FORMULA SHEET (tear off)

1A	2A											3A	4A	5A	6A	7A	8A
1 H 1.01																	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]

$N_A = 6.022 \times 10^{23}$

1 amu = 1.661×10^{-27} kg

1 atm = 760 torr = 760 mm Hg

R = 0.08206 L•atm/mol•K

R = 8.314 J/mol•K

F = 96485. C/mol

°C = $(^5/_9)$ (°F - 32)

°C = K - 273.15

1 atm = 1.013 bar

1 L•atm = 101.3 J

1 J= 1 kg•m^2/s^2

°F = $(^9/_5)$(°C) + 32

K = °C + 273.15

$pV = nRT$

$\ln(p) = -\frac{\Delta H^\circ_{vap}}{T} + C$

$\ln(p_2/p_1) = -(\Delta H^\circ_{vap}/R)\ \{ (1/T_2) - (1/T_1) \}$

$p_A = X_A\, p_A^\circ$ $\qquad$ $[B] = k\, p_B$ $\qquad$ $\Delta p_A = X_B p_A^\circ$

$\Delta T_b = K_b\, m_B$ $\qquad$ $\Delta T_f = K_f\, m_B$ $\qquad$ $\Pi = [B]RT$

$H = U + pV$ $\qquad$ $G = H - TS$

$\Delta G_{rxn} = \Delta G^\circ_{rxn} + RT \ln Q$ $\qquad$ $\ln K = -\Delta G^\circ_{rxn}/RT$ $\qquad$ $K_p = K_C\,(RT)^{\Delta n}$

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

$K_a \cdot K_b = K_w = 1.0 \times 10^{-14}$ (at T = 25°C) $\qquad$ $pH = pK_a + \log_{10}\{[\text{base}]/[\text{acid}]\}$

$\Delta G = -nFE_{cell}$ $\qquad$ $E_{cell} = E^\circ_{cell} - (RT/nF) \ln Q$ $\qquad$ $\ln K = nFE^\circ_{cell}/RT$

GENERAL CHEMISTRY 2
THIRD EXAM
December 1, 2017

Name ______Key - Vesion 4______________________________

Panthersoft ID ____

Signature ____

Part 1 ________________ **(24 points)**

Part 2 ________________ **(32 points)**

Part 3 ________________ **(44 points)**

TOTAL ________________ **(100 points)**

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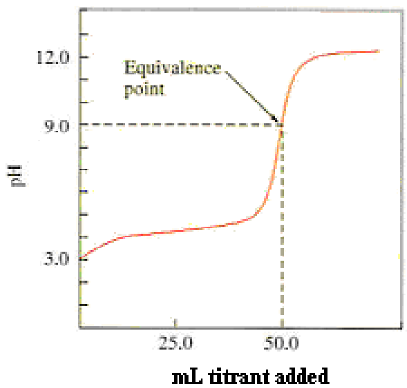
Do all of the following problems. <u>Show your work.</u>

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 small amount of a strong acid is added to a buffer solution. What will happen to the pH of the solution?

a) The pH will increase by a large amount
b) The pH will decrease by a large amount
D c) The pH will increase by a small amount
d) The pH will decrease by a small amount
e) The pH will not change

2) A titration curve is given in the figure below. The titration is carried out at T = 25. °C.



Based on this curve, we may say that

a) a strong acid is being titrated with a strong base
b) a weak acid is being titrated with a strong base
B c) a strong base is being titrated with a strong acid
d) a weak base is being titrated with a strong acid
e) cannot tell from the information given

3) Calcium carbonate ($CaCO_3$) is a slightly soluble ionic compound. For which of the following solutions will the number of grams per liter of $CaCO_3$ that will dissolve be largest (at T = 25. °C)?

a) A 0.0100 M solution of hydrochloric acid (HCl)
b) A 0.0100 M solution of sodium chloride (NaCl)
A c) A 0.0100 M solution of sodium hydroxide (NaOH)
d) A 0.0100 M solution of calcium nitrate ($Ca(NO_3)_2$)
e) pure water

4) The half cell reduction potential for the process

$$Cl_2(g) + 2\ e^- \rightarrow 2\ Cl^-(aq)$$

is E° = + 1.36 v at T = 25. °C. The half cell oxidation potential for the process

$$Cl^-(aq) \rightarrow {}^1/_2\ Cl_2(g) + e^-$$

at T = 25. °C, is

a) + 1.36 v
b) - 1.36 v
B c) + 0.68 v
d) - 0.68 v
e) 0.00 v

5) Which of the following statements about galvanic cells is true?

a) In a galvanic cell, oxidation occurs at the anode
b) In a galvanic cell, oxidation occurs at the cathode
D c) In a galvanic cell, the anode is negative and the cathode is positive
d) Both a and c
e) Both b and c

6) For a galvanic cell reaction to be spontaneous at standerd conditions which of the following must be true?

a) $\Delta G°_{rxn} = 0$ and $E°_{cell} = 0$
b) $\Delta G°_{rxn} < 0$ and $E°_{cell} < 0$
C c) $\Delta G°_{rxn} < 0$ and $E°_{cell} > 0$
d) $\Delta G°_{rxn} > 0$ and $E°_{cell} < 0$
e) $\Delta G°_{rxn} > 0$ and $E°_{cell} > 0$

Version 1: B, A, D, A, D, E **Version 2: C, D, B, E, E, A** **Version 3: A, C, C, D, E, B**

Part 2. Short answer.

1) A buffer is formed by adding an equal number of moles of hypochlorous acid (HClO, $K_a = 3.5 \times 10^{-8}$) and potassium hypochlorite (KClO) to water, at T = 25. °C.

a) What is the pH of the buffer? [4 points]

From the Henderson equation, $pH = pK_a + \log_{10}\{[base]/[acid]\}$. But $[HClO] = [ClO^-]$, so

$pH = pK_a = -\log_{10}(3.5 \times 10^{-8}) = 7.46$

b) Give the balanced reaction that takes place when a small amount of potassium hydroxide (KOH) is added to the above buffer. [4 points]

$KOH(aq) + HClO(aq) \rightarrow K^+(aq) + ClO^-(aq) + H_2O(\ell)$

2) What is the difference (if any) between a galvanic cell and an electrolytic cell? [5 points]

In a galvanic cell a chemical reaction is used to generate a voltage. In an electrolytic cell, an external voltage is provided to force a chemical reaction to take place, usually in a direction it would not normally go.

3) Balance the following oxidation-reduction reactions for acid conditions. [10 points each]

$H_2O_2(aq) + Cr_2O_7^{2-}(aq) \rightarrow O_2(g) + Cr^{3+}(aq)$

ox $H_2O_2(aq) \rightarrow O_2(g) + 2\ H^+(aq) + 2\ e^-$ 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 $Cr_2O_7^{2-}(aq) + 3\ H_2O_2(aq) + 8\ H^+(aq) \rightarrow 2\ Cr^{3+}(aq) + 3\ O_2(g) + 7\ H_2O(\ell)$

4) Several standard reduction potentials are given below, at T = 25. °C.

$Cu^{2+}(aq) + 2\ e^- \rightarrow Cu(s)$ E° = + 0.34 v
$Pb^{2+}(aq) + 2\ e^- \rightarrow Pb(s)$ E° = - 0.13 v
$Ni^{2+}(aq) + 2\ e^- \rightarrow Ni(s)$ E° = - 0.25 v
$Cd^{2+}(aq) + 2\ e^- \rightarrow Cd(s)$ E° = - 0.40 v

For each of the following questions circle the correct answer. There is one and only one correct answer per problem. [3 points each]

a) The substance that is the best oxidizing agent?

$Cd^{2+}(aq)$ **$Cu^{2+}(aq)$** $Ni^{2+}(aq)$ $Pb^{2+}(aq)$

b) The reaction with the largest value for the standard half-cell oxidation potential?

$Cd(s) \rightarrow Cd^{2+}(aq) + 2e^-$ $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$ $Ni(s) \rightarrow Ni^{2+}(aq) + 2e^-$ $Pb(s) \rightarrow Pb^{2+}(aq) + 2e^-$

c) The substance that will produce the most of grams of metal when electrolysis is carried out on the molten salt for 1.00 hour at i = 40.0 amp.

$CdCl_2$ $CuCl_2$ $NiCl_2$ **$PbCl_2$**

Part 3. Problems.

1) A 0.687 g sample of a weak monoprotic acid is titrated with a 0.1826 M solution of NaOH, a strong base. After 25.89 mL of the NaOH solution has been added the equivalence point for the titration is reached. What is the molecular mass of the weak monoprotic acid? [12 points]

Let HA = weak acid $HA(aq) + NaOH(aq) \rightarrow NaA(aq) + H_2O(\ell)$

$$\text{moles HA} = 0.02589 \text{ L NaOH soln} \ \frac{0.1826 \text{ mol NaOH}}{\text{L soln}} \ \frac{1 \text{ mol HA}}{1 \text{ mol NaOH}} = 4.73 \times 10^{-3} \text{ mol HA}$$

$$\text{MW} = \frac{0.687 \text{ g HA}}{4.73 \times 10^{-3} \text{ mol HA}} = 145. \text{ g/mol}$$

Version 1: MW = 141. g/mol Version 2: MW = 100. g/mol Version 3: MW = 106. g/mol

2) A chemist prepares 1.000 L of a 0.0218 M solution of iodoacetic acid (CH_2ICOOH, MW = 185.9 g/mol), a weak monoprotic acid with $K_a = 7.6 \times 10^{-4}$ at T = 25. °C. How many grams of sodium iodoacetate ($NaCH_2ICOO$, MW = 207.9 g/mol) must be added to the solution to convert it into a pH = 3.00 buffer? [12 points]

From the Henderson equation, $pH = pK_a + \log_{10}\{[base]/[acid]\}$

$\log_{10}\{[base]/[acid]\} = pH - pK_a$ $pK_a = - \log_{10}(7.6 \times 10^{-4}) = 3.12$

$= 3.00 - 3.12 = - 0.12$

Taking the inverse $\log_{10}$, we get $\{[base]/[acid]\} = 10^{-0.12} = 0.759$

$[base] = 0.759\ [acid] = 0.759\ (0.0218 \text{ M}) = 0.01654 \text{ M}$

$$\text{So mass of } NaCH_2ICOO = 1.000 \text{ L} \ \frac{0.01654 \text{ mol}}{\text{L}} \ \frac{207.9 \text{ g}}{\text{mol}} = 3.44 \text{ g } NaCH_2ICOO$$

Version 1: mass = 3.69 g Version 2: mass = 3.98 g Version 3: mass = 3.88 g

3) Consider the following galvanic cell and half cell reduction potentials. Note the data and the problems assume T = 25.0 °C.

$Cu(s)|Cu^{2+}(aq)||Fe^{2+}(aq),Fe^{3+}(aq)|Pt(s)$

$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$ E°= 0.77 v $Cu^{2+}(aq) + 2 e^- \rightarrow Cu(s)$ E° = 0.34 v

a) What is the purpose of the Pt(s) in the above galvanic cell? [4 points]

The Pt(s) serves as the site of the Fe^{3+}/Fe^{2+} reduction reaction. Pt is used as it will not itself be oxidized or reduced.

b) Give the half cell oxidation reaction, the half cell reduction reaction, and the net cell reaction for the galvanic cell. [6 points]

ox	$Cu(s) \rightarrow Cu^{2+}(aq) + 2 e^-$		E° = - 0.34 v
red	$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	x 2	E°= + 0.77 v
net	$Cu(s) + 2 Fe^{3+}(aq) \rightarrow Cu^{2+}(aq) + 2 Fe^{2+}(aq)$		$E°_{cell}$ = + 0.43 v

c) Find the value for $E°_{cell}$ for the galvanic cell. [4 points]

$E°_{cell}$ = + 0.43 v (see above)

d) The following ion concentrations are observed in the above galvanic cell

$[Fe^{2+}] = 2.1 \times 10^{-4}$ M $[Fe^{3+}] = 0.0120$ M $[Cu^{2+}] = 4.6 \times 10^{-3}$ M

What is E_{cell} for the galvanic cell? [6 points]

$$Q = \frac{[Cu^{2+}]\,[Fe^{2+}]^2}{[Fe^{3+}]^2} = \frac{(4.6 \times 10^{-3})\,(2.1 \times 10^{-4})^2}{(0.0120)^2} = 1.41 \times 10^{-6}$$

Fron Nernst, $E_{cell} = E°_{cell} - (RT/nF) \ln Q = + 0.43\text{ v} - \frac{(8.314\text{ J/mol•K})(298.\text{ K})}{(2)(96485.\text{ C/mol})} \ln(1.41 \times 10^{-6})$

$= + 0.43\text{ v} - (- 0.17\text{ v}) = + 0.60\text{ v}$

Version 1: $Q = 3.0 \times 10^{-6}$, E_{cell} = 0.59 v
Version 2: $Q = 8.7 \times 10^{-6}$, E_{cell} = 0.58 v
Version 3: $Q = 1.0 \times 10^{-6}$, E_{cell} = 0.60 v