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]

$N_A = 6.022 \times 10^{23}$
$1\ amu = 1.661 \times 10^{-27}\ kg$
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
(1 v) (1 C) = 1 J

°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 $x = \left(\frac{-b \pm [b^2 - 4ac]^{1/2}}{2a} \right)$

$K_a \bullet K_b = K_w = 1.0 \times 10^{-14}$ (at T = 25°C)

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

GENERAL CHEMISTRY 2
THIRD EXAM (SAMPLE)

Name ____

Panthersoft ID ____

Signature ____

Part 1 ________________ **(16 points)**

Part 2 ________________ **(32 points)**

Part 3 ________________ **(52 points)**

TOTAL ________________ **(100 points)**

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Do all of the following problems. Show your work.

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) Which of the following reactions goes essentially to completion in aqueous solution?

a) The reaction of a strong acid with a strong base
b) The reaction of a strong acid with a weak base
D c) The reaction of a weak acid with a weak base
d) Both a and b
e) Both a and b and c

2) Consider the following three aqueous solutions

Solution A	0.0500 moles of $HClO_2$ (chlorous acid) + 0.0200 moles of $NaClO_2$ (sodium chlorite) dissolved in water, with final volume V = 500.0 mL
Solution B	0.0500 moles of $HClO_2$ (chlorous acid) + 0.0200 moles of NaOH (sodium hydroxide) dissolved in water, with final volume V = 500.0 mL
Solution C	0.0500 moles of $HClO_2$ (chlorous acid) + 0.0200 moles of NaCl (sodium chloride) dissolved in water, with final volume V = 500.0 mL

Which of the sbove solutions is a buffer solution?

a) Solution A only
b) Solution B only
D c) Solution C only
d) Both solution A and solution B
e) Both solution A and solution C

3) Consider the following four weak acids (K_a values are for T = 25. °C)

Acetic acid (CH_3COOH)	$K_a = 1.8 \times 10^{-5}$	Hypobromous acid (HOBr)	$K_a = 2.0 \times 10^{-9}$
Iodic acid (HIO_3)	$K_a = 1.7 \times 10^{-1}$	Nitrous acid (HNO_2)	$K_a = 4.5 \times 10^{-4}$

Which of the following weak acid/conjugate base pairs would be best to use to prepare a buffer solution with pH = 4.4?

a) CH_3COOH and CH_3COO^-
b) HOBr and OBr^-
A c) HIO_3 and IO_3^-
d) HNO_2 and NO_2^-
e) All of the above would be equally suitable to prepare the buffer

4) Consider the following three reactions

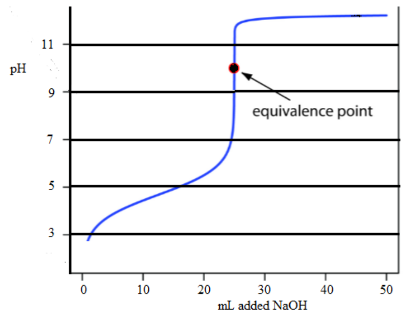
i. $NH_3(aq) + HCl(aq) \rightarrow NH_4Cl(aq)$
ii. $2\ H_2O_2(aq) \rightarrow 2\ H_2O(\ell) + O_2(g)$
iii. $CaO(s) + CO_2(g) \rightarrow CaCO_3(s)$

Which of these reactions is an oxidation-reduction (redox) reaction?

a) Reaction i. only.
b) Reaction ii. only.
B c) Reaction iii. only.
d) Both reaction i. and reaction ii.
e) Both reaction i. and reaction iii.

Part 2. Short answer.

1) A chemist prepares an aqueous solution of nitrous acid (HNO_2), a weak acid. To determine the concentration of nitrous acid in the solution, she titrates a 20.00 mL sample of the solution with a 0.2447 M solution of sodium hydroxide (NaOH), a strong soluble base. The titration was carried out at T = 25. °C. The equivalence point for the titration occurs when the volume of added sodium hydroxide solution is 23.81 mL.



a) What is the concentration of nitrous acid in the weak acid solution prepared by the chemist ? [6 points]

Reaction is $HNO_2 + NaOH \rightarrow NaNO_2 + H_2O$

Based on this, at the equivalence point moles HNO_2 = moles NaOH

$(M_{acid})\ (20.00 \times 10^{-3}\ L) = (0.2447\ M)\ (23.81 \times 10^{-3}\ L)$

$M_{acid} = (23.81/20.00)\ (0.2447\ M) = 0.2913\ M$

b) Which of the following indicators would be the best choice to use in the above titration (circle the correct answer). [4 points]

bromophenol blue	methyl red	bromothymol blue	**phenolphthalein**
$pK_a = 3.8$	$pK_a = 5.2$	$pK_a = 6.6$	**$pK_a = 9.0$**

2) The molar solubility of lead II bromide ($PbBr_2$) in water is 0.012 mol/L at T = 25.0 °C. Based on this, find the numerical value for K_{sp} for $PbBr_2$. [8 points]

$PbBr_2(s) \leftrightarrows Pb^{2+}(aq) + 2\ Br^-(aq)$ $K_{sp} = [Pb^{2+}]\ [Br-]^2$

For every mole of $PbBr_2$ that dissolves we get one mole of Pb^{2+}, and so

$[Pb^{2+}] = 0.012\ M$ $[Br^-] = 2\ (0.012\ M) = 0.024\ M$

$K_{sp} = (0.012)\ (0.024)^2 = 6.9 \times 10^{-6}$

3) 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_______

4) Balance the following reaction for the indicated condition. [8 points]

$Al(s) + NO_2^-(aq) \rightarrow AlO_2^-(aq) + NH_3(aq)$ (for base conditions)

ox $Al(s) + 2\ H_2O(\ell) \rightarrow AlO_2^-(aq) + 4\ H^+(aq) + 3\ e^-$ x 2

red $NO_2^-(aq) + 7\ H^+(aq) + 6\ e^- \rightarrow NH_3(aq) + 2\ H_2O(\ell)$

net (acid) $2\ Al(s) + NO_2^-(aq) + 2\ H_2O(\ell) \rightarrow 2\ AlO_2^-(aq) + H^+(aq) + NH_3(aq)$

convert to base $OH^-(aq) \rightarrow OH^-(aq)$

net base $2\ Al(s) + NO_2^-(aq) + H_2O(\ell) + OH^-(aq) \rightarrow 2\ AlO_2^-(aq) + NH_3(aq)$

Part 3. Problems.

1) The following question concerns the slightly soluble ionic compound silver iodide (AgI, $K_{sp} = 8.3 \times 10^{-17}$).

A student adds excess solid silver iodide (AgI, $K_{sp} = 8.3 \times 10^{-17}$) to a 0.0400 M solution of sodium iodide (NaI), and shakes the resulting mixture until no more silver iodide dissolves. What is the concentration of Ag^+ present in the solution? [10 points]

We have an initial concentration of I^- from the dissolution of NaI (a strong electrolyte)

$NaI(s) \rightarrow Na^+(aq) + I^-(aq)$ $[I^-] = 0.0400$ M

	Initial	Change	Equil
Ag^+	0	x	x
I^-	0.0400	x	0.0400 + x

$(x)(0.0400 + x) = 8.3 \times 10^{-17}$ Assume x << 0.0400

$x\ (0.0400) = 8.3 \times 10^{-17}$ $x = [Ag^+] = \frac{8.3 \times 10^{-17}}{0.0400} = 2.1 \times 10^{-15}$ M (note x is small is a correct assumption)

2) A chemist prepares 500.0 mL of a 0.0200 M aqueous solution of hypochlorous acid ($HOCl$, $K_a = 3.5 \times 10^{-8}$).

a) What is the pH of the above solution? [10 points]

Reaction is $HOCl + H_2O \leftrightarrows H_3O^+ + OCl^-$

$$K_a = \frac{[H_3O^+][OCl^-]}{[HOCl]} = 3.5 \times 10^{-8}$$

	Initial	Change	Equil.
HOCl	0.0200	-x	0.0200 - x
H_3O^+	0	x	x
OCl^-	0	x	x

So $\frac{(x)(x)}{(0.0200 - x)} = 3.5 \times 10^{-8}$ Assume x << 0.0200, then

$\frac{x^2}{0.0200} = 3.5 \times 10^{-8}$ $x^2 = (0.0200)(3.5 \times 10^{-8}) = 7.0 \times 10^{-10}$

$x = [H_3O^+] = (7.0 \times 10^{-10})^{1/2} = 2.65 \times 10^{-5}$ M (Note that x is small is a correct assumption)

$pH = - \log_{10}(2.65 \times 10^{-5}) = 4.58$

b) 0.00400 moles of potassium hydroxide (KOH, a strong soluble base) is added to the above solution of hydrochlorous acid. After the addition of KOH, what is the new value for pH? You may assume that the volume of the solution remains constant at V = 500.0 mL. [10 points]

We have the neutralization reaction, which goes to completion (because the base is a strong base)

$HOCl + KOH \rightarrow K^+ + OCl^- + H_2O$

initial moles HOCl = (0.0200 M) (0.5000 L) = 0.0100 mol
initial moles KOH = 0.00400 mol

After neutralization
moles NaOH = 0 (limiting reactant)
moles HOCl = (0.0100 - 0.00400) = 0.00600 mol [HOCl] = 0.01200 M
moles OCl^- = 0.00400 mol $[OCl^-]$ = 0.00800 M

We have significant amounts of weak acid and conjugate base, and so can use the Henderson equation (we can also do this problem using our usual ICE table)

$pH = pK_a + \log_{10}\{[base]/[acid]\} = - \log_{10}(3.5 \times 10^{-8}) + \log_{10}\{(0.00800\text{ M})/(0.01200\text{ M})\}$

$= 7.456 + (- 0.176) = 7.28$

3) A portion of the electrochemical series is given below and may be of use in doing the following problem

$Cl_2(g) + 2e^- \rightarrow 2\,Cl^-(aq)$	$E°_{red} = 1.36$ v
$Ag^+(aq) + e^- \rightarrow Ag(s)$	$E°_{red} = 0.80$ v
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	$E°_{red} = 0.34$ v
$Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$	$E°_{red} = -0.14$ v
$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$	$E°_{red} = -0.25$ v
$Co^{2+}(aq) + 2e^- \rightarrow Co(s)$	$E°_{red} = -0.28$ v
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	$E°_{red} = -0.76$ v

a) What is the strongest reducing agent from the above table of half-cell reduction reactions (circle the correct answer)? [4 points]

Zn(s) $Zn^{2+}(aq)$ $Cl_2(g)$ $Cl^-(aq)$

b) Consider the following galvanic cell

$Ni(s) \mid Ni^{2+}$ (0.0400 M) $\|$ Sn^{2+} (0.600 M) $\mid Sn(s)$

Give the half-cell oxidation reaction, the half-cell reduction reaction, and the net cell reaction for the above galvanic cell. [10 points]

ox $Ni(s) \rightarrow Ni^{2+}(aq) + 2\,e^-$ $E° = +0.25$ v

red $Sn^{2+}(aq) + 2\,e^- \rightarrow Sn(s)$ $E° = -0.14$ v

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net $Ni(s) + Sn^{2+}(aq) \rightarrow Ni^{2+}(aq) + Sn(s)$ $E°_{cell} = +0.11$ v

c) Find the values for E_{cell} and $E°_{cell}$ for the above galvanic cell. [8 points]

$E°_{cell} = +0.11$ v (see above)

From Nernst, $E_{cell} = E°_{cell} - (RT/nF) \ln Q$

$$Q = \frac{[Ni^{2+}]}{[Sn^{2+}]} = \frac{0.0400}{0.600} = 6.7 \times 10^{-2} \quad n = 2$$

So $$E_{cell} = 0.11\text{ v} - \frac{(8.314\text{ J/mol•K})\,(298.\text{ K})}{(2)\,(96485.\text{ C/mol})} \ln(6.7 \times 10^{-2})$$

$$= 0.11\text{ v} - (-0.035\text{ v}) = 0.145\text{ v}$$