DO NOT OPEN

UNTIL INSTRUCTED TO DO SO

CHEM 111 – Dr. McCorkle – Exam #2 ***KEY***

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	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IB	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]

For #1-5, predict how the following reaction will respond to the indicated stress.

$$2\ C(s) + O_2(g) \rightleftharpoons 2\ CO(g) \qquad \Delta H = -221\ kJ/mol$$

1. CO is added

   A) **shifts left** B) shifts right C) no effect

2. Reaction is cooled

   A) shifts left B) **shifts right** C) no effect

3. Volume of the container is doubled

   A) shifts left B) **shifts right** C) no effect

4. C is removed

   A) shifts left B) shifts right C) **no effect**

5. Ne is added

   A) shifts left B) shifts right C) **no effect**

For #6-9, when the compound listed is dissolved in water, predict if the resulting solution will be acidic, basic, or neutral.

6. NH_4ClO_4

   A) **acidic** B) basic C) neutral

7. $Cu(NO_3)_2$

   A) **acidic** B) basic C) neutral

8. CaI_2

   A) acidic B) basic C) **neutral**

9. NaCN

   A) acidic B) **basic** C) neutral

10. What is the conjugate acid of HCO_3^-?

    A) CO_3^{2-} B) H_3O^+ C) H_2O D) OH^- E) **H_2CO_3**

11. A substance that accepts H^+ (proton acceptor) in solution is a(n):

A) Arrhenius acid B) Arrhenius base C) Lewis acid

D) Lewis base E) **Brønsted-Lowry base**

12. A substance that donates an electron pair in solution is a(n):

A) Brønsted-Lowry acid B) Brønsted-Lowry base C) Lewis acid

D) **Lewis base** E) Arrhenius acid

13. Calculate the pOH of a solution that contains 3.9×10^{-4} *M* H_3O^+ at 25°C.

A) 4.39 B) 3.41 C) **10.59** D) 6.15 E) 7.85

14. Based on its molecular structure, which of the following is the strongest acid?

A) **$HClO_2$** B) $HBrO_2$ C) HIO_2

15. Based on its molecular structure, which of the following is the strongest acid?

A) HF B) HCl C) HBr D) **HI** E) H_2S

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. Refer to the table of K_a values at the end as necessary. Place a box around your final answer.

16. Given the following information,

$$HF(aq) \rightleftharpoons H^+(aq) + F^-(aq) \qquad K_c = 6.8\times10^{-4}$$

$$H_2C_2O_4(aq) \rightleftharpoons 2\,H^+(aq) + C_2O_4^{2-}(aq) \qquad K_c = 3.8\times10^{-6}$$

determine the value of K_c for the reaction:

$$2\,HF(aq) + C_2O_4^{2-}(aq) \rightleftharpoons 2\,F^-(aq) + H_2C_2O_4\,(aq)$$ [4 points]

$2HF(aq) \rightleftharpoons 2H^+(aq) + 2F^-(aq)$ $\qquad K_c^2 = 4.6\times10^{-7}$

$2\,H^+(aq) + C_2O_4^{2-}(aq) \rightleftharpoons H_2C_2O_4(aq)$ $\qquad K_c^{-1} = 2.6\times10^{5}$

$2\,HF(aq) + C_2O_4^{2-}(aq) \rightleftharpoons 2\,F^-(aq) + H_2C_2O_4\,(aq)$ $\qquad K = 4.6\times10^{-7} \times 2.6\times10^{5}$

$K = 0.12$

17. At a certain temperature, 3.00 mol of NH_3 and 6.00 mol of O_2 were introduced into a 2.00-L container and reacted by the following equation:

$$4\,NH_3(g) + 5\,O_2(g) \rightleftharpoons 4\,NO(g) + 6\,H_2O(g)$$

At equilibrium, 1.00 mol of NH_3 and 3.50 mol of O_2 remain. What is the value of K for this reaction? [5]

	$4\,NH_3(g) + 5\,O_2(g) \rightleftharpoons 4\,NO(g) + 6\,H_2O(g)$			
I	**1.50 *M***	**3.00 *M***	**0**	**0**
C	**− 4x**	**− 5x**	**+ 4x**	**+ 6x**
E	**0.50 *M***	**1.75 *M***	**4x**	**6x**

$4x = 1.00$ $\qquad 5x = 1.25$
$x = 0.25\ M$ $\qquad x = 0.250\ M$

$[NO] = 4x = 4(0.25) = 1.0\ M$
$[H_2O] = 6x = 6(0.25) = 1.5\ M$

$$K = \frac{[NO]^4[H_2O]^6}{[NH_3]^4[O_2]^5} = \frac{(1.0)^4(1.5)^6}{(0.50)^4(1.75)^5} = 11$$

18. The equilibrium constant, *K*, is 3.9×10^{-4} at a certain temperature for the reaction:

$$2\ \mathrm{NOBr}(g) \rightleftharpoons 2\ \mathrm{NO}(g) + \mathrm{Br_2}(g)$$

A 3.00-L flask contains 0.165 g NOBr, 0.102 g NO, and 5.39 g Br_2. Determine if the reaction is at equilibrium. If not, what direction will the system shift? [7]

$$\mathbf{[NOBr] = 0.165\ g \times \frac{1\ mol\ NOBr}{109.91\ g} \div 3.00\ L = 5.00 \times 10^{-4}\ \mathit{M}}$$

$$\mathbf{[NO] = 0.102\ g \times \frac{1\ mol\ NO}{30.01\ g} \div 3.00\ L = 1.13 \times 10^{-3}\ \mathit{M}}$$

$$\mathbf{[Br_2] = 5.39\ g \times \frac{1\ mol\ Br_2}{159.80\ g} \div 3.00\ L = 1.12 \times 10^{-2}\ \mathit{M}}$$

$$\mathbf{Q = \frac{[NO]^2[Br_2]}{[NOBr]^2} = \frac{(1.13\times10^{-3})^2(1.12\times10^{-2})}{(5.00\times10^{-4})^2} = 5.72 \times 10^{-2}}$$

Q > K so reaction shifts left

19. Nitrogen and oxygen gases react to form nitrous oxide according to the following reaction:

$$N_2(g) + O_2(g) \rightleftharpoons 2\ NO(g) \qquad K = 4.6\times10^{-31}$$

If 70.0 g of N_2 and 110.0 g of O_2 are mixed in a 1.50-L flask at 25°C, calculate the concentration of all species at equilibrium. (Enter results in the blanks provided.) [10]

$$[N_2] = 70.0\ \text{g} \times \frac{1\ \text{mol}\ N_2}{28.02\ \text{g}} \div 1.50\ \text{L} = 1.67\ M$$

$$[O_2] = 110.0\ \text{g} \times \frac{1\ \text{mol}\ O_2}{32.00\ \text{g}} \div 1.50\ \text{L} = 2.29\ M$$

	$N_2(g)$	+ $O_2(g)$	$\rightleftharpoons$ $2\ NO(g)$
I	1.67 *M*	2.29 *M*	0 *M*
C	− x	− x	+ 2x
E	1.67–x	2.29–x	2x
	≈1.67	≈2.29	

$$K = \frac{[NO]^2}{[N_2][O_2]}$$

$$4.6\times10^{-31} = \frac{(2x)^2}{(1.67)(2.29)} = \frac{4x^2}{(1.67)(2.29)}$$

$x = 6.6\times10^{-16}$

$[N_2]_{equil}$ = **1.67 *M*** $[O_2]_{equil}$ = **2.29 *M*** $[NO]_{equil}$ = **$2x = 1.3\times10^{-15}$ *M***

20. Trimethylamine, $(CH_3)_3N$, is a gas with a fishy, ammonia-like odor. An aqueous solution that is 0.25 *M* trimethylamine has a pH of 11.63. What is K_b for trimethylamine? *Hint: Do amines typically behave like acids or bases?* [7]

pOH = 14 – pH = 14 – 11.63 = 2.37

$[OH^-] = 10^{-pOH} = 10^{-2.37} = 4.3\times10^{-3}$ *M*

$$(CH_3)_3N + H_2O \rightleftharpoons (CH_3)_3NH^+ + OH^-$$

	$(CH_3)_3N$	H_2O	$(CH_3)_3NH^+$	OH^-
I	0.25 *M*		0	0
C	− x		+ x	+ x
E	0.25 – x		4.3×10^{-3}	4.3×10^{-3}

$x = 4.3\times10^{-3}$

$[(CH_3)_3N] = 0.25 - 4.3\times10^{-3} = 0.25$ *M*

$[(CH_3)_3NH^+] = 4.3\times10^{-3}$ *M*

$[OH^-] = 4.3\times10^{-3}$

$$K_b = \frac{(4.3\times10^{-3})(4.3\times10^{-3})}{0.25} = 7.4\times10^{-5}$$

21. Calculate the pH of a mixture of 0.145 *M* HC_6H_5O and 0.110 *M* $HC_2H_2O_2Cl$. [7]

$HC_2H_2O_2Cl$ $K_a = 1.4\times10^{-3}$

HC_6H_5O $K_a = 1.3\times10^{-10}$

K_a for $HC_2H_2O_2Cl$ is much larger than the K_a for HC_6H_5O so ignore HC_6H_5O.

	$HC_2H_2O_2Cl$	+ H_2O ⇌	$C_2H_2O_2Cl^-$	+ H_3O^+
I	0.110 *M*		0	0
C	− x		+ x	+ x
E	0.110 – x		x	x

$$K_a = \frac{[C_2H_2O_2Cl^-][H_3O^+]}{[HC_2H_2O_2Cl]}$$

$$1.4\times10^{-3} = \frac{x^2}{0.110 - x}$$

$$0 = x^2 + 1.4\times10^{-3}x - 1.54\times10^{-4}$$

$x = 0.012 = [H_3O^+]$

$pH = -\log[H_3O^+] = -\log(0.012) = 1.92$

22. ***Challenge Question:*** Calculate the mass in milligrams of $C_6H_5O_7^{3-}$ in 1.75 L of a 0.150 *M* citric acid ($H_3C_6H_5O_7$) solution. ($K_{a1} = 7.4\times10^{-4}$, $K_{a2} = 1.7\times10^{-5}$, $K_{a3} = 4.0\times10^{-10}$) [10]

	$H_3C_6H_5O_7 + H_2O \rightleftharpoons H_2C_6H_5O_7^- + H_3O^+$		
I	0.150 *M*	0	0
C	− x	+ x	+ x
E	0.150 – x	x	x

$$K_a = \frac{[H_2C_6H_5O_7^-][H_3O^+]}{[H_3C_6H_5O_7]}$$

$$7.4\times10^{-4} = \frac{(x)(x)}{(0.150 - x)}$$

$0 = x^2 + 7.4\times10^{-4}x - 1.11\times10^{-4}$

$x = 1.02\times10^{-2} = [H_2C_6H_5O_7^-] = [H_3O^+]$

	$H_2C_6H_5O_7^- + H_2O \rightleftharpoons HC_6H_5O_7^{2-} + H_3O^+$		
I	1.02×10^{-2}	0	1.02×10^{-2}
C	− x	+ x	+ x
E	$1.02\times10^{-2} - x$	x	$1.02\times10^{-2} + x$
	$\approx 1.02\times10^{-2}$		$\approx 1.02\times10^{-2}$

$$K_a = \frac{[HC_6H_5O_7^{2-}][H_3O^+]}{[H_2C_6H_5O_7^-]}$$

$$1.7\times10^{-5} = \frac{(x)(1.02\times10^{-2})}{(1.02\times10^{-2})}$$

$x = 1.7\times10^{-5} = [HC_6H_5O_7^{2-}]$

	$HC_6H_5O_7^{2-} + H_2O \rightleftharpoons C_6H_5O_7^{3-} + H_3O^+$		
I	1.7×10^{-5}	0	1.02×10^{-2}
C	− x	+ x	+ x
E	$1.7\times10^{-5} - x$	x	$1.02\times10^{-2} + x$
	$\approx 1.7\times10^{-5}$		$\approx 1.02\times10^{-5}$

$$K_a = \frac{[C_6H_5O_7^{3-}][H_3O^+]}{[HC_6H_5O_7^{2-}]}$$

$$4.0\times10^{-10} = \frac{(x)(1.02\times10^{-2})}{(1.7\times10^{-5})}$$

$x = [C_6H_5O_7^{3-}] = 6.7\times10^{-13}\ M$

$$1.75\ \text{L} \times \frac{6.7\times10^{-13}\ \text{mol}}{1\ \text{L}} \times \frac{189.11\ \text{g}}{\text{mol}} \times \frac{1\ \text{mg}}{10^{-3}\ \text{g}} = 2.2\times10^{-7}\ \text{mg}$$

Extra Credit: Explain why boron-containing compounds such as BF_3 typically make good Lewis acids. [2] **B compounds are often electron deficient so they can accept an e^- pair.**

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

$S_{gas} = k_H \cdot P_{gas}$

$\Delta H_{sol'n} = \Delta H_{hydration} - \Delta H_{lattice}$

$f = e^{-Ea/RT}$

$k = Ae^{-Ea/RT}$

$\ln \frac{k_2}{k_1} = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$

$\ln k = -\frac{E_a}{R}\left(\frac{1}{T}\right) + \ln A$

$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$K_p = K_c(RT)^{\Delta n}$

$K_w = 1.0\times10^{-14}$ @ 25°C

$K_a \times K_b = K_w$

$K_w = [H_3O^+][OH^-]$

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

$pH = -\log[H_3O^+]$

$pOH = -\log[OH^-]$

$\Delta G = \Delta G° + RT \ln Q$

$\Delta G° = \Delta H° - T\Delta S°$

$K = e^{-\Delta G°/RT}$

$\Delta G° = -nFE°$

F = 96,485 J/V·mol

$E°cell = E°(cathode) - E°(anode)$

$E = E° - (0.0592/n) \log Q$

$E = E° - (RT/nF) \ln Q$

1 V = 1 J/C

Acid Dissociation Constants at 25°C

Name	**Formula**	**K_a**
Benzoic	$HC_7H_5O_2$	6.5×10^{-5}
Chloroacetic	$HC_2H_2O_2Cl$	1.4×10^{-3}
Phenol	HC_6H_5O	1.3×10^{-10}

Scratch Page
(to be handed in)