patent describes an engine that can run at 99% efficiency. The patent review scientist scribbles some numbers on a sheet of paper. She assumes that the engine cannot be more efficient than an ideal reversible Carnot cycle. After completing the calculation, she shakes her head, smiles, and stamps REJECT on the application.
   A. Given that exhaust temperature of the engine must be approximately 300 K, what is the thermodynamic temperature required for the expansion cycle of the engine?

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

4. Oxygen, nitrogen, and argon gases are placed in an insulated vessel with volume V with a gas tight seal dividing the vessel into three equal volumes. The initial pressures of all three gases is 1 atm. The seal is removed reversibly and the three gases are allowed to come to equilibrium.

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).

5. The standard enthalpy of the reaction $O_2$ (g) + 2 $H_2$ (g) → 2 $H_2O$ (l) is – 571.6 kJ/mol of water and the third law entropies of $H_2$, $O_2$, and $H_2O$ 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 1000 K. The enthalpy of vaporization of water is $\Delta_{vap}H^o$ = 40.7 kJ/mol. Given the heat capacity data below calculate the Gibb's free energy at 1000 K based on the temperature dependence of the enthalpy and entropy.

| Substance | $C_p$ (J/mol-K) | $S^o$ (J/mol-K) |
|---|---|---|
| $H_2O$ (l) | 75.3 | 70.0 |
| $H_2O$ (g) | 30.54 | ----- |
| $H_2$ (g) | 27.28 | 130.6 |
| $O_2$ (g) | 29.96 | 205.1 |

6. Calculate the vapor pressure of water at 298 K. Use data given problem 5 for any needed parameters.