CHEMISTRY 104
Hour Exam I
Summer 2024

Name _____

Net ID _____

Multiple Choice 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.

1. How many of the following four relationships describe a **basic** solution?

$[H^+] < 1.0 \times 10^{-7}\ M$; pOH < 7.00; pH > 7.00; $[OH^-] > 1.0 \times 10^{-7}\ M$

a) 0 (None) b) 1 c) 2 d) 3

e) 4 (All describe a basic solution.)

2. Consider several 1.0 *M* solutions each containing a different acid, HA. How many of the following four statements (I-IV) is/are **true**?

I. As the K_a value of the acid increases, the pH of the solution increases.

II. As the K_a value of the acid increases, the percent dissociation of the acid increases.

III. As the K_a value of the acid increases, the $[H^+]$ of the solution increases.

IV. As the K_a value of the acid increases, the K_b value for the conjugate base decreases.

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

3. One mole of a weak base, B, is dissolved in 1.0 L of water and no other substance is added. Which of the following, to a close approximation, is **true**?

a) $[BH^+] > [B]$ b) $[B] = [OH^-]$ c) $[BH^+] = [OH^-]$

d) $[H^+] > [OH^-]$ e) $[BH^+] > [OH^-]$

4. H_2SO_4 is a diprotic acid with the following K_a values:

$H_2SO_4 \rightleftharpoons HSO_4^- + H^+$ $K_{a1} = 1 \times 10^7$

$HSO_4^- \rightleftharpoons SO_4^{2-} + H^+$ $K_{a2} = 1.2 \times 10^{-2}$

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

a) The pH of a 0.10 *M* H_2SO_4 solution should be greater than one (pH > 1.00).

b) HSO_4^- is a stronger acid than H_2SO_4.

c) HSO_4^- is a stronger base than SO_4^{2-}.

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

5. The equilibrium constants K_w, K_a, and K_b refer to specific reactions. Which of the following four reactions (a-d) is **incorrectly** matched with the equilibrium constant?

a) $H^+ + OH^- \leftrightharpoons H_2O$ K_w for H_2O

b) $HONH_2 + H_2O \leftrightharpoons HONH_3^+ + OH^-$ K_b for $HONH_2$

c) $F^- + H_2O \leftrightharpoons OH^- + HF$ K_b for F^-

d) $NH_4^+ \leftrightharpoons NH_3 + H^+$ K_a for NH_4^+

e) All the above reactions are correctly matched with the equilibrium constant.

The next three questions refer to the titration of 100.0 mL of 0.40 *M* HOBr by 0.20 *M* KOH. The K_a value for HOBr is 2.0×10^{-9}.

6. Calculate the pH after 0.0 mL of KOH has been added.

a) 3.19 b) 2.67 c) 3.67 d) 4.55 e) 7.00

7. Calculate the pH after 50.0 mL of KOH has been added.

a) 8.22 b) 9.18 c) 8.70 d) 3.19 e) 7.00

8. Calculate the pH after 100.0 mL of KOH has been added.

a) 3.19 b) 9.18 c) 8.70 d) 8.22 e) 7.00

9. Calculate the pH after 200.0 mL of KOH has been added.

a) 10.91 b) 3.09 c) 12.20 d) 4.79 e) 7.00

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10. Arrange the following 0.10 *M* solutions in order of **increasing** pH:

HI, HF, NaF, NaI

a) HI < HF < NaF < NaI b) HI < HF < NaI < NaF c) HF < HI < NaI < NaF

d) HF < HI < NaF < NaI e) NaF < NaI < HI < HF

11. When first studying acid-base chemistry, students sometimes assume that the conjugate base of a weak acid is a strong base. However, this assumption is false. Which of the following **best** explains why the conjugate base of a weak acid is **not** a strong base?

a) The conjugate bases of weak acids all have K_b values greater than 1.
b) The conjugate bases of weak acids all have K_b values equal to 1.
c) The conjugate bases of weak acids all have K_b values less than 1.
d) The conjugate bases of weak acids all have K_b values less than K_w ($= 1.0 \times 10^{-14}$).

12. Consider 0.25 *M* solutions of each of the following potassium salts:

KCl, KBr, KNO_3, $KClO_4$

How many of the solutions are basic?

a) 0 (none) b) 1 c) 2 d) 3

e) 4 (All are basic solutions.)

13. Which of the following solutions has pOH = 3.00?

a) 3.0 *M* NaOH b) 5.0×10^{-4} *M* $Ca(OH)_2$ c) 1.0×10^{-11} *M* HCl

d) 3.0 *M* HCl e) 1.0×10^{-11} *M* NaOH

14. A 1.0 L flask is filled initially with 4.0 mol of H_2 and 6.0 mol of F_2. This mixture then reacts by the following equation:

$$H_2(g) + F_2(g) \rightleftharpoons 2HF(g) \qquad K = ?$$

At equilibrium, 3.5 mol of F_2 remains. Calculate the value of K for the above reaction.

a) 2.0 b) 1.2 c) 0.95 d) 5.0 e) 4.8

15. The $[H^+]$ in a buffer solution consisting of $HONH_3Cl$ and $HONH_2$ is equal to the K_a value for $HONH_3^+$ ($[H^+] = K_a = 9.1 \times 10^{-7}\ M$). Which of the following statements about this solution is **false**?

a) In this solution, the concentration of $HONH_3^+$ equals the concentration of $HONH_2$ ($[HONH_3^+] = [HONH_2]$).
b) If NaOH is added to this solution, the pH will increase.
c) If HCl is added to this solution, the $[H^+]$ will increase.
d) If HCl is added to this solution, the concentration of $HONH_3^+$ will decrease and the concentration of $HONH_2$ will increase.
e) The pH of this solution would be higher than the pH of a solution where the concentration of $HONH_3^+$ is greater than the concentration of $HONH_2$ ($[HONH_3^+] > [HONH_2]$).

16. Consider the process $N_2(g) \rightarrow N_2(l)$. The boiling point for N_2 is 77 K. Predict the signs for ΔS_{univ}, ΔS_{surr}, and ΔS_{sys} when this process is carried out at 50 K.

	ΔS_{univ}	ΔS_{surr}	ΔS_{sys}
a)	+	–	–
b)	–	+	+
c)	–	+	–
d)	+	–	+
e)	+	+	–

17. Consider the following reaction at equilibrium:

$$N_2(g) + 3\ H_2(g) \leftrightharpoons 2\ NH_3(g) \qquad \Delta H = -92.0\ kJ$$

Which of the following changes will shift the equilibrium to the right (to products)?

1. increasing the temperature
2. decreasing the temperature
3. increasing the volume of the reaction container
4. decreasing the volume of the reaction container
5. removing some NH_3
6. adding some NH_3

a) 1, 4, 6 b) 2, 3, 5 c) 1, 6 d) 2, 4, 5 e) 1, 3, 5

18. A solution is to be buffered at pH = 4.5. Which of the following pairs of substances would be the **best** choice for buffering this solution?

a) HNO_2 (K_a for $HNO_2 = 4.0 \times 10^{-4}$) and KNO_2

b) $HOCl$ (K_a for $HOCl = 3.5 \times 10^{-8}$) and $Ca(OCl)_2$

c) $HClO_4$ (K_a for $HClO_4 \approx 10^{7}$) and $NaClO_4$

d) CH_3NH_2 (K_b for $CH_3NH_2 = 4.4 \times 10^{-4}$) and $CH_3NH_3NO_3$

e) $C_6H_5NH_2$ (K_b for $C_6H_5NH_2 = 3.8 \times 10^{-10}$) and $C_6H_5NH_3Cl$

19. Sublimation occurs when a substance changes from the solid state directly into the gaseous state. A common example of sublimation is solid CO_2 (dry ice) changing into gaseous CO_2. However, another substance that undergoes sublimation is $I_2(s)$. Given the following thermodynamic data at 25°C for the I_2 sublimation process, estimate the temperature at which $I_2(s)$ sublimes. Assume $\Delta H°$ and $\Delta S°$ are temperature independent.

$$I_2(s) \rightarrow I_2(g) \qquad \Delta G° = 19 \text{ kJ}; \ \Delta H° = 62 \text{ kJ}$$

a) 398 K b) 298 K c) 430. K

d) 456 K e) 333 K

20. Consider the reaction:

$$Cl_2O(g) + 3/2\ O_2(g) \rightleftharpoons 2\ ClO_2(g)$$

for which $\Delta H = -126.4$ kJ and $\Delta S = -74.9$ J/K. Which of the following statements (a-d) about this reaction is **true**?

a) The reaction will decrease the entropy of the universe at 298 K.
b) As the temperature increases, the reaction will eventually cease to be spontaneous.
c) The reaction will increase the positional disorder of the system.
d) At 274.8 K, the reaction is at equilibrium.
e) None of the above statements (a-d) are true.

21. Consider the following reactions for which the sign of the enthalpy change is given. Which of the reactions can **never** be spontaneous at any temperature?

a) $2\ H_2O_2(l) \rightarrow 2\ H_2O(l) + O_2(g)$ $\Delta H(-)$
b) $3\ O_2(g) \rightarrow 2\ O_3(g)$ $\Delta H(+)$
c) $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$ $\Delta H(+)$
d) $4\ Fe(s) + 3\ O_2(g) \rightarrow 2\ Fe_2O_3(s)$ $\Delta H(-)$

22. Two gas cylinders each contain 1.0 mol of the same ideal gas, but the first cylinder is 50 L and the second cylinder is 150 L. What is the relationship between the entropy values for the gas in each of the two cylinders? Assume a constant temperature.

a) Because the identity of the gas is the same in each cylinder, the entropy value is the same in each cylinder.
b) The gas in cylinder 2 has a larger entropy value than the gas in cylinder 1.
c) The gas in cylinder 2 has a smaller entropy value than the gas in cylinder 1.
d) This can't be predicted unless the identity of the specific ideal gas is known.

23. If the reaction quotient for a reaction is equal to 1.0, which of the following relationships must be **true**?

a) $\Delta G = \Delta G^\circ$ b) $\Delta G^\circ = 0$ c) $\Delta S^\circ = 0$

d) $\Delta G = 0$ e) $\Delta H^\circ = T\Delta S^\circ$

24. Diborane (B_2H_6) is a highly reactive substance and was once considered as a possible rocket fuel. Using the following data:

	ΔH°
$2\ B(s) + 3/2\ O_2(g) \rightarrow B_2O_3(s)$	−1273 kJ
$B_2H_6(g) + 3\ O_2(g) \rightarrow B_2O_3(s) + 3\ H_2O(g)$	−2035 kJ
$H_2O(l) \rightarrow H_2(g) + 1/2\ O_2(g)$	286 kJ
$H_2O(l) \rightarrow H_2O(g)$	44 kJ

calculate ΔH° for the following reaction to produce diborane:

$2\ B(s) + 3\ H_2(g) \rightarrow B_2H_6(g)$ $\Delta H^\circ = ?$

a) −96 kJ b) −52 kJ c) 36 kJ

d) 520. kJ e) 2582 kJ

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

a) The sign of ΔG for a reaction indicates whether the reaction is spontaneous.
b) If ΔG° is positive for a reaction, then K is less than 1 ($K < 1$).
c) When $Q = K$ for a reaction, then $\Delta G = 0$.
d) The entropy of the universe is increasing.
e) The equilibrium position represents the highest free energy state available to a reaction.

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)