FACULTY OF APPLIED SCIENCE AND ENGINEERING
UNIVERSITY OF TORONTO
CHE 150F Exam, Dec. 10, 1993
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Each of the eight questions will be marked out of 10. You must answer all questions in your exam booklet.

Given Information

R = 8.314 J/(mol K)  1 F = 96,500 J/(V mol)  1 atm = 101.325 kPa = 760 mmHg

molar masses (g/mol)  N: 14.0, Mg: 24.3

$$\ln\left[\frac{P_2^\circ}{P_1^\circ}\right] = -\frac{\Delta H_{vap}}{R}\left[\frac{1}{T_2}-\frac{1}{T_1}\right]$$

$$E = E^o - \frac{RT}{nF}\ln Q$$

At 25°C $E = E^o - \frac{0.0591}{n}\log Q$

$Mg^{2+}(aq) + 2e^- \longrightarrow Mg(s)$  $E^o = -2.37$ V

$Ag^{+}(aq) + e^- \longrightarrow Ag(s)$  $E^o = +0.80$ V

1) A piece of magnesium metal weighing 1.56 g is placed in 100.0 mL of 0.100 M $AgNO_3$ at 25°C.

a) Calculate [$Mg^{2+}$] and [$Ag^+$] in solution at equilibrium.

b) What mass of magnesium is left? You may assume that the volume remains constant.

2) 1.00 mole of gas containing an unknown mix of methane ($CH_4$) and propane ($C_3H_8$) was combined with 5.00 moles of oxygen gas in a 40.0 litre constant volume reactor. The mixture was burned completely to $H_2O(g)$ and $CO_2(g)$. After combustion a total of 6.40 moles of gas were left.

a) What was the molar ratio of methane to propane in the original gas mixture?

b) If the original gas mixture was at 25°C, what was the partial pressure of oxygen in this mixture?

3) An ideal solution consisting of benzene, toluene and p-xylene has a normal boiling point of 100°C. The mole fraction of benzene in the vapour phase is 0.632 Calculate:

a) the mole fraction of benzene in the liquid phase, and

b) the mole fraction of p-xylene in the vapour phase.

Vapour pressures at 100°C:. benzene 1350 mmHg; toluene 556 mmHg; p-xlene 240 mmHg.



4) The experimental data given below are for the *real gas* TMA at 273.2 K.

| | | | | |
|---|---|---|---|---|
| Pressure (atm) | 0.2000 | 0.4000 | 0.6000 | 0.8000 |
| Density (g/L) | 0.5336 | 1.0790 | 1.6363 | 2.2054 |

a) Using the ideal gas law, calculate the molar mass of TMA at each pressure. (use 4 significant figures)

b) Which of the values obtained in part (a) is the best estimate of the molar mass of TMA? (use 4 significant figures) Briefly defend your choice.

c) What is *your* best estimate of the molar mass of TMA? (use 4 significant figures)

d) What is the compressibility (Z) of the gas at a pressure of 0.8000 atm? (use 4 significant figures)

5) A gas stream which is 40.0 mole percent $N_2$ and 60.0 mole percent acetone is at 100 kPa and 70°C.

a) What is the percent saturation of the acetone in the gas stream?

b) To what temperature must the gas stream be cooled to condense 80.0% of the acetone? Assume that the total pressure remains constant at 100 kPa.

$\Delta H_v^o$ of acetone at 56.0°C (its normal boiling point) is 30.2 kJ/mole.

6) 1.00 kg of $N_2$ ($C_p$ = 29.1 J/mol K) undergoes the change in state:

$$N_2(g)\ (5.0\ \text{atm},\ 125^oC) \longrightarrow N_2(g)\ (1.0\ \text{atm},\ 25^oC)$$

by expanding against a fixed external pressure of 1.0 atm. Assuming that $N_2$ behaves as an ideal gas and that $C_p$ is independent of T, calculate:

a) the change in the internal energy ($\Delta E$) of the $N_2$,

b) the change in the enthalpy ($\Delta H$) of the $N_2$,

c) the change in the entropy ($\Delta S$) of the $N_2$,

d) the work done on the $N_2$, and

e) the heat absorbed by the $N_2$.

... the reaction $H_2O(g) + CH_4(g) \longrightarrow CO(g) + 3H_2(g)$

a) For the reaction at 298 K, calculate $K_p$ and $\Delta S^o$.

b) Is the sign of $\Delta S^o$ obtained in part (a) what you would expect? Briefly explain.

c) Stating any assumptions made, determine the temperature at which the reaction becomes favourable under standard state conditions - i.e. the temperature at which $K_p = 1$.

At 298K

| | $\Delta H^o_f$(kJ/mol) | $\Delta G^o_f$(kJ/mol) |
|---|---|---|
| $H_2O(g)$ | -241.8 | -228.6 |
| $CH_4(g)$ | -74.9 | -50.8 |
| $CO(g)$ | -110.5 | -137.3 |

8) Steam is passed over a hot bed of C(gr) in a reactor maintained at 950K and the following equilibria are established:

$C(gr) + H_2O(g) \Longleftrightarrow H_2(g) + CO(g)$ $K_p$ at 950K = 1.25 atm

$2CO(g) \Longleftrightarrow C(gr) + CO_2(g)$ $K_p$ at 950K = 1.60 $atm^{-1}$

a) If 0.8 mol of $H_2(g)$ are produced per mole of steam fed, calculate:

i) the number of moles of $CO_2(g)$ produced per mole of steam fed, and

ii) the total pressure in the reactor at equilibrium.

b) Calculate $K_p$ for the reaction $C(gr) + 2H_2O(g) \Longleftrightarrow 2H_2(g) + CO_2(g)$ at 950K.