CHEMISTRY 104
Hour Exam I
Summer 2024

Name _____

Net ID _____

Free Response Questions

GRADING:

MC_____ (75)

26. _____ (15)

27. _____ (10)

28. _____ (6)

29. _____ (13)

30. _____ (9)

31. _____(5)

Total _____ **133**

For best results please don't leave blanks on the objective or written-out problems.
Please show all steps or logic on the written problems so partial credit can be awarded.

Written out problems – Show all work for partial credit.

26. Ammonia (NH_3) is produced commercially for the following reaction. Utilizing the thermodynamic data given, answer the following five questions.

(15 pts.)

	$N_2(g)$ +	$3\ H_2(g)$ ⇌	$2\ NH_3(g)$
ΔH_f° (kJ/mol)	?	?	−46
S° (J/K•mol)	192	131	193

a) Calculate ΔH° and ΔS° for this reaction.

b) Calculate ΔG° for this reaction at 25° C.

c) An industrial engineer is designing a plant to produce ammonia. Two important conditions to examine are temperature and pressure dependence of this reaction. Assuming standard pressures ($P_{N_2} = P_{H_2} = P_{NH_3} = 1.00$ atm) and assuming that ΔH° and ΔS° do not depend on temperature, what temperature conditions should be designed for in the plant? Be specific, i.e., give specific temperatures.

d) As mentioned previously, pressure dependence of this reaction is another important consideration. To examine this dependence, two experiments were run at two different initial conditions. They are:

Experiment 1: T = 25°C; $P_{N_2} = P_{H_2} = P_{NH_3} = 1.00$ atm

Experiment 2: T = 25°C; $P_{N_2} = P_{H_2} = P_{NH_3} = 10.0$ atm

Calculate ΔG for each of these experiments.

e) When designing the ammonia plant, should the reaction be run at high pressure or at low pressure? Explain. Hint: look at your answer to part d.

27. Impure nickel (nickel that contains impurities) is converted into pure nickel by the Mond process. The equilibrium reaction involved in the Mond process is:

(10 pts.)

$$Ni(CO)_4(g) \rightleftharpoons Ni(s) + 4\ CO(g)$$

The Mond process consists of two steps. They are:

Step 1: Converting the nickel in the impure nickel sample to $Ni(CO)_4$ at T = 25°C.

Step 2: Separating out the $Ni(CO)_4$ formed from the first step, then increasing the temperature to 227°C.

The standard free energy changes ($\Delta G°$) for the above reaction at 25°C and at 227°C are:

$\Delta G°_{25} = 78$ kJ at T = 25°C; $\Delta G°_{227} = -38$ kJ at T = 227°C

a) Calculate K for this reaction at 25°C and at 227°C.

b) Why is the temperature increased in the second step of the Mond process? Be specific. Hint: look at your answer to part a.

c) Is the Mond process reaction exothermic or endothermic? Explain your reasoning.

28. Consider a weak acid, HX. If a 0.10 *M* solution of HX has a pH of 5.83 at 25°C, calculate $\Delta G°$ for the acid's dissociation reaction at 25°C.

(6 pts)

$$HX(aq) \rightleftharpoons H^+(aq) + X^-(aq) \qquad \Delta G° = ?$$

29. Consider the following solutions for the next three questions.
(13 pts)

I. 100.0 mL of 0.50 *M* $(C_2H_5)_3N$ (K_b for $(C_2H_5)_3N = 4.0 \times 10^{-4}$)
II. 50.0mL of 0.30 *M* $HClO_4$
III. 50.0 mL of 0.30 *M* KOH
IV. 100.0 mL of 0.50 *M* $(C_2H_5)_3NHI$

a) Calculate the pH of solution IV.

b) Calculate the pH of the resulting solution when solutions I, III, and IV are mixed together.

29. (cont.) Consider the following solutions for the next three questions.

I. 100.0 mL of 0.50 *M* $(C_2H_5)_3N$ (K_b for $(C_2H_5)_3N = 4.0 \times 10^{-4}$)

II. 50.0mL of 0.30 *M* $HClO_4$

III. 50.0 mL of 0.30 *M* KOH

IV. 100.0 mL of 0.50 *M* $(C_2H_5)_3NHI$

c) Calculate the pH of the resulting solution when solutions I, II, III, and IV are mixed together.

30. Consider the titration 50.0 mL of 0.100 *M* $HClO_4$ by 0.0500 *M* KOH. Determine the pH at the **halfway point to equivalence** and the pH at the **equivalence point**. Also **sketch** the general shape of each **titration curve** showing the **volume and pH** of the two points that you calculated. Determine all pH values to 2 decimal places.

(9 pts)

31. Consider the reaction:

(5 pts)

$$2\ CO(g) + O_2(g) \leftrightarrow 2\ CO_2(g) \qquad K = 2.0$$

An equilibrium mixture contains 4.0 *M* CO_2 and 2.0 *M* O_2 in a 3.0 L container. How many moles of CO are present in this equilibrium mixture?