Exam #1 for Physical Chemistry for Energy Science
Department of Nuclear Engineering, Seoul National University

10/10/01 Monday PM 2:30-4:00
90 minutes, closed book
One spike sheet and the formula booklet are allowed.

1. (20) One mole of Argon is contained in a bottle and two moles of helium is contained in another bottle, both at one atmosphere and 25 C.
   a) Van der Waals constants are a= 0.1342 for Ar, a=0.003577 for He, b=3.167x10^{-5} m3/mole for Ar, b=22.405x10^{-5} m3/mole for He. Determine the molecular diameter for each gas. 22.05 x 10^{-6}
   b) When two bottles are connected and molecules are allowed to mix, determine van der Waals gas constants and molar volume for the mixture using Amagat's law.
   c) Show that the internal pressure of a real gas can be determined from equation of state using the following relationship;
   $$(\partial U/\partial V)_T = T(\partial P/\partial T)_V - P$$
   d) For a van der Waals gas, show that $(\partial U/\partial V)_T = a/Vm^2$ and determine the internal pressure for the mixture.

2. (20) UO_2 gas is a linear molecule with uranium atom at its center
   a) If you can assume that the equipartition principle is applicable to UO_2, estimate specific heat at constant volume as function of temperature.
   b) Assuming an idela gas behavior, show that the mean gas molecular speed is $u=(3RT/M)^{1/2}$.
   c) Draw the molecular speed distribution for the ideal gas.
   d) One needs to measure the vapor pressure of UO_2 in a fuel rod with 5% enrichment at room temperature. Knowing that the value will be too small to measure by any pressure gauges, a clever scientist suggested to use a mass spectroscopy that can measure the collision frequency with a wall, $Z=n^*(RT/2\pi M)^{1/2}$. How can you determine the vapor pressure?

3. (25) A mole of an ideal gas in a piston was expanded from V_1 to V_2 in an isothermal process at T_1.

a) What are the requirements to be a reversible process?

b) What is the change in entropy due to the volume increase in a reversible process?

c) What is the change in entropy due to the volume increase in an irreversible process

d) What is the physical meaning of the entropy change by the volume increase?

e) Determine the isothermal compressibility at the initial pressure P_1.

4. (20) Assume, the Carnot efficiency for an engine operating between two heat reserviors is given as $(T_2-T_1)/T_2$

a) Derive the Clausius inequality ($TdS \geq dq$), starting from the first law.

b) Show that the perpetual motion machine of type I is unphysical.

c) Show that the perpetual motion machine of type II is unphysical.

d) Show that the absolute 0 K is inaccessible.

5. (15) Assuming that the internal energy, U, is given, derive that:

a) Helmholtz free energy A=U-TS

b) $(\partial A/\partial V)_T = -P$

c) $(\partial H/\partial P)_T = V - T(\partial V/\partial T)_P$

END.