KWANTLEN UNIVERSITY COLLEGE
CHEMISTRY 1210 S-10
EXAM No. 2A
November 20, 1997

NAME: ____

Instructions: This exam contains **Five** questions. Read the exam carefully and judge your time accordingly. A thermodynamic data sheet and periodic chart are included with this exam. **Return** this exam paper with your exam booklet. **ALL CALCULATIONS MUST BE SHOWN TO RECEIVE ANY CREDIT !** Maximum Score: **62 + 4 bonus** points.

Question One: (6 MARKS)

a) The following reaction takes place in liquid ammonia as the solvent:

$H^- + NH_3 \text{ ---> } NH_2^- + H_2$

In this reaction ammonia acts as

i) a Brønsted-Lowry base ii) an Arrhenius acid iii) a Lewis base

iv) a Brønsted-Lowry acid v) an Arrhenius base vi) a conjugate base

b) Choose the couple which is not a conjugate acid-base pair,

i) HCO_3^-, CO_3^{2-} ii) H_3O^+, H_2O iii) OH^-, O^{2-} iv) H_3PO_4, HPO_4^{2-}

v) $NH_2OH_2^+$, NH_2OH

c) What is the pH of a 0.10 *M* solution of $Ba(OH)_2$?

i) 13.00 ii) 13.30 iii) 0.20 iv) 0.10 v) none of these

d) What is the pH of the solution when 10.00 mL of 0.30 *M* HNO_3 is mixed with 10.00 mL of 0.10 *M* KOH?

i) 7.0 ii) 13.0 iii) 0.82 iv) 1.0 v) 0.70

e) Which of the following aqueous mixtures is **not** a buffer solution?

i) NH_4Cl and NH_3 ii) HCN and NaCN iii) H_3PO_4 and NaH_2PO_4

iv) CH_3COONa and NaClv) Na_2HPO_4 and NaH_2PO_4

Question Two: (15 MARKS)

Dinitrogen pentoxide, $N_2O_5(s)$, decomposes at 25.0°C according to the equation,

$$N_2O_5(s) \rightleftharpoons 2\,NO_2(g) + \tfrac{1}{2}\,O_2(g) \qquad K_p = 2.0 \times 10^5 \quad \text{and} \quad \Delta H_{298}^{o} = +109.55\ \text{kJ}$$

a) Calculate K_c at 298K for this reaction. **(2)**

b) Calculate K_p for the above equilibrium at 398K. **(4)**

c) Find the equilibrium pressure of $NO_2(g)$ at 298K when the equilibrium pressure of $O_2(g)$ is 2.00 atm. **(3)**

d) What happens (increase, decrease, or no change) to the mass of $NO_2(g)$ and the value of K_p when,**(4)**

i) $O_2(g)$ is added to the flask.
ii) some $N_2O_5(s)$ is added (assume volume does not change).
iii) volume is increased.
iv) temperature is decreased.

e) Determine the value of K_p for the following equilibrium: **(2)**

$$4\,NO_2(g) + O_2(g) \rightleftharpoons 2\,N_2O_5(s) \qquad K_p = ?$$

f) If excess solid N_2O_5 was injected into an evacuated 1.00L reaction vessel at 25.0 °C, what would be the total pressure of this system at equilibrium? **BONUS QUESTION (4 MARKS)**

Question Three: (18 MARKS)

The combustion reaction for methane gas is given by the following thermochemical equation at 25.0 °C:

$$CH_4(g) + 2\,O_2(g) \text{ ---> } CO_2(g) + 2\,H_2O(l) \qquad \Delta H^{o} = -889.7\ \text{kJ}$$

a) Determine the standard enthalpy of formation of $H_2O(l)$ using the enthalpy of combustion and the following standard enthalpies of formation at 298K: **(3)**

$\Delta H_f^{o}(CH_4(g)) = -74.8$ kJ/mol $\qquad \Delta H_f^{o}(CO_2(g)) = -393.5$ kJ/mol

b) Calculate the work done if the above reaction was carried out at constant pressure (1.00 atm) at 25°C. **(2)**

c) Calculate the change in internal energy, ΔE^{o}, at 25°C for the above reaction. **(2)**

Question Three: (Continued)

d) What size sample of $CH_4(g)$ (Molar mass = 16.0 g/mol) would have to be burned in a bomb calorimeter to cause a temperature rise of 5.00 °C? The total heat capacity of the calorimeter (including the water) was found to be 8.000 kJ/°C. **(4)**

e) Calculate the approximate enthalpy of combustion for $CH_4(g)$ using the bond energies given below: **(3)**

C-H(413 kJ/mol); C=O(802 kJ/mol); O=O(498 kJ/mol); O-H(463 kJ/mol)

f) Give two reasons why the value of ΔH^o calculated in part **e)** so different than the heat of combustion given above? **(1)**

g) Calculate ΔS^o for the combustion of methane given the absolute molar entropies: **(2)**

S^o ($CH_4(g)$) = 186.26 J/mol-K S^o ($O_2(g)$) = 205.14 J/mol-K
S^o ($CO_2(g)$) = 213.74 J/mol-K S^o ($H_2O(l)$) = 69.91 J/mol-K

h) Briefly comment on the sign and magnitude of ΔS^o calculated in part **g)** above in terms of the reaction. **(1)**

Question Four: (17 MARKS)

Methylamine (CH_3NH_2) is a weak base which undergoes hydrolysis as follows:

$$CH_3NH_2(aq) + H_2O(l) \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq) \quad K_b = 4.4 \times 10^{-4}$$

A 20.00 mL sample of 0.2000 M methylamine is titrated with 0.1000 M HCl solution.

a) Calculate the pH of the methylamine solution before any HCl is added. **(3)**

b) Calculate the pH after the addition of 10.00 mL of the HCl solution. **(3)**

c) Calculate the pH at the equivalence point. **(3)**

d) Calculate the pH after the addition of 50.00 mL of HCl solution. **(3)**

e) Which indicator methyl red ($pK_{ind} \approx 5.0$) or thymol blue ($pK_{ind} \approx 9.0$) would be most suitable for this titration? (Assume color change occurs when pH = pK_{ind}.) **EXPLAIN (1)**

f) Roughly sketch a titration curve (not necessarily to scale) for this titration, clearly show the following: **(4)**

i) units on both x and y axis and **all points calculated above**.
ii) equivalence point
iii) buffer region(s)
iv) regions or point(s) where pH is dependent **only** upon:

1) [CH_3NH_2]   2) [$CH_3NH_3^+$]

3) [CH_3NH_2] / [$CH_3NH_3^+$]   4) [H^+]

Question Five: (6 MARKS)

a) A solution contains 1.00 x 10^{-4} M Cu^{+} and 2.00 x 10^{-2} M Pb^{2+}. If a source of I^{-} is added to this solution will PbI_2 (K_{sp} = 8.49 x 10^{-9}) or CuI (K_{sp} = 1.27 x 10^{-12}) precipitate first? Specify the concentration of I^{-} necessary to begin precipitation of each compound.

b) Calculate the % left in solution of the first ion to precipitate when the second ion just starts to precipitate.