FIRST NAME ___________________________ LAST NAME ___________________________

STUDENT NUMBER ___________________________

UNIVERSITY OF TORONTO

FINAL EXAM, DEC. 4, 1997

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 8 WHICH IS BLANK AND MAY BE SEPARATED AND USED AS SCRAP. PAGE 8 WILL NOT BE MARKED. ALWAYS PUT YOUR FINAL ANSWERS IN THE BOXES PROVIDED.** Please answer all questions to only 3 significant figures.

Cl = 35.5, Ca = 40.1

Equations that may be of some use.

$$dU = TdS - PdV$$

$$H = U + PV$$

$$G = H - TS$$

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

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

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

$$273K = 0°C$$

Molar Masses (g/mol)

H = 1.01, C = 12.0, O = 16.0,

Marks

1	
2	
3	
4	
5	
6	
7	
TOTAL	

Problem 1 (8 marks total)

1 mole of an ideal gas goes through the following reversible processes

a) 1.00 atm, 25.0 $^oC \Rightarrow$ 1.00 atm, 75.0 ^oC
b) 1.00 atm, 75.0 $^oC \Rightarrow$ 0.100 atm, 75.0 ^oC

For the two processes (a), and (b) calculate ΔU, ΔH, ΔS, and ΔG.
C_p for the gas is 29.0 J/(mol K), and S^o = 190.0 J/(mol K) at 25.0^{o}C.

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

Problem 2 (12 marks total)

A tanker truck containing 5510 L of commercial HCl solution (30.1% by mass HCl, density 1.15 g/mL) spills. What mass of powdered limestone (90.0% by mass $CaCO_3$, 10.0% inert material) is required to neutralize the spill? (See pg. 1 for molar masses)

$$HCl + CaCO_3 \Rightarrow CaCl_2 + H_2O + CO_2$$

ANSWER: Mass =

Problem 3 [12 marks total]

A gas stream at 900.0 K and 2.00 atm has the following composition:

CO: 30.0 mole % CO_2: 70.0 mole %.

a) Is there a possibility that carbon deposits will form? Justify your answer with an appropriate calculation.

b) If carbon deposits do have a tendency to form, they can be prevented by diluting the gas stream with nitrogen. What will be the composition of the gas stream (in mol %) which will have just enough nitrogen to prevent the formation of carbon deposits? Assume that the temperature and total pressure do not change.

K_p for the reaction $2CO\ (g) \Leftrightarrow C\ (s) + CO_2\ (g)$ is 5.70 atm^{-1} at 900.0 K.

ANSWERS: (a)	(b) % nitrogen =

Problem 4 [14 marks total]

a) A 100.0 L tank is designed to withstand a maximum pressure of 150.0 bar. Determine the maximum mass of CO_2 that can be safely stored in the tank at 40.0 ^oC using:

i) the ideal gas law,

ii) the truncated van der Waals equation for one mole of gas is:

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

b) Is it possible that some of the gas stored in the tank at 40.0 ^oC and 150.0 bar is in the liquid state? Support your answer with a brief statement of 10 words or less.

c) Define the Boyle temperature.

d) Calculate the Boyle temperature of CO_2 using the truncated van der Waals equation.

Data: van der Waals constants for CO_2: a = 3.66 bar L^2/mol^2; b = 0.0428 L/mol; T_c = 304.2 K; P_c = 73.8 bar.

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

Problem 5 [24 marks total]

At 298K	**C^o_p(J/mol K)**	**DH^o_f(kJ/mol)**
H_2O (l)	75.3	-285.8
H_2O (g)	33.6	-241.8

A 1.00 L pressure cooker contains 900.0 g of H_2O (l) at 120.0^{o}C when the safety valve suddenly blows open setting the external pressure to 1.00 atm instantaneously. Some of the water in the cooker spontaneously boils, and boiling stops when the temperature of the remaining liquid reaches 100.0^{o}C. The process occurs so rapidly that it may be considered to be adiabatic. If the end-point of the process is the point at which the temperature just reaches 100.0^{o}C , calculate:

ANSWERS

(a) The heat of vapourization at 100.0 ^{o}C.
(b) The vapour pressure of water at 120.0 ^{o}C.
(c) The mass of water which vapourizes in grams.

For parts d, e, f, use 3 moles vapourized if you can't solve for part c.

(d) The ΔS for the process.
(e) The work done during the process.
(f) The ΔU for the process.

a)

b)

c)

d)

e)

f)

<u>Problem 6 [16 marks total]</u>

Air at a temperature of 25.0^oC, and a pressure of 1.00 atm, picks up water while passing over a lake until it has a relative humidity of 80.0%.

a) What is the mole fraction of water vapour in the air?
b) The moist air then travels up a mountain, and the total pressure is lowered to 92.0 kPa, and the temperature drops to 10.0^oC. What percentage of the water vapour condenses as rain during this process ?

Data: The vapour pressure of water at 25.0^oC is 3.17 kPa, and for water the ΔH_{vap} (25.0^oC) = 44.0 kJ/mole.

ANSWERS: (a)	(b)

Problem 7 [14 marks total]

An ideal solution of methanol, ethanol, and propanol is in equilibrium with its vapour at 80.0 ^{o}C. The mole fraction of the methanol in the liquid phase is 0.400. The mole fraction of the methanol in the vapour phase is 0.635. Calculate:

a) the total pressure of the vapour in mmHg,
b) the mole fraction of ethanol in the liquid phase.

Data: vapour pressure at 80.0^{o}C:
methanol 1349 mmHg; ethanol 813 mmHg; propanol 381 mmHg

ANSWER: (a)	(b)

ROUGH WORK