FORMULA SHEET (tear off)

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

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

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

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

R = 0.08206 L•atm/mol•K $\quad$ 1 L•atm = 101.3 J

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

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

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

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

$\Delta G_{rxn} = \Delta G°_{rxn} + RT \ln Q$ $\quad$ $\ln K = -\dfrac{\Delta G°_{rxn}}{RT}$ $\quad$ $K_p = K_C\,(RT)^{\Delta ng}$

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

$K_a \cdot K_b = K_w$ $\quad$ $pH + pOH = pK_w$

$K_a \cdot K_b = 1.0 \times 10^{-14}$ (at T = 25. °C) $\quad$ $pH + pOH = 14.00$ (at T = 25. °C)

GENERAL CHEMISTRY 2
SECOND HOUR EXAM

Name ________**Version 4**________________________________

Panthersoft ID ____

Signature ____

Part 1 ________________ **(20 points)**

Part 2 ________________ **(44 points)**

Part 3 ________________ **(36 points)**

TOTAL ________________ **(100 points)**

Unless otherwise stated, you may assume T = 25.0 °C in all of the problems below.

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) Which of the following will cause a change in the numerical value for K_C?

a) A change in temperature
b) A change in pressure
A c) A change in volume
d) Both b and c
e) Both a and b and c

2) The numerical value for the equilibrium constant for the reaction

$$2\ NO_2(g) \leftrightarrows N_2O_4(g)$$

is $K_C = 220.$ at T = 25. °C. The numerical value for the equilibrium constant for the reaction

$$NO_2(g) \leftrightarrows \tfrac{1}{2}\ N_2O_4(g)$$

at T = 25. °C is

a) $K_C = 220.$
b) $K_C = 110.$
C c) $K_C = 14.8$
d) $K_C = 4.5 \times 10^{-3}$
e) Cannot tell from the information given in the problem

3) Consider the following chemical reaction

$$N_2(g) + O_2(g) \leftrightarrows 2\ NO(g) \qquad \Delta H^\circ_{rxn} = +\ 180.8\ \text{kJ/mol}$$

A system containing $N_2(g)$, $O_2(g)$, and NO(g) is initially at equilibrium at T = 25. °C. If the temperature of the system is changed to T = 80. °C under conditions of constant volume, which of the following will occur as the system reestablishes equilibrium?

a) Moles of $N_2(g)$ will increase
b) Moles of $O_2(g)$ will increase
C c) Moles of NO(g) will increase
d) Both a and b
e) Both a and b and c

4) An Arrhenius base

a) forms $H^+(aq)$ when added to liquid water
b) forms $OH^-(aq)$ when added to liquid water
B c) donates a proton in an acid-base reaction
d) accepts a proton in an acid-base reaction
e) is an electron pair donor

5) A weak diprotic acid has $K_{a1} = 4.6 \times 10^{-9}$ Which of the following are possible values for K_{a2}?

a) 3.7×10^{-3}
b) 7.7×10^{-7}
C c) 2.5×10^{-12}
d) Both b and c
e) Both a and b and c

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

Part 2. Short answer.

1) For the following chemical reaction write the expressions for K_C, K_p, and K. If it is not possible to write an expression, then indicate this by writing n/a (not available). [8 points]

$$2\ ZnS(s) + 3\ O_2(g) \leftrightarrows 2\ ZnO(s) + 2\ SO_2(g)$$

$$K_C = \frac{[SO_2]^2}{[O_2]^3} \qquad K_p = \frac{(p_{SO2})^2}{(p_{O2})^3}$$

$$K = \frac{(p_{SO2})^2}{(p_{O2})^3}$$

Note that versions 2 and 3 of the exam have the reverse of the above reaction, and so for those versions the numerator and denominator should be switched.

2) For the chemical reaction

$$Co(OH)_2(s) \leftrightarrows Co^{2+}(aq) + 2\ OH^-(aq)$$

$\Delta H°_{rxn} = + 21.5$ kJ/mol $\qquad \Delta S°_{rxn} = - 213.6$ J/mol•K $\qquad \Delta G°_{rxn} = + 85.5$ kJ/mol

Based on the above information, find the numerical value for K for the above reaction. Assume T = 25. °C.
[8 points]

$$\ln K = -\frac{\Delta G°_{rxn}}{RT} = -\frac{(85.5\ \text{kJ/mol})\ (1000\ \text{J/kJ})}{(8.314\ \text{J/mol•K})\ (298.\ \text{K})} = -\ 34.51$$

So $K = e^{-34.51} = 1.0 \times 10^{-15}$

3) For each of the following questions circle the correct answer. There is only one correct answer per problem. [4 points each]

a) The value for Q_C for a system at equilibrium

$Q_C > K_C$ **$Q_C = K_C$** $Q_C < K_C$

b) An insoluble base

$Co(OH)_2$ RbOH $Sr(OH)_2$

c) The pH of a 0.040 M aqueous solution of analinium bromide, $C_6H_5NH_4Br$, the salt of a strong acid and a weak base.

pH < 7.0 pH = 7.0 pH > 7.0

4) An aqueous solution has pH = 3.71 Ba[OH$^-$] = 2.4 x 10^{-11} M sed on this, find the values for [H_3O^+] and [OH^-] for the solution.
[4 points each]

[H_3O^+] = ___1.9 x 10^{-4} M______ [OH^-] = ___5.1 x 10^{-11} M______

pH + pOH = 14.00 and so pOH = 14.00 – pH = 14.00 – 3.71 = 10.29

$[H_3O^+] = 10^{-pH} = 10^{-3.71} = 1.9 \times 10^{-4}$ M $[OH^-] = 10^{-pOH} = 10^{-10.29} = 5.1 \times 10^{-11}$ M

Version 1: [H_3O^+] = 4.2 x 10^{-4} M Version 2: [H_3O^+] = 1.4 x 10^{-3} M Version 3: [H_3O^+] = 3.6 x 10^{-3} M
[OH^-] = 2.4 x 10^{-11} M [OH^-] = 7.1 x 10^{-12} M [OH^-] = 2.8 x 10^{-12} M

5) Consider the following four weak bases

ammonia NH_3	$K_b = 1.8 \times 10^{-5}$	methylamine CH_3NH_2	$K_b = 4.4 \times 10^{-4}$
aniline $C_6H_5NH_2$	$K_b = 3.8 \times 10^{-10}$	pyradine C_5H_5N	$K_b = 1.7 \times 10^{-9}$

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

a) The strongest base from the choices below

NH_3 $C_6H_5NH_2$ **CH_3NH_2** C_5H_5N

b) The strongest conjugate acid from the choices below

NH_4^+ **$C_6H_5NH_3^+$** $CH_3NH_3^+$ $C_5H_5NH^+$

Part 3. Problems.

1) In the gas phase sulfur dioxide (SO_2) and hydrogen (H_2) will exist in equilibrium with sulfur (S) and water (H_2O). The reaction that occurs is as follows

$$SO_2(g) + 2\,H_2(g) \leftrightarrows S(g) + 2\,H_2O(g) \qquad K_C = 9.9 \times 10^{-15}$$

A system initially has $[SO_2] = 0.074$ M, $[H_2] = 0.053$ M, and $[H_2O] = 5.6 \times 10^{-5}$ M. There is initially no S(g) in the system.

a) Give an appropriate ICE table for the above system. [8 points]

$$K_C = \frac{[S]\,[H_2O]^2}{[SO_2]\,[H_2]^2} = 9.9 \times 10^{-15}$$

	Initial	Change	Equilibrium
S	0	x	x
H_2O	5.6×10^{-5}	2x	$5.6 \times 10^{-5} + 2x$
SO_2	0.074	– x	0.074 – x
H_2	0.053	– 2x	0.053 – 2x

b) What is the value for [S], the concentration of S(g), when the above system reaches equilibrium. [8 points]

Based on the ICE table and the expression for K_C

$$\frac{(x)\,(5.6 \times 10^{-5} + 2x)^2}{(0.074 - x)\,(0.053 - 2x)^2} = 9.9 \times 10^{-15} \qquad \text{Assume } x \ll 5.6 \times 10^{-5}$$

Then $$\frac{(x)\,(5.6 \times 10^{-5})^2}{(0.074)\,(0.053)^2} = 9.9 \times 10^{-15}$$

$$x = \frac{(9.9 \times 10^{-15})\,(0.074)\,(0.053)^2}{(5.6 \times 10^{-5})^2} = 6.6 \times 10^{-10}$$ Our assumption that $x \ll 5.6 \times 10^{-5}$ was good

So $[S] = 6.6 \times 10^{-10}$ M

Version 1: $[S] = 4.1 \times 10^{-10}$ M Version 2: $[S] = 7.8 \times 10^{-11}$ M Version 3: $[S] = 3.6 \times 10^{-10}$ M

2) Find the pH for the following:

a) A 0.044 M solution of hydrobromic acid (HBr, MW = 80.92 g/mol), a strong monoprotic acid. [8 points]

HBr is a strong monoprotic acid, and reacts by the process

$HBr(aq) + H_2O(\ell) \rightarrow H_3O^+(aq) + Br^-(aq)$

Since the acid is strong the reaction goes to completion.

Therefore $[H_3O^+] = \frac{0.044 \text{ mol HBr}}{\text{L soln}} \frac{1 \text{ mol } H_3O^+}{1 \text{ mol HBr}} = \frac{0.044 \text{ mol } H_3O^+}{\text{L soln}}$

$pH = -\log_{10}[H_3O^+] = -\log_{10}(0.044) = 1.36$

Version 1: pH = 1.09 **Version 2: pH = 1.64** **Version 3: pH = 1.21**

b) A 7.2×10^{-3} M solution of aniline ($C_6H_5NH_2$, MW = 93.13 g/mol), a weak base, with $K_b = 3.8 \times 10^{-10}$ [12 points]

$C_6H_5NH_2$ is a weak base, so

$C_6H_5NH_2(aq) + H_2O(\ell) \leftrightarrows C_6H_5NH_3^+(aq) + OH^-(aq)$ $K_b = \frac{[C_6H_5NH_3^+][OH^-]}{[C_6H_5NH_2]} = 3.8 \times 10^{-10}$

Now we need the ICE table

	Initial	Change	Equilibrium
$C_6H_5NH_3^+$	0	x	x
OH^-	0	x	x
$C_6H_5NH_2$	7.2×10^{-3}	– x	$7.2 \times 10^{-3} - x$

And so $\frac{(x)(x)}{(7.2 \times 10^{-3} - x)} = 3.8 \times 10^{-10}$ Assume $x << 7.2 \times 10^{-3}$

Then $\frac{x^2}{(7.2 \times 10^{-3})} = 3.8 \times 10^{-10}$ $x^2 = (3.8 \times 10^{-10})(7.2 \times 10^{-3}) = 2.74 \times 10^{-12}$

$x = (2.74 \times 10^{-12})^{1/2} = 1.65 \times 10^{-6}$ Our assumption that $x << 7.2 \times 10^{-3}$ was good

So $[OH^-] = 1.65 \times 10^{-6}$ M $pOH = -\log_{10}[OH^-] = -\log_{10}(1.65 \times 10^{-6}) = 5.78$

pH + pOH = 14.00, so pH = 14.00 – pOH = 14.00 – 5.78 = 8.22

Version 1: pH = 8.18 **Version 2: pH = 8.27** **Version 3: 8.36**