DO NOT OPEN

UNTIL INSTRUCTED TO DO SO

CHEM 111 – Dr. McCorkle – Exam #3A

While you wait, please complete the following information:

Name: ________________________________

Student ID: ________________________________

Turn off cellphones and stow them away. No headphones, mp3 players, hats, sunglasses, food, drinks, restroom breaks, graphing calculators, programmable calculators, or sharing calculators. Grade corrections for incorrectly marked or incompletely erased answers will not be made.

Periodic Table of the Elements

PERIOD / GROUP	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 H 1.01																	2 He 4.00
2	3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	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
4	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 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.97	35 Br 79.90	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.95	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.29
6	55 Cs 132.91	56 Ba 137.33	57 La * 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra (226)	89 Ac ** (227)	104 Rf (267)	105 Db (268)	106 Sg (271)	107 Bh (270)	108 Hs (277)	109 Mt (276)	110 Ds (281)	111 Rg (280)	112 Cn (285)	113 Uut (284)	114 Fl (289)	115 Uup (288)	116 Lv (293)	117 Uus (294)	118 Uuo (294)

Lanthanide Series *	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05	71 Lu 174.97
Actinide Series **	90 Th 232.04	91 Pa 231.04	92 U 238.03	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 (262)

Multiple Choice – Choose the answer that best completes the question. Use an 815-E Scantron to record your response. [2 points each]

1. Which of the following combinations is the best choice for creating a buffer solution with a pH of 3.50?

   A) HNO_2/KNO_2 B) HCl/NaCl C) NH_3/NH_4F

   D) $HCHO_2/NaC_2H_3O_2$ E) $HClO_2/NaClO_2$

2. If ΔS is positive and ΔH is positive, when is the reaction spontaneous?

   A) high temperatures B) low temperatures C) all temperatures

   D) never

3. Which of the following is more soluble in acidic solution than in pure water?

   A) AgCl B) $MgCO_3$ C) $CaBr_2$ D) $Ba(NO_3)_2$ E) NaI

4. If the pK_a of $HCHO_2$ is 3.74 and the pH of an $HCHO_2/NaCHO_2$ solution is 3.11, which of the following is true?

   A) $[HCHO_2] < [NaCHO_2]$

   B) $[HCHO_2] = [NaCHO_2]$

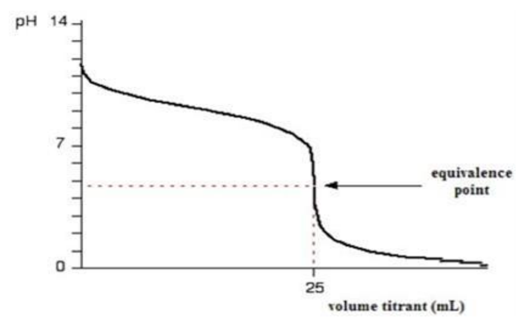
   C) $[HCHO_2] << [NaCHO_2]$

   D) $[HCHO_2] > [NaCHO_2]$

   E) It is not possible to make a buffer of this pH from $HCHO_2$ and $NaCHO_2$.

5. The plot at right illustrates which type of titration?

   A) a weak acid titrated with a weak base
   B) a weak acid titrated with a strong base
   C) a strong base titrated with a weak acid
   D) a weak base titrated with a strong acid
   E) a weak base titrated with a weak acid



6. Without doing any calculations, which of the following processes would you expect to be spontaneous?

   A) $2\ KCl(s) + 3\ O_2(g) \rightarrow 2\ KClO_3(s)$
   B) $2\ H_2S(g) + 3\ O_2(g) \rightarrow 2\ H_2O(g) + 2\ SO_2(g)$
   C) $HCl(g) + NH_3(g) \rightarrow NH_4Cl(g)$
   D) $NaCl(s) \rightarrow Na(s) + \frac{1}{2}\ Cl_2(g)$
   E) $N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g)$

7. The ______ Law of Thermodynamics states that for any spontaneous process, the entropy of the universe increases.

   A) Zero B) First C) Second D) Third E) Fourth

8. A process is always spontaneous under which conditions?

   A) positive ΔS and positive ΔH
   B) negative ΔS and positive ΔH
   C) positive ΔS and negative ΔH
   D) negative ΔS and negative ΔH
   E) no process is always spontaneous

9. Place the following in increasing order of molar entropy at 298 K: NO, CO, SO

   A) NO < CO < SO
   B) SO < CO < NO
   C) SO < NO < CO
   D) CO < SO < NO
   E) CO < NO < SO

10. A reaction that is spontaneous as written __________.

    A) has an equilibrium position that lies far to the left
    B) is also spontaneous in the reverse direction
    C) will proceed without outside intervention
    D) is very rapid
    E) is very slow

Calculations – Write your initials in the upper-right corner of every page that contains work. For full credit show all work and write neatly; give answers with correct significant figures and units. Place a box around your final answer.

11. Use the Henderson–Hasselbalch equation to calculate the pH of a solution that is 10.0 g of $HC_2H_3O_2$ and 12.0 g of $NaC_2H_3O_2$ in 150.0 mL of solution. ($K_a = 1.8\times10^{-5}$) [4 points]

12. What mass of sodium benzoate ($NaC_7H_5O_2$) should be added to 180.0 mL of a 0.16 *M* benzoic acid ($HC_7H_5O_2$) solution in order to obtain a buffer with a pH of 4.25? ($K_a = 6.5\times10^{-5}$) [5]

13. Calculate the molar solubility of calcium hydroxide in a solution buffered at pH = 9.00. ($K_{sp} = 4.68\times10^{-6}$) [5]

14. Will a precipitate of MgF_2 form when 300. mL of 1.1×10^{3} *M* $MgCl_2$ solution are added to 500. mL of 1.2×10^{3} *M* NaF? (MgF_2, $K_{sp} = 6.9\times10^{9}$) [5]

15. A 0.327 g sample of an unknown monoprotic acid was titrated with 0.127 *M* KOH. The equivalence point was determined to be 30.5 mL. What is the molar mass of the unknown acid? [3]

16. 250.0 mL of 1.3×10^{-4} *M* $Zn(NO_3)_2$ is mixed with 175.0 mL of 0.150 *M* NH_3. After the solution reaches equilibrium, what concentration of $Zn^{2+}(aq)$ remains? ($[Zn(NH_3)_4]^{2+}$, $K_f = 2.8\times10^9$) [7]

17. Calculate the pH after 0.010 mol HCl is added to 225.0 mL of a buffer solution that is 0.10 *M* ethylamine and 0.15 *M* ethylammonium nitrate? (ethylamine, $K_b = 6.4\times10^{-4}$) [7]

18. Consider the reaction: $2\ Hg(g) + O_2(g) \rightarrow 2\ HgO(s)$ $\Delta G° = -180.8$ kJ

Calculate ΔG_{rxn} at 25°C under these conditions: $P_{Hg} = 0.025$ atm, $P_{O2} = 0.037$ atm [5]

19. Consider the titration of 30.00 mL of 0.0800 M acetic acid ($HC_2H_3O_2$, $K_a = 1.8\times10^{-5}$) with 0.1600 M NaOH. Calculate the pH of the resulting solution after the following volumes of NaOH have been added. [15]

a) 10.00 mL

b) 15.00 mL

c) 20.00 mL

20. Using the data provided, calculate ΔH°, ΔS° and ΔG° at 298K for the following reaction. Also, show that ΔG° = ΔH° − TΔS°. [8]

$$3\ NO_2(g) + H_2O(l) \rightarrow 2\ HNO_3(aq) + NO(g)$$

Substance	**Δ*H*°$_f$ (kJ/mol)**	**Δ*G*°$_f$ (kJ/mol)**	***S*° (J/mol·K)**
$H_2O(l)$	−285.8	−237.1	70.0
$HNO_3(aq)$	−207	−110.9	146
$NO(g)$	91.3	87.6	210.8
$NO_2(g)$	33.2	51.3	240.1

21. ***Challenge Question:*** Consider the following reaction: $2\ SO_2(g) + O_2(g) \rightarrow 2\ SO_3(g)$

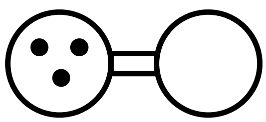
Using the information below, solve for the $\Delta H°_f$ of SO_3. [10 points]

$S(s, rhombic) + O_2(g) \rightarrow SO_2(g)$ $\Delta G°_{rxn} = -295.4$ kJ

$S(s) + 3/2\ O_2(g) \rightarrow SO_3(g)$ $\Delta G°_{rxn} = -395.8$ kJ

Substance	**$\Delta H°_f$ (kJ/mol)**	**$S°$ (J/mol·K)**
$O_2(g)$	0	205.2
$S(s, rhombic)$	0	32.1
$SO_2(g)$	−296.8	248.2
$SO_3(g)$	???	256.8

Extra Credit: Consider two flasks that are joined together, one evacuated and one containing 3 molecules of a gas. When the flasks are allowed to mix, how many microstates are possible? [2 points]



Scratch Page
(to be handed in)

Formulas & Constants

$M = \frac{\text{mol solute}}{\text{liters solution}}$	$m = \frac{\text{mol solute}}{\text{kg solvent}}$	$\chi_A = \frac{\text{mol A}}{\text{total moles}}$
$P_A = \chi_A \cdot P_A^o$	$R = 0.08206 \frac{\text{L·atm}}{\text{mol·K}}$	$R = 8.314 \frac{\text{J}}{\text{mol·K}}$
$\Delta T_f = \underline{m} \cdot K_f$	$\Delta T_b = \underline{m} \cdot K_b$	$\Pi = \underline{M}RT$
$\Delta T_f = i \cdot \underline{m} \cdot K_f$	$\Delta T_b = i \cdot \underline{m} \cdot K_b$	$\Pi = i \cdot \underline{M}RT$
K = °C + 273.15	1 atm = 760 torr = 760 mmHg	$S_{gas} = k_H \cdot P_{gas}$
$\Delta H_{sol'n} = \Delta H_{hydration} - \Delta H_{lattice}$	$f = e^{-Ea/RT}$	$k = Ae^{-Ea/RT}$
$\ln \frac{k_2}{k_1} = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$	$\ln k = -\frac{E_a}{R}\left(\frac{1}{T}\right) + \ln A$	1 V = 1 J/C
$K_p = K_c(RT)^{\Delta n}$	$K_w = 1.0 \times 10^{-14}$	$K_a \times K_b = K_w$
$K_w = [H_3O^+][OH^-]$	$pH = pK_a + \log \frac{[base]}{[acid]}$	$pH = -\log[H_3O^+]$
$pOH = -\log[OH^-]$	$\Delta G = \Delta G° + RT \ln Q$	$\Delta G° = \Delta H° - T\Delta S°$
$\Delta S°_{rxn} = \sum n(S°_{prod}) - \sum n(S°_{reac})$	$\Delta H°_{rxn} = \sum n(\Delta H°_{prod}) - \sum n(\Delta H°_{reac})$	$K = e^{-\Delta G°/RT}$
$\Delta G° = -nFE°$	$\Delta G°_{rxn} = \sum n(\Delta G°_{prod}) - \sum n(\Delta G°_{reac})$	F = 96,485 J/V·mol
$S = k \ln W$	$k = 1.38 \times 10^{-38}$ J/K	1 A = 1 C/s
$E°_{cell} = E°_{cathode} - E°_{anode}$	$E = E° - (0.0592/n) \log Q$	$E = E° - (RT/nF) \ln Q$

Order in [A]	Rate Law	Integrated Form, $y = mx + b$	Straight Line Plot	Half-Life $t_{1/2}$
zero-order (n = 0)	rate = $k\,[A]^0 = k$	$[A]_t = -kt + [A]_0$	$[A]_t$ vs. t	$t_{½} = \frac{[A]_0}{2k}$
first-order (n = 1)	rate = $k\,[A]^1$	$\ln[A]_t = -kt + \ln[A]_0$	$\ln[A]_t$ vs. t	$t_{½} = \frac{\ln 2}{k} = \frac{0.693}{k}$
second-order (n = 2)	rate = $k\,[A]^2$	$\frac{1}{[A]_t} = kt + \frac{1}{[A]_0}$	$\frac{1}{[A]_t}$ vs. t	$t_{½} = \frac{1}{k[A]_0}$

Various Constants at 25°C

Substance	**Formula**	
Formic acid	$HCHO_2$	$K_a = 1.8\times10^{-4}$
Chlorous acid	$HClO_2$	$K_a = 1.1\times10^{-2}$
Nitrous acid	HNO_2	$K_a = 4.6\times10^{-4}$
Ammonia	NH_3	$K_b = 1.76\times10^{-5}$
Ethylamine	$CH_3CH_2NH_2$	$K_b = 6.4\times10^{-4}$
Magnesium fluoride	MgF_2	$K_{sp} = 6.9\times10^{9}$
Tetraamminezinc(II) ion	$[Zn(NH_3)_4]^{2+}$	$K_f = 2.8\times10^{9}$