4.50

PRINT YOUR NAME CLEARLY ON EVERY PAGE

FIRST NAME______________ LAST NAME ______________________

STUDENT NUMBER______________________

UNIVERSITY OF TORONTO

FINAL EXAM, 1996

CHE 150F - CHEMISTRY

EXAMINERS - M.T. Kortschot, R. Luus

1. Do *five out of six* questions. Each question is worth equal marks. Indicate which questions you want marked very clearly by circling the corresponding numbers on the marks list below. If you do not do this, questions 1-5 will be marked.

2. Calculator Type 2 - Non-programmable calculators are allowed. No programmable calculators are allowed. No other aids are allowed.

3. **ALL WORK IS TO BE DONE ON THESE SHEETS!** Use the back of the page if you need more space. Be sure to indicate clearly if your work continues elsewhere. **DO NOT SEPARATE THE SHEETS. ALWAYS PUT YOUR FINAL ANSWERS IN THE BOXES PROVIDED.**

Equations that may be of some use:

$dU = TdS - PdV$

$H = U + PV$

$G = H - TS$

$F = U - TS$

$TdS = C_v dT + T(\partial P / \partial T)_v dV$

$TdS = C_p dT - T(\partial V / \partial T)_p dP$

$$\ln\left(\frac{P_{vap2}}{P_{vap1}}\right) = \frac{\Delta H^o_{vap}}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$$\left(\frac{\partial x}{\partial y}\right)_z \left(\frac{\partial y}{\partial z}\right)_x \left(\frac{\partial z}{\partial x}\right)_y = -1$$

$R = 0.082 \quad atm\ L / (mol\ K)$

$R = 8.314 \quad J / (mol\ K)$

$1\ atm = 101.3\ kPa = 1.013\ bar$

CIRCLE THE NUMBERS OF THE FIVE QUESTIONS TO BE MARKED

1	
2	
3	
4	
5	
6	
TOTAL	

1. The normal boiling point of toluene is 110.4°C. At 84°C, the vapour pressure of toluene is 44.4 kPa.

a) Calculate the heat of vaporization, ΔH°_{vap} of toluene.
b) What is the entropy change when one mole of toluene vaporizes at 110.4°C?
c) What is the work done when one mole of toluene vaporizes at 110.4°C?

ANSWERS: a) ΔH°_{vap} = b) ΔS = c) w =

Name:____________________

2. A gaseous mixture of 90.0 moles of benzene and 40.0 moles of toluene was cooled to 88°C, whereupon some condensation occurred. At 88°C the vapour pressure of benzene and toluene are 128.0 and 50.6 kPa respectively. If the total pressure above the condensate is 101.3 kPa:

a) Calculate the number of moles of toluene in the condensate.
b) How many moles of benzene are in the vapour phase?

ANSWERS: (a) $n_{toluene}$ = (b) $n_{benzene}$ =

... g of liquid H_2O is supercooled to -10.0°C in an adiabatic container. Suddenly, ...ne of the water freezes. After equilibrium is established, find:

the mass of ice formed,

ΔS for the system, and

ΔS for the surroundings.

...$H^\circ_{melting}$ = 6.0 kJ/mol, $C_p(H_2O)$ = 75.3 J/(mol K) mm_{H2O} = 18.0 g/mol

...NSWERS: a) m =	b) ΔS_{sys}=	c) $\Delta S_{surr.}$ =

4. a) By starting with the expression $dU = TdS - PdV$, and using the definitions of the heat capacities C_p and C_v, derive an expression for $C_p - C_v$ in terms of the measureable quantities α and κ. Do not start with the TdS equations for the derivation.

Recall that $\alpha = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P$ $\kappa = -\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_T$.

b) Calculate $C_p - C_v$ for 1.0 mole of methane at T = 273K and P = 100 atm, by using either form of the van der Waals equation provided below:

$$\left(P+\frac{a}{V^2}\right)(V-b) = RT, \qquad V = \frac{RT}{P}+b-\frac{a}{RT}.$$

For methane: a = 2.26 atm L^2/mol^2, b = 0.0428 L/mol.

c) If methane were an ideal gas, what would $C_p - C_v$ be?

5. For the gaseous reaction $PCl_5(g) \Leftrightarrow PCl_3(g) + Cl_2(g)$ $K_p = 1.78$ atm at 250°C.
a) If 0.1 mole of PCl_5 and 0.30 mole of N_2 are held at 250°C in a 5.0 litre flask, how much Cl_2 is formed? Note that N_2 is an inert gas.
b) How should the volume of the container be changed to increase the Cl_2 formed by 20%?

ANSWERS: a) n =	b) new total Volume =

6. To investigate the order of the reaction $A(g) \Rightarrow 2B(g)$, pure A was put into a constant volume reactor and the total pressure was recorded as a function of time.
a) Derive the relationship between the partial pressure of A, denoted P_A, and the total pressure.
Note: The derivations for parts b) and c) must start with the differential rate laws.
b) If the reaction is first order, show that some function of P_A plotted against time gives a straight line.
c) If the reaction is second order, show that a different function of P_A plotted against time gives a straight line.