FORMULA SHEET (tear off)

1A												3A	4A	5A	6A	7A	8A
1 H 1.01	2A																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											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 47.87	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 65.41	31 Ga 69.72	32 Ge 72.64	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	71 Lu 175.0	72 Hf 178.5	73 Ta 181.0	74 W 183.8	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]	103 Lr [262]	104 Rf [261]	105 Db [262]	106 Sg [266]												

57 La 138.9	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 157.2	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0
89 Ac [227]	90 Th 232.0	91 Pa 231.0	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]

$N_A = 6.022 \times 10^{23}$ | $°C = (^5/_9)(°F - 32)$ | $°F = (^9/_5)(°C) + 32$

1 amu = 1.661×10^{-27} kg | $°C = K - 273.15$ | $K = °C + 273.15$

1 atm = 760 torr = 760 mm Hg | 1 atm = 1.013 bar | $pV = nRT$

$R = 0.08206$ L•atm/mol•K | 1 L•atm = 101.3 J | (1 volt) (1 Coulomb) = 1 Joule

$R = 8.314$ J/mol•K | 1 J= 1 kg•m^2/s^2

$F = 96485.$ C/mol

$p_A = X_A p_A°$ | $[B] = k p_B$ | $\Delta p_A = X_B p_A°$

$\Delta T_b = K_b m_B$ | $\Delta T_f = K_f m_B$ | $\Pi = M_B RT$

$H = U + pV$ | $G = H - TS$

$\Delta G_{rxn} = \Delta G°_{rxn} + RT \ln Q$ | $\ln K = - \Delta G°_{rxn}/RT$ | $K_p = K_C (RT)^{\Delta n}$

If $ax^2 + bx + c = 0$, then $x = \dfrac{-b \pm [b^2 - 4ac]^{1/2}}{2a}$

$K_a \cdot K_b = K_w = 1.0 \times 10^{-14}$ (at T = 25°C) | $pH + pOH = pK_w$

$pH = pK_a + \log_{10}\{[base]/[acid]\}$ | pH + pOH = 14.00 at T = 25. °C

$\Delta G = - nFE_{cell}$ | $E_{cell} = E°_{cell} - (RT/nF) \ln Q$ | $\ln K = nFE°_{cell}/RT$

GENERAL CHEMISTRY 2
THIRD HOUR EXAM

Name _____

Panthersoft ID _____

Signature _____

Part 1 _____ **(24 points)**

Part 2 _____ **(40 points)**

Part 3 _____ **(36 points)**

TOTAL_____ **(100 points)**

Do all of the following problems. Show your work.
*******Unless otherwise stated, you may assume T = 25. °C*******

Part 1. Multiple choice. Circle the letter corresponding to the correct answer. There is one and only one correct answer per problem. [4 points each]

1) A 1.000 L sample of a buffer solution contains 0.100 moles of acetic acid (CH_3COOH), a weak acid, and 0.100 moles of sodium acetate ($NaCH_3COO$) a soluble ionic compound. 1.00 mL of a 1.00 M solution of sodium hydroxide (NaOH), a strong soluble base, is added to the solution. The pH of the solution

a) will increase by a large amount (more than 0.50 pH units).
b) will increase by a small amount (less than 0.10 pH units).
B c) will decrease by a large amount (more than 0.50 pH units).
d) will decrease by a small amount (less than 0.10 pH units).
e) will not change.

2) Potassium hydrogen phthalate (KHP, M = 204.2 g/mol) is a weak monoprotic acid often used to find the concentrations of stock solutions of strong soluble bases. Consider the titration of a 1.5 g sample of KHP (dissolved in ~ 25 mL of water) with a stock solution of NaOH, a strong soluble base, whose concentration is approximately 0.10 M. Which of the following would be the best indicator for the titration?

a) Thymol blue ($pK_a = 2.0$)
b) Bromcresol blue ($pK_a = 4.5$)
D c) Bromthymol blue ($pK_a = 6.6$)
d) o-Cresolphthalein ($pK_a = 9.0$)
e) All of the above indicators would be equally good for finding the equivalence point for this titration

3) In which of the following buffer solutions will the molar solubility of copper II hydroxide ($Cu(OH)_2$, $K_{sp} = 2.2 \times 10^{-20}$) be largest?

a) A buffer solution at pH = 5.0
b) A buffer solution at pH = 7.0
A c) A buffer solution at pH = 9.0
d) A buffer solution at pH = 11.0
e) The molar solubility will be the same in all of the above buffer solutions

4) Consider the reaction forming the complex ion $Cu(CN)_4^{2-}(aq)$

$$Cu^{2+}(aq) + 4\ CN^-(aq) \leftrightarrows Cu(CN)_4^{2-}(aq) \qquad K_f = 1.0 \times 10^{25} \text{ (at T = 25. °C)}$$

A system initially contains 0.100 M Cu^{2+} ion and 0.100 M CN^- ion at T = 25. °C. At equilibrium

a) the concentration of $Cu(CN)_4^{2-}$ ion will be small (less than 10^{-4} M)
b) the concentration of Cu^{2+} ion will be small (less than 10^{-4} M)
C c) the concentration of CN^- ion will be small (less than 10^{-4} M)
d) Both b and c
e) None of the ion concentrations will be small

5) For which of the following substances will the oxidation number for oxygen be equal to -2 ?

a) OF_2
b) H_2O
B c) H_2O_2
d) Both b and c
e) Both a and b and c

6) A reduction reaction takes place

a) At the cathode of a galvanic cell
b) At the anode of a galvanic cell
A c) At the anode of an electrolytic cell
d) Both a and c
e) Both b and c

Part 2. Short answer.

1) Define the following terms [4 points]

a) end point – The point in a titration where the indicator changes color. We pick an indicator so that the volume of titrant needed to reach end point and the equivalence point are as close as possible.

b) oxidizing agent – The substance in an oxidation-reduction reaction that is reduced (and therefore must be balanced by an oxidation reaction).

2) The solubility of aluminum fluoride (AlF_3, MW = 83.98 g/mole) is 5.59 g/L at T = 25. °C. What is the value for K_{sp}, the solubility product, for AlF_3? [8 points]

$AlF_3(s) \leftrightarrows Al^{3+}(aq) + 3\ F^-(aq)$ $\quad K_{sp} = [Al^{3+}][F^-]^3$

	Initial	Change	Equilibrium
Al^{3+}	0	x	x
F^-	0	3x	3x

$(x)(3x)^3 = 27\ x^4 = K_{sp}$

But x is equal to the molar solubility, which is

$$\text{mol sol} = \frac{5.59\ \text{g}}{\text{L}} \frac{1\ \text{mol}}{83.98\ \text{g}} = 0.0666\ \text{mol/L}$$

$K_{sp} = 27\ (0.0666)^4 = 5.3 \times 10^{-4}$

3) A buffer contains significant amounts of hypobromous acid (HBrO), a weak acid, and sodium hypobromite (NaBrO), a soluble ionic compound. Write equations showing how this buffer neutralizes added strong acid (HCl) and added strong base (NaOH). [6 points]

strong acid (HCl) $HCl(aq) + BrO^-(aq) \rightarrow HBrO(aq) + Cl^-(aq)$
converts strong acid into weak acid

strong base (NaOH) $NaOH(aq) + HBrO(aq) \rightarrow Na^+(aq) + OBr^-(aq) + H_2O(l)$
converts strong base into weak base

4) What is the oxidation number for sulfur (S) in each of the following molecules or ions? [2 points each]

H_2S _____-2_____ $S_2O_3^{2-}$ _____+2_____

H_2SO_3 _____+4_____ S_8 _____0_____

5) Balance the following oxidation-reduction reaction for the indicated condition. [10 points each]

$H_3AsO_3(aq) + Cr_2O_7^{2-}(aq) \rightarrow H_3AsO_4(aq) + Cr^{3+}(aq)$ (in acid solution)

ox $H_3AsO_3(aq) + H_2O(l) \rightarrow H_3AsO_4(aq) + 2\ e^- + 2\ H^+(aq)$ x 3

red $Cr_2O_7^{2-}(aq) + 6\ e^- + 14\ H^+(aq) \rightarrow 2\ Cr^{3+}(aq) + 7\ H_2O(\ell)$

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net $3\ H_3AsO_3(aq) + Cr_2O_7^{2-}(aq) + 8\ H^+(aq) \rightarrow 3\ H_3AsO_4(aq) + 2\ Cr^{3+}(aq) + 4\ H_2O(\ell)$

Part 3. Problems.

1) Nitrous acid (HNO_2, M = 47.02 g/mol) is a weak monoprotic acid, with $K_a = 4.6 \times 10^{-4}$ at T = 25. °C.

A student adds 4.04 g of potassium hydroxide (KOH, M = 56.1 g/mol), a strong soluble base, to 500.0 mL of a 0.4268 M aqueous solution of nitrous acid. The addition of KOH causes no significant change in the volume of the solution.

a) Write the reaction that occurs when the KOH is added to the nitrous acid solution. [4 points]

$HNO_2(aq) + KOH(aq) \rightarrow K^+(aq) + NO_2^-(aq) + H_2O(\ell)$

b) What is the pH of the above solution after the addition of KOH? [12 points]

moles HNO_2 = (0.4268 mol/L) (0.5000 L) = 0.2134 mol

moles KOH = 4.04 g (1 mol/56.1 g) = 0.0720 mol

So KOH is the limiting reactant in the above reaction. We may make a table of the number of moles before and after neutralization.

	Initial	After neutralization
HNO_2	0.2134	0.1414
KOH	0.0720	0.0000
NO_2^-	0.0000	0.0720

The solution is a buffer, so we may use the Henderson equation to find pH

$pH = pK_a + \log_{10}\{[base]/[acid]\} = \{ - \log_{10}(4.6 \times 10^{-4}) + \log_{10}\{(0.0720)/(0.1414)\}$

$= 3.04$

c) Does the addition of the potassium hydroxide lead to the formation of a buffer solution (yes/no, and a justification for your answer)? [4 points]

Yes, since after addition of the KOH there are appreciable amounts of both a weak acid (HNO_2) and its conjugate base (NO_2^-).

2) Consider the following galvanic cell (at T = 25. °C)

$Cu(s) \mid Cu^{2+}(0.5000\ M) \parallel Ag^{+}(0.00200\ M) \mid Ag(s)$

Find the following. You may need to use some of the reduction data given below in doing part of this problem

$Ag^{+}(aq) + e^{-} \rightarrow Ag(s)$ $\quad E° = 0.80$ v
$Cu^{+}(aq) + e^{-} \rightarrow Cu(s)$ $\quad E° = 0.52$ v

$Cu^{2+}(aq) + 2e^{-} \rightarrow Cu(s)$ $\quad E° = 0.34$ v
$Cu^{2+}(aq) + e^{-} \rightarrow Cu^{+}(aq)$ $\quad E° = 0.16$ v

a) The half cell oxidation reaction, the half cell reduction reaction, and the net cell reaction [6 points]

ox $\quad Cu(s) \rightarrow Cu^{2+}(aq) + 2\ e^{-}$ $\quad E° = -\ 0.34$ v

red $\quad Ag^{+}(aq) + e^{-} \rightarrow Ag(s)\ \times 2$ $\quad E° = +\ 0.80$ v

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cell $\quad Cu(s) + 2\ Ag^{+}(aq) \rightarrow Cu^{2+}(aq) + 2\ Ag(s)$ $\quad E°_{cell} = +\ 0.46$ v

b) $E°_{cell}$ [4 points]

$E°_{cell} = 0.46$ v (see above)

c) E_{cell} [6 points]

From Nernst

$E_{cell} = E°_{cell} - (RT/nF)\ \ln(Q)$ $\qquad Q = \dfrac{[Cu^{2+}]}{[Ag^{+}]^2} = \dfrac{(0.5000)}{(0.00200)^2} = 1.25 \times 10^5$

$E_{cell} = (0.46\text{ v}) - \dfrac{(8.314\text{ J/mol·K})(298.\text{ K})}{(2)(96485\text{ C/mol})} \ln(1.25 \times 10^5) = 0.31$ v