CHEMISTRY 104
Hour Exam I
Summer 2023

Name _____

Net ID _____

Multiple Choice Questions

GRADING:

MC_____ (60)

21. _____ (6)

22. _____ (6)

23. _____ (7)

24. _____ (7)

25. _____ (9)

26. _____ (5)

27. _____ (13)

28. _____ (7)

Total _____ **120**

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.

MULTIPLE CHOICE – three (3) points each.

1. Consider a 0.10 *M* aqueous solution of sulfurous acid, H_2SO_3 where $K_{a_1} = 1.5 \times 10^{-2}$ and $K_{a_2} = 1.0 \times 10^{-7}$. Which of the following statements is **false**?

   a) A 0.10 *M* H_2SO_3 solution would have a lower pH than a 0.10 *M* H_2SO_4 solution.
   b) Sulfurous acid is a diprotic acid.
   c) A combination of $NaHSO_3$ and Na_2SO_3 could be used to form a pH = 7.0 buffer solution.
   d) The second dissociation can be ignored when calculating the pH of this solution.
   e) SO_3^{2-} is a stronger base than HSO_3^-.

2. Which of the following only contain compounds which would produce **basic** solutions when 0.10 mol of compound were dissolved in 100.0 mL of solution?

   a) NH_3, NaOH, NH_4NO_3 b) NaF, KOH, $KClO_4$ c) NaCl, KCl, $LiNO_3$

   d) NH_4NO_3, NH_4Cl, SO_3 e) NH_3, KCN, CaO

3. Consider a 0.10 *M* solution of a monoprotic acid, HA, in which the acid is 10.0% dissociated. How many of the following four statements (I-IV) is/are **true**?

   I. At equilibrium, $[A^-] = 0.10$ *M*.

   II. At equilibrium, pH > 1.00.

   III. At equilibrium, $[A^-] = [H^+]$.

   IV. At equilibrium, $[HA] > [A^-]$.

   a) 0 (none) b) 1 c) 2 d) 3 e) 4 (All are true.)

4. Consider the reaction: $NH_4NO_3(s) \rightleftharpoons N_2O(g) + 2\ H_2O(g)$ $K_p = 4.85$

   200. g of $NH_4NO_3(s)$ are placed in a reaction vessel containing $H_2O(g)$ at a partial pressure of 2.0 atm and $N_2O(g)$ at a partial pressure of 2.0 atm. After equilibrium is reached, will the mass of $NH_4NO_3(s)$ increase, decrease, or remain unchanged?

   a) The mass of $NH_4NO_3(s)$ will decrease (< 200. g).
   b) The mass of $NH_4NO_3(s)$ will increase (> 200. g).
   c) The mass of $NH_4NO_3(s)$ will remain unchanged (= 200. g).

5. Consider the following endothermic reaction at equilibrium:

$$SiHCl_3(g) + 3\ H_2O(g) \rightleftharpoons SiH(OH)_3(s) + 3\ HCl(g) \quad \Delta H = +450\ kJ$$

Which of the following would cause the reaction to shift toward reactants (shift left) to reestablish equilibrium?

a) Adding $H_2O(g)$.
b) Increasing the temperature.
c) Adding Ar(g).
d) Increasing the volume of the reaction container.
e) Adding $SiH(OH)_3(s)$.

Consider the titration of 50.0 mL of 0.20 *M* hydrazine, H_2NNH_2, by 0.20 *M* HNO_3 for the next two questions. The K_b value for H_2NNH_2 is 3.0×10^{-6}.

6. At what volume of HNO_3 added does the pH of the resulting solution equal 8.48 (pH = 8.48)?

a) 0.0 mL b) 20.0 mL c) 25.0 mL d) 40.0 mL e) 80.0 mL

7. At what volume of HNO_3 added does the pH of the resulting solution equal about 7.9 ($pH \approx 7.9$)? Hint: No detailed calculation is necessary to answer this question.

a) 0.0 mL b) 20.0 mL c) 25.0 mL d) 40.0 mL e) 80.0 mL

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8. Which of the following statements is **true** concerning a $C_2H_5NH_2$ / $C_2H_5NH_3^+$ buffer solution. K_b for $C_2H_5NH_2 = 5.6 \times 10^{-4}$.

a) If initially in the buffer, $[C_2H_5NH_2] = [C_2H_5NH_3^+]$, then pH = 3.25.
b) If initially in the buffer, $[C_2H_5NH_2] > [C_2H_5NH_3^+]$, then pH > 10.75.
c) If initially in the buffer, $[C_2H_5NH_3^+] = 2\ [C_2H_5NH_2]$, then pH = 11.82.
d) If initially in the buffer, $[C_2H_5NH_2] = 6\ [C_2H_5NH_3^+]$, then pH = 6.72.
e) Added NaOH to the buffer solution will cause the $C_2H_5NH_3^+$ concentration to increase.

9. Calculate the $[H^+]$ in a 0.20 *M* C_5H_5N solution (K_b for $C_5H_5N = 1.7 \times 10^{-9}$).

a) $2.9 \times 10^{-5}\ M$ b) $5.4 \times 10^{-10}\ M$ c) $1.8 \times 10^{-5}\ M$ d) $3.4 \times 10^{-10}\ M$

10. Consider a buffer solution consisting of 0.050 *M* HF and an unknown concentration of NaF. What concentration of NaF is necessary to form a pH = 3.00 buffer solution? K_a for HF = 7.2×10^{-4}

a) 0.036 *M* b) 0.069 *M* c) 0.050 *M* d) 0.72 *M* e) 0.018 *M*

11. Which of the following statements is **false**?

a) The conjugate acid of C_5H_5N is $C_5H_5NH^+$.

b) At 25°C, a solution of an acid in water cannot have a pH greater than 7.0.

c) At 25°C, a solution of a base in water cannot have a pOH greater than 7.0.

d) Because HSO_4^- is the conjugate base of a strong acid, the K_b value for HSO_4^- should be between 1 and 1×10^{-14}.

e) In general, the stronger the acid, the weaker the conjugate base.

12. The following acids are listed in order of **decreasing** acid strength in water:

$$HI > HNO_2 > HOCl > HCN$$

Which of the following statements is **false** concerning these acids?

a) HI is assumed to be 100% dissociated in water.

b) The K_a value for HNO_2 is larger than the K_a value for HCN.

c) The K_b value for NO_2^- is larger than the K_b value for I^-.

d) The $[H^+]$ in a 1.0 *M* HOCl solution would be larger than the $[H^+]$ in a 1.0 *M* HCN solution.

e) The pH of a 0.10 *M* HCN solution would be lower than the pH of a 0.10 *M* HNO_2 solution.

13. If a 2.0 *M* solution of a monoprotic acid is 5.0% dissociated, calculate the K_a value for the acid.

a) 1.0×10^{-2} b) 2.0×10^{-2} c) 5.0×10^{-2}

d) 1.0×10^{-3} e) 5.3×10^{-3}

14. Equal volumes of 0.10 *M* HCl and 0.10 *M* $Ca(OH)_2$ are added together. The pH of the resulting solution is:

a) acidic (pH < 7.0). b) basic (pH > 7.0). c) neutral (pH = 7.0).

15. For the process of melting of an ice cube at −10°C, what are the signs for ΔS_{surr}, ΔS, and ΔS_{univ}?

	ΔS_{surr}	ΔS	ΔS_{univ}
a)	+	−	−
b)	+	+	0
c)	−	+	−
d)	+	−	+
e)	−	+	+

16. Consider the following reaction:

$$2\ NO_2(g) \rightarrow 2\ NO(g) + O_2(g) \qquad \Delta G°_{298\ K} = 69.7\ kJ$$

If the temperature is raised to 400. K, what will happen to the value of K?

a) K will increase as the temperature is increased to 400. K.
b) K will decrease as the temperature is increased to 400. K.
c) K will remain unchanged as the temperature is increased to 400. K.

17. For which of the following five processes is there a **decrease** in the entropy of the system ($\Delta S < 0$)?

a) $2\ MgO(s) \rightarrow 2\ Mg(s) + O_2(g)$
b) $2\ H_2O(g) \rightarrow 2\ H_2(g) + O_2(g)$
c) $I_2(l) \rightarrow I_2(s)$
d) $NaBr(s) \rightarrow Na^+(aq) + Br^-(aq)$
e) $H_2(g) \rightarrow 2\ H(g)$

18. Consider the following reaction at 800. K:

$$N_2(g) + 3\ F_2(g) \rightarrow 2\ NF_3(g) \qquad \Delta G°_{800\ K} = ?$$

An equilibrium mixture at 800. K contains the following partial pressures: $P_{N_2} = 0.021$ atm, $P_{F_2} = 0.063$ atm, $P_{NF_3} = 0.48$ atm. Calculate $\Delta G°$ for the reaction at 800. K.

a) −39 kJ b) 71 kJ c) −71 kJ d) 26.5 kJ e) −26.5 kJ

19. Which expression correctly gives the value for the standard enthalpy of formation for liquid carbon disulfide (CS_2) using the following data:

$C(graphite) + O_2(g) \rightarrow CO_2(g)$ $\quad \Delta H^\circ_{rxn} = -393$ kJ

$S(s) + O_2(g) \rightarrow SO_2(g)$ $\quad \Delta H^\circ_{rxn} = -296$ kJ

$CS_2(l) + 3\ O_2(g) \rightarrow CO_2(g) + 2\ SO_2(g)$ $\quad \Delta H^\circ_{rxn} = -1072$ kJ

$\Delta H^\circ_{f,\ CS_2} = ?$

a) [−1072 + 393 + 296] kJ

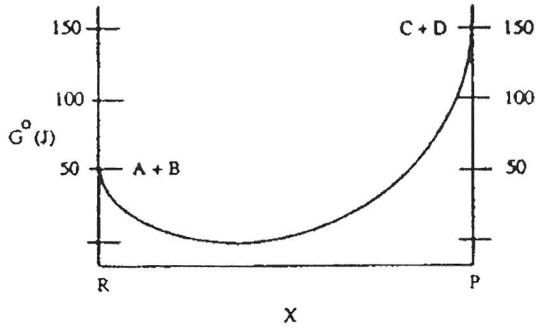
b) [1072 − 393 − 2(296)] kJ

c) [2(1072) − 393 − 296] kJ

d) [−1072 + 393 + 2(296)] kJ

e) [1072 − 393 − 296] kJ

20. Consider the following plot of total free energy vs. X (fraction of A and B reacted) for the reaction of A + B → C + D.



Note: Assume G°(products) = 150 J and G°(reactants) = 50 J.

Which of the following statements (a-c) is/are **true**?

a) The reverse reaction is spontaneous at standard conditions.

b) K is greater than 1 for this reaction at 298 K.

c) All reactions want to maximize free energy, so a mixture of only A and B will react completely to form a mixture of only C and D.

d) All of the above statements (a-c) are true.

e) None of the above statements (a-c) are true.

USEFUL CONSTANTS AND RELATIONS:

$N = 6.022 \times 10^{23}$; $PV = nRT$

$R = 8.3145\ J/mol \cdot K = 0.08206\ \frac{L \cdot atm}{mol \cdot K}$

$\Delta G = \Delta G° + RT \ln Q$; $\Delta G = w_{max}$

$K = °C + 273$

$F = 96{,}485\ Coul/mol\ e^-$

$Volt = J/Coul$

$$E = E° - \frac{RT}{nF} \ln Q$$

$$E = E° - \frac{0.0591}{n} \log Q \quad (at\ 25°C)$$

$$\Delta G°_{rxn} = \Sigma \Delta G°_{f,\ products} - \Sigma \Delta G°_{f,\ reactants}$$

$$\Delta S_{univ} = \frac{-\Delta G}{T}$$

$$\Delta S_{surr} = \frac{-\Delta H}{T}$$

$\Delta G = -nFE$

$\Delta G° = -nFE°$

$\Delta G° = -RT \ln K$

$\Delta G = \Delta H - T\Delta S$

$\Delta G° = \Delta H° - T\Delta S°$

$$E° = \frac{0.0591}{n} \log K \quad (at\ 25°C)$$

$Amp = Coul/sec$

$k = A\ e^{-E_a/RT}$

$$\%\ dissociation = \frac{amount\ dissociated}{initial\ concentration} \times 100$$

$K_w = K_a \cdot K_b = [H^+][OH^-]$

$K_w = 1.0 \times 10^{-14}$ (at 25°C)

$pH + pOH = 14.00$

$pK_a + pK_b = 14.00$

$pH = -\log[H^+]$, $[H^+] = 10^{-pH}$

$pK_a = -\log K_a$

$$pH = pK_a + \log \frac{[base]}{[acid]}$$

Acid	K_a
HF	7.2×10^{-4}
$HC_3H_5O_2$	1.3×10^{-5}
HCN	6.2×10^{-10}

Base	K_b
NH_3	1.8×10^{-5}
H_2NNH_2	3.0×10^{-6}

$$pH = \frac{pK_{a_1} + pK_{a_2}}{2}$$

Zero order reaction:

$$[A] - [A]_0 = -kt$$

$$t_{1/2} = \frac{[A]_0}{2k}$$

First order reaction:

$$\ln [A] - \ln [A]_0 = -kt \quad or$$

$$\ln\left(\frac{[A]}{[A]_0}\right) = -kt$$

$$t_{1/2} = \frac{0.693}{k}$$

Second order reaction:

$$\frac{1}{[A]} - \frac{1}{[A]_0} = kt$$

$$t_{1/2} = \frac{1}{k[A]_0}$$

PERIODIC TABLE OF THE ELEMENTS

1A	2A											3A	4A	5A	6A	7A	8A
1 H 1.008																	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 La* 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226	89 Ac‡ (227)	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn						

atomic number → 26 Fe 55.85 ← atomic mass

lanthanides* ⇒	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
actinides‡ ⇒	90 Th 232.0	91 Pa (231)	92 U 238.0	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)