UNIVERSITY OF TORONTO

FACULTY OF APPLIED SCIENCE AND ENGINEERING

FINAL EXAMINATIONS - DECEMBER 1991

First Year, Program 5, Engineering Science

CHE 150F - CHEMISTRY

Examiners: Prof. M.T. Kortschot, Prof. W.H. Burgess

Answer all seven questions. The marks are shown in the margin. No aids are permitted. Any non-programmable calculator may be used.
Please read the paper carefully and make sure that your solutions are legible!

Given Information

R = 8.314 J/(mol K) = 0.08206 L atm/(mol K)

1 atm = 101.325 kPa

atomic masses (g/mol) C = 12.0, H = 1.0, O = 16.0, N = 14.0

$$G = H - TS \qquad \ln\left[\frac{P_1^\circ}{P_2^\circ}\right] = \frac{\Delta H_{vap}}{R}\left[\frac{1}{T_2} - \frac{1}{T_1}\right] \qquad E = E^\circ - \frac{.0592}{n}\log Q$$

The composition of dry air is 21.0 mol % O_2 and 79.0 mol % N_2.

1. An electric kettle transfers heat to its contents at the rate of 1500 J/s. It is used to boil 1.00 kg of H_2O. The water is initially liquid at 25°C and ends up as steam at 100°C and 1.00 atm. Assuming that no heat is lost to the surroundings:

   a) How long does it take for the kettle to boil?
   b) What is the heat of vapourization of water at 100°C?
   c) How long does it take for the kettle to boil dry?
   d) How much work is done in vapourizing all of the water?

	C°_p (J/mol K)	ΔH°_f (kJ/mol)
H_2O (l)	75.29	-285.8
H_2O (g)	33.58	-241.8

2. a) A furnace burns methane (CH_4) in air at the rate of 1 kg of methane per hour producing CO_2 and H_2O. A 20% excess of air is required to achieve complete combustion. Calculate the volumetric flowrate of air (at 1.0 atm, 25°C) required by the furnace if the relative humidity is 85%. The vapour pressure of water at 25°C is 3.17 kPa.

b) What is the molar composition of the product gas stream, assuming that the gases leave the furnace at a temperature of 305°C and 1.0 atm pressure.

Given the following information, calculate the solubility product (K_{sp}) of AgBr.

$AgBr(s) + e^-$	$\rightarrow$	$Ag(s) + Br^-(aq)$	$E° = 0.07$ V
$Ag^+(aq) + e^-$	$\rightarrow$	$Ag(s)$	$E° = 0.80$ V

10 4. Diethyl ether in equilibrium with its vapour is stored in plastic bottles which are designed to withstand a maximum pressure of 200 kPa. What is the maximum temperature to which the bottles of ether can be safely exposed?

For the ether: n.b.p. is 34.6°C; ΔH_v equals 27.0 kJ mol^{-1}.

15 5. 150 g of supercooled water, held in a thermos bottle at -10°C, spontaneously freezes. The result is a mixture of ice and water at 0°C. Assuming that the process is adiabatic, calculate (a) the grams of ice formed and (b) ΔS for the process. Is the sign of the ΔS what you would expect? Briefly explain. Given: c_p of supercooled water is 4.18 J g^{-1} °C^{-1}; ΔH fusion of ice at 0°C is 333 J g^{-1}.

20 6. A study of the equilibrium, $N_2O_4(g) \Leftrightarrow 2NO_2(g)$, yielded the following results:

Temperature °C	Total pressure at equilibrium atm	Density at equilibrium g/L
25	1.000	3.166
45	1.000	2.577

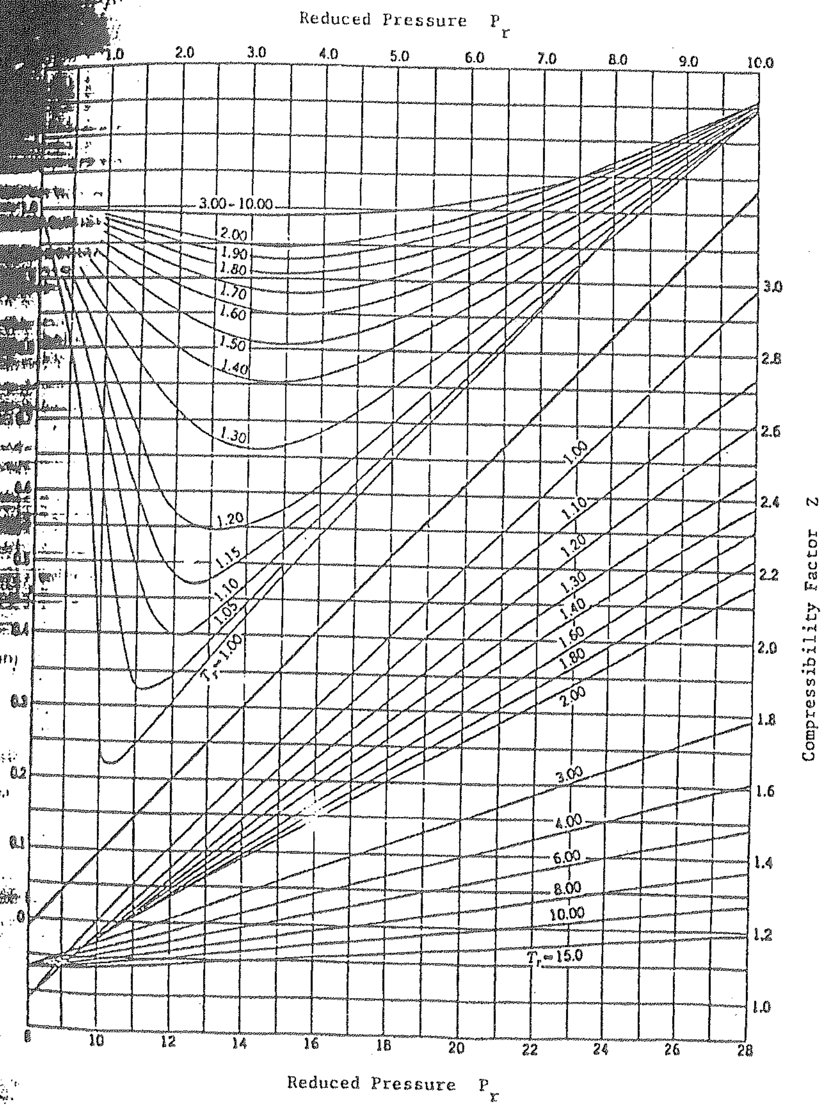
a) Calculate K_p, K_c and $\Delta G°$ at 45°C for the above reaction.

b) Determine $\Delta S°$ and $\Delta H°$ for the above reaction. You may assume that both $\Delta S°$ and $\Delta H°$ are independent of temperature.

10 7. Calculate the volume of tank required to store 500 kg of ethylene (C_2H_4) at 25°C and 75 atm, using (a) the ideal gas law and (b) the attached generalized compressibility chart.

For ethylene: $T_c = 283$ K; $P_c = 50.5$ atm.

GENERALIZED COMPRESSIBILITY CHART *



* J.M. Smith and H.C. Van Ness, Introduction to Chemical Engineering Thermodynamics, McGraw-Hill, (1959).