FIRST NAME _____   LAST NAME _____

STUDENT NUMBER _____

UNIVERSITY OF TORONTO

FINAL EXAM, DEC. 11, 1998

CHE 150F - CHEMISTRY

EXAMINERS - M.T. Kortschot, W.H. Burgess

1. Do all questions. The marking scheme for each question is indicated in the margin. The marks add up to 100.

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 EXCEPT FOR PAGE 9 WHICH IS BLANK AND MAY BE SEPARATED AND USED AS SCRAP. PAGE 9 WILL NOT BE MARKED. ALWAYS PUT YOUR FINAL ANSWERS IN THE BOXES PROVIDED.**

Equations that may be of some use.

$$dU = TdS - PdV$$

$$H = U + PV$$

$$G = H - TS$$

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

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

$$1\,atm = 101.3\,kPa = 760\,mmHg$$

$$273.15\,K = 0°\,C \quad 1m^3 = 1000L$$

$$C_p - C_v = R$$

Molar Masses (g/mol)
H = 1.01, C = 12.01, O = 16.00,
S = 32.06

Marks

1	
2	
3	
4	
5	
6	
7	
TOTAL	

Problem 1 [12 marks total]

N_2 (g) saturated with acetone vapour (C_3H_6O) enters a continuous flow condenser at 39.5°C and at a pressure of 800 mmHg.   It leaves the condenser at 7.70°C and at a pressure of 750 mmHg. Assuming steady state operation of the condenser, calculate the amount of acetone condensed (in kg) per 100.0 m³ of entering gas.

Vapour pressure of acetone: at 7.70 °C, 100 mmHg; at 39.5, 400 mmHg

ANSWER:

Problem 2 [12 marks total]

Data at 25°C	ΔG_f^o (kJ/mol)	ΔH_f^o (kJ/mol)
$CH_3CH_3(g)$	-32.92	-84.68
$CH_2CH_2(g)$	68.08	52.26
$H_2(g)$	0	0

a) For the reaction $CH_3CH_3(g) \Leftrightarrow CH_2CH_2(g) + H_2(g)$, calculate K_p and ΔS^o at 25°C. Is the sign of the ΔS^o what you would expect? Briefly explain.

b) Stating any assumptions made, estimate the temperature at which the reaction becomes favourable under standard conditions – i.e. the temperature at which $K_p = 1$.

ANSWERS: (a)   (b)

Problem 3 [12 marks total]

A gas cylinder contains pure SO_3 at 1.39 atm and 25.0°C. The cylinder is heated to 800.0 °C and held at this temperature until the equilibrium
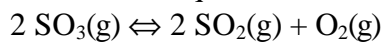
$$2\ SO_3(g) \Longleftrightarrow 2\ SO_2(g) + O_2(g)$$

is established. At equilibrium, the total pressure is 6.50 atm. Assuming that the gases are ideal and that the volume of the gas cylinder has not changed, calculate
a) the percent dissociation of the SO_3,
b) K_p and K_c for the reaction $2\ SO_3(g) \Longleftrightarrow 2\ SO_2(g) + O_2(g)$

ANSWER: (a)   (b)

Problem 4[18 marks total]

a) An aqueous sulfuric acid solution is 54.0% by mass H_2SO_4 and at $20^{\circ}C$ has a density of 1.435 g/mL. Calculate its molality and its molarity at $20^{\circ}C$.

b) An ideal solution consisting of benzene and toluene has a normal boiling point of $100.0^{\circ}C$. Calculate the mole fraction of benzene
(i) in the liquid phase, and (ii) in the vapour phase.
Vapour pressures at $100.0\,^{\circ}C$ are: benzene 180.0 kPa; toluene 74.1 kPa.

c) A sample of steam at $400\,^{\circ}C$ and 30.0 MPa has a density of 358.4 g/L. Calculate its compressibility factor (Z)

ANSWERS:	(a)		
	(b) (i)	(ii)	
	(c)		

Problem 5 (18 marks total – 1.5 marks per answer)

1 mole of nitrogen gas goes through the following processes

a) Reversible, isothermal expansion from 2.0 atm, 25.0 $^{\circ}$C $\Rightarrow$ 1.0 atm, 25.0 $^{\circ}$C
b) Irreversible expansion against a fixed external pressure of 1 atm
             from 2.0 atm, 25.0 $^{\circ}$C $\Rightarrow$ 1.0 atm, -5.00 $^{\circ}$C

For the two processes (a) and (b), calculate ΔU, ΔH, ΔS, w and q.
C_p for the gas is 29.1 J/(mol K), and S° = 191.5 J/(mol K) at 25.0°C.

ANSWERS:					
a) ΔU	ΔH	ΔS	ΔG	w	q
b) ΔU	ΔH	ΔS	ΔG	w	q

Problem 6 (12 marks total)

a) Starting with $dU = TdS - PdV$, and the definitions of H and G show that

$$\left(\frac{\partial S}{\partial P}\right)_T = -\left(\frac{\partial V}{\partial T}\right)_P$$

b) Starting with $dH = TdS + VdP$, show that $\left(\frac{\partial H}{\partial P}\right)_T = -T\left(\frac{\partial V}{\partial T}\right)_P + V$

c) Calculate $\left(\frac{\partial H}{\partial P}\right)_T$ for an ideal gas.

d) Calculate $\left(\frac{\partial H}{\partial P}\right)_T$ for a gas obeying the truncated van der Waals equation of state:

$$PV = RT + (b - \frac{a}{RT})$$

Problem 7 [16 marks total]

(For this question, use $0^{\circ}C = 273.15$, and assume that the water obeys Raoult's Law)

a) Calculate the vapour pressure at $100.0\ ^{\circ}C$ of a solution consisting of 20.0g of glucose (mm = 180.0g/mol) and 200.0g of water.

b) What would the change in temperature (from $100.0\ ^{\circ}C$) have to be to bring the partial pressure of water in equilibrium with this solution to 1.000 atm. $\Delta H_{vap}(H_2O) = 40.65$ kJ/mol at $100.0^{\circ}C$.

c) Use the answer from part (b) to calculate the molal boiling point elevation constant for water.

d) If the solution is held at $-1.50^{\circ}C$, what mass of ice (in grams) will eventually form? K_f of water is 1.86 K kg/mol.

ANSWERS: (a)	(b)	(c)	(d)

ROUGH WORK (THIS PAGE WILL NOT BE MARKED)