Key

Name (please print)

CHEMISTRY 128
HOUR TEST 3
June 26 2009

USEFUL INFORMATION:

$R = 8.314$ J/K*mole 1 amp = 1 C/s $F = 96{,}500$ C/mol $N = 6.02 \times 10^{23}$

1 V = 1 J/C $N = 6.022 \times 10^{23}$ $K_w = 1 \times 10^{-14}$ $pH = -\log[H_3O^+]$

$pK_a = -\log(K_a)$ $pOH = -\log[OH^-]$ $K_w = [H_3O^+]*[OH^-]$

$K_w = (K_a)*(K_b)$ $pH = pKa + \log\left(\frac{[A-]}{[HA]}\right)$ $y = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$\Delta G_{system} = \Delta G^o_{system} - RT\ln Q$ $\Delta G^o_{system} = -RT\ln K$ $E^o_{cell} = E^o_{red} + E^o_{ox}$

$\Delta G^o_{system} = -nFE^o_{cell}$ $E_{cell} = E^o_{cell} - (0.0592/n)\log Q$ $\log K = (nE^o_{cell})/0.0592$

1 IA																	18 VIIIA
1 H 1.008	2 IIA											13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	2 He 4.00
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
11 Na 22.99	12 Mg 24.31	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	11 IB	12 IIB	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	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 58.71	29 Cu 63.54	30 Zn 65.37	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.91	36 Kr 83.30
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 98.91	44 Ru 101.07	45 Rh 102.91	46 Pd 106.4	47 Ag 107.87	48 Cd 112.40	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.30
55 Cs 132.91	56 Ba 137.34	71 Lu 174.97	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.09	79 Au 196.97	80 Hg 200.59	81 Tl 204.37	82 Pb 207.19	83 Bi 208.98	84 Po 210	85 At 210	86 Rn 222
87 Fr 223	88 Ra 226.03	103 Lr 262.1	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt									

57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm 146.92	62 Sm 150.35	63 Eu 151.96	64 Gd 157.25	65 Tb 158.92	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04
89 Ac 227.03	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np 237.05	94 Pu 239.05	95 Am 241.06	96 Cm 247.07	97 Bk 249.08	98 Cf 251.08	99 Es 254.09	100 Fm 257.10	101 Md 258.10	102 No 255

There Are 6 Pages On This Test Including This Cover Page.
The Test Contains 100 Points.

Part I. (25 points) Short Answers

1. (3 points) A solution was prepared by dissolving $CH_3CH_2CO_2H$ (aq) and $CH_3CH_2CO_2K$ (s) in 1 L of water. Write the net-ionic chemical equation for the reaction that occurs when 1 drop of 1.0 M HNO_3 (aq) is added to the solution.

$H^+(aq) + CH_3CH_2CO_2^-(aq) \rightarrow CH_3CH_2CO_2H(aq)$

2. (3 points) How many mL of 0.383 M NaOH are required to titrate 75.00 mL of 0.23 M benzoic acid ($C_6H_5CO_2H$) to the equivalence point?

volume 45 mL

$V_{NaOH} = \frac{M_{acid} V_{acid}}{M_{NaOH}} = \frac{(0.23\,M)(75.00\,mL)}{(0.383\,M)} = 45\,mL$

3. The oxidation state of Fe in $Fe_2(CO_3)_3$ is +3 and the oxidation state of C is +4. (4 pts)

4. The oxidation number of S in SO_4^{2-} is (Circle one: **more positive than, the same as, less positive than**) the oxidation number of S in SO_3^{2-}.(2 pts)

5. Write the half-reaction that is used as a reference in electrochemistry. In other words, write the half-reaction for the process that has $E^\circ_{red} = 0$. Be sure to include the states of the species involved. (3 pts)

$2H^+(aq) + 2e^- \rightarrow H_2(g)$

6. Considering the following half-reactions:

$Li^+(aq) + 1\,e^- \rightarrow Li(s)$	$E^\circ_{red} = -3.05$ V
$Ni^{2+}(aq) + 2\,e^- \rightarrow Ni(s)$	$E^\circ_{red} = -0.28$ V
$Ti^{2+}(aq) + 2\,e^- \rightarrow Ti(s)$	$E^\circ_{red} = -1.63$ V

   a. Which species is most easily reduced (at standard conditions)? Ni^{2+} (2 pts)

   b. Which species is the strongest reducing agent (at standard conditions)? Li (2 pts)

   c. What species will react with Ti (s)? Ni^{2+} (2 pts)

7. In the following electrochemical cell,

$$Al(s) \mid Al^{3+}(0.0500\,M) \parallel Ga^{3+}(0.10\,M) \mid Ga(s)$$

the anodic reaction involves the (Circle one: **oxidation, reduction**) of Al. (4 pts)

Part III. Problems (51 points) **Show all calculations for full credit**. No calculations, no credit.

8. Benzoic acid ($C_6H_5CO_2H$) has a $K_a = 6.46 \times 10^{-5}$.

a. (10 points) How many grams of potassium benzoate ($C_6H_5CO_2K$) must be added to 75.00 mL of 0.23 M benzoic acid ($C_6H_5CO_2H$) to form a solution with a pH of 4.06?

mass of $C_6H_5CO_2K$ 2.0 g

$pH = pK_a + \log\left(\frac{[base]}{[acid]}\right)$

$4.06 = -\log(6.46\times10^{-5}) + \log\left(\frac{y}{0.23}\right)$

$4.06 = 4.19 + \log\left(\frac{y}{0.23}\right)$

$-0.13 = \log\left(\frac{y}{0.23}\right)$

$10^{-0.13} = 10^{\log(y/0.23)}$

$0.74 = \frac{y}{0.23}$

$\frac{0.17\ mol\ C_6H_5CO_2K}{1\ L} \times \frac{0.01500\ L}{1} \times \frac{160.2\ g}{1\ mol} = 2.0\ g\ C_6H_5CO_2K$

$y = [base] = [C_6H_5CO_2K] = (0.74)(0.23\ M) = 0.17\ M$

b. (8 points) Determine the pH of the solution after 49.50 mL of 0.383 M NaOH is added to 75.00 mL of 0.23 M benzoic acid ($C_6H_5CO_2H$).

pH 12.2

$C_6H_5CO_2H + NaOH \longrightarrow H_2O + C_6H_5CO_2Na$

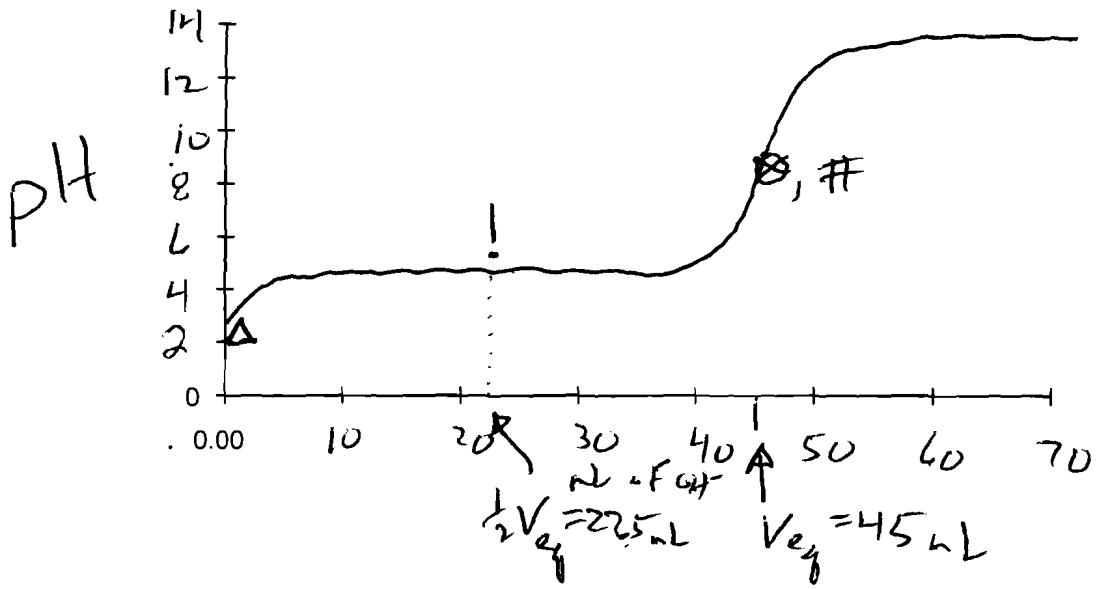
	$C_6H_5CO_2H$	NaOH	H_2O + $C_6H_5CO_2Na$
mmol before = $(0.23\ \frac{mmol}{mL})(75.00\ mL)$ / $(0.383\ \frac{mmol}{mL})(49.50\ mL)$	17 mmol	19 mmol	0 mmol
change in mmol	−17 mmol	−17 mmol	+17 mmol
mmol after	0 mmol	2 mmol	17 mmol

$pOH = -\log[OH^-] = -\log\left(\frac{2\ mmol}{124.50\ mL}\right) = 1.8$

$pH = 14 - pOH = 14 - 1.8 = 12.2$

c. (8 points) *Sketch* the curve for the titration of 75.00 mL of 0.23 M benzoic acid ($C_6H_5CO_2H$) with 0.383 M NaOH. Be sure to label the axes.

1. Mark the equivalence point of the curve with a " ⊗ "
2. Mark the point on the curve where the pH = pKa with a "!".
3. Mark the point on the curve where the pH only depends on the [$C_6H_5CO_2H$] with a " Δ " .
4. Mark the point on the curve where the pH only depends on the [$C_6H_5CO_2^-$] with a " # ".



9. (10 points) A constant current of 1.16 A was passed through 735 mL of a solution of $Al(ClO_4)_3$. After 45.0 minutes, all of the $Al(ClO_4)_3$ was consumed. What was the initial concentration (in M) of the $Al(ClO_4)_3$ solution?

$Al(ClO_4)_3 \xrightarrow{H_2O} Al^{3+} + 3ClO_4^-$

$Al^{3+} + 3e^- \rightarrow Al$

Initial $[Al(ClO_4)_3]$ $\frac{1.47 \times 10^{-2}\ mol}{L}$

$[Al^{3+}] = \frac{mol\ Al^{3+}}{L\ of\ solution} = \frac{1.08 \times 10^{-2}\ mol}{0.735\ L} = 1.47 \times 10^{-2}\ \frac{mol}{L}$

$mol\ of\ Al^{3+} = 1.16\ \frac{C}{s} \times \frac{60\ s}{1\ min} \times \frac{45.0\ min}{1} \times \frac{1\ mol\ e^-}{96{,}500\ C} \times \frac{1\ mol\ Al^{3+}}{3\ mol\ e^-} = 1.08 \times 10^{-2}\ mol\ Al^{3+}$

10. (13 points) What volume (in mL) of 0.383 M NaOH must be added to 75.00 mL of 0.23 M benzoic acid ($C_6H_5CO_2H$, $K_a = 6.46 \times 10^{-5}$) to obtain a solution with a pH of 5.25 assuming that all of the NaOH will be consumed?

Volume of NaOH 41

	$C_6H_5CO_2H$	+ $NaOH$	$\longrightarrow$ H_2O +	$C_6H_5CO_2Na$
mmol before addition	$(0.23 \frac{mmol}{mL})(75.00 mL)$	$(0.383 \frac{mmol}{mL})(y\ mL)$		
	17 mmol	$0.383y$		0
change in mmol	$-0.383y$	$-0.383y$		$+0.383y$
mmol after addition	$17 - 0.383y$	0		$0.383y$

$$pH = pK_a + \log\left(\frac{[base]}{[acid]}\right)$$

$$5.25 = -\log(6.46 \times 10^{-5}) + \log\left(\frac{0.383y}{17 - 0.383y}\right)$$

$$5.25 = 4.190 + \log\left(\frac{0.383y}{17 - 0.383y}\right)$$

$$1.06 = \log\left(\frac{0.383y}{17 - 0.383y}\right)$$

$$10^{1.06} = 10^{\log\left(\frac{0.383y}{17 - 0.383y}\right)}$$

$$11.5 = \frac{0.383y}{17 - 0.383y}$$

$$196 - 4.40y = 0.383y$$

$$196 = 4.78y$$

$$y = \frac{196}{4.78} = 41.0 = 41\ mL$$

11. What is the pH of a saturated solution of manganese (II) hydroxide ($K_{sp} = 1.6 \times 10^{-13}$)? (10 points)

pH of $Mn(OH)_2$ solution 9.84

$$Mg(OH)_2(s) \rightleftharpoons Mg^{2+}(aq) + 2OH^-(aq)$$

Initial	0	0
Change	y	$2y$
Equil	y	$2y$

$$K_{sp} = [Mg^{2+}][OH^-]^2$$

$$1.6 \times 10^{-13} = [y][2y]^2$$

$$1.6 \times 10^{-13} = 4y^3$$

$$[Mg^{2+}] = y = \sqrt[3]{\frac{1.6 \times 10^{-13}}{4}} = 3.4 \times 10^{-5} \text{ M}$$

$$[OH^-] = 2y = 2(3.4 \times 10^{-5}) = 6.8 \times 10^{-5}$$

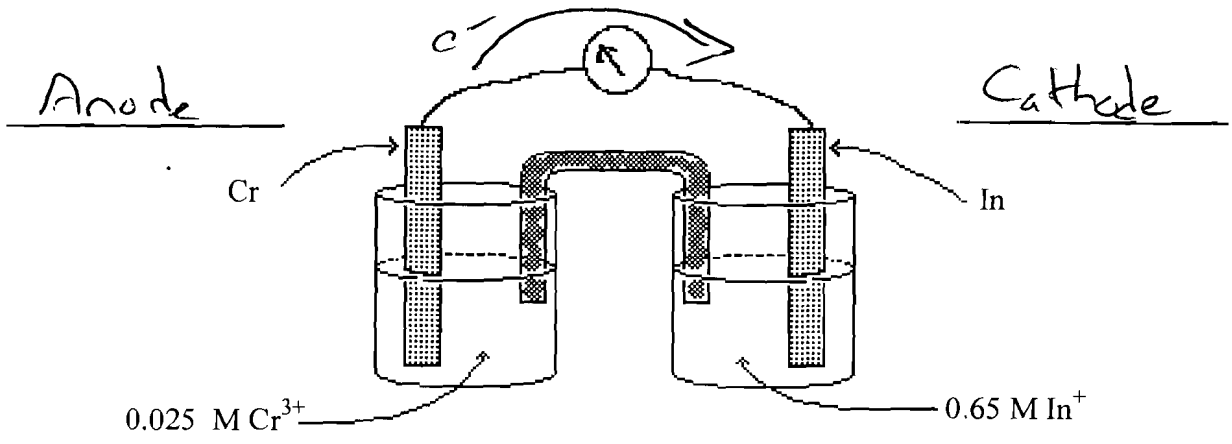
$$pOH = -\log(6.8 \times 10^{-5}) = 4.16$$

$$pH = 14 - pOH = 9.84$$

12. (16 points) On the cell diagram below:
   a. Label the cathode and the anode.
   b. Use an arrow to indicate the direction in which electrons will flow.

Cr^{3+} (aq) + 3 e^- → Cr (s) $\quad E^\circ_{red} = -0.74$ V

In^+ (aq) + 1 e^- → In (s) $\quad E^\circ_{red} = -0.14$ V



c. Write the balanced cell reaction. $3(In^+ + 1e^- \rightarrow In)$ $\quad E^\circ_{red} = -0.14$ V

$Cr \rightarrow Cr^{3+} + 3e^-$ $\quad E^\circ_{ox} = +0.74$ V

$3\,In^+ + Cr \rightarrow Cr^{3+} + In$ $\quad E^\circ_{cell} = +0.60$ V

d. Calculate the E°_{cell}.

e. Calculate the expected E_{cell} at 25°C for this system.

$E_{cell} = E^\circ_{cell} - \frac{0.0592}{n} \log \frac{[Cr^{3+}]}{[In^+]^3}$

$E_{cell} = 0.60 - \frac{0.0592}{3} \log \frac{0.025}{(0.65)^3}$

$E_{cell} = 0.60 - (-0.02) = 0.62$V

E_{cell} 0.62V

f. As current flows through the cell, the mass of Cr(s) will (Circle one: **increase, remain the same, decrease**).

g. If a large amount of water is added to the In^+ | In cell, the value of the E_{cell} will (Circle one: **increase, remain the same, decrease**).