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

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

$$\ln(p) = - \frac{\Delta H°_{vap}}{T} + C \qquad \ln(p_2/p_1) = - (\Delta H°_{vap}/R) \{ (1/T_2) - (1/T_1) \}$$

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

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

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

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

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

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

GENERAL CHEMISTRY 2
SECOND EXAM
November 3, 2017

Name **_____KEY Version 2_____**

Panthersoft ID **_____**

Signature **_____**

Part 1 **_____** **(20 points)**

Part 2 **_____** **(32 points)**

Part 3 **_____** **(48 points)**

TOTAL_____ **(100 points)**

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) For the chemical reaction

$$Cl_2(g) + 2\ NO_2(g) \leftrightarrows 2\ NO_2Cl(g)$$

$K_C = 1.8$ at a temperature T. For a particular set of starting conditions and the same temperature $Q_C = 0.040$ As the system approaches equilibrium, which of the following will occur?

a) The moles of $NO_2Cl(g)$ will increase
b) The moles of $Cl_2(g)$ will increase
A c) The moles of $NO_2(g)$ will increase
d) Both b and c
e) None of the above

2) Consider the following three reactions

I $H_2(g) + Cl_2(g) \leftrightarrows 2\ HCl(g)$
II $3\ Fe(s) + 4\ H_2O(g) \leftrightarrows Fe_3O_4(s) + 4\ H_2(g)$
III $C(s) + H_2O(g) \leftrightarrows CO(g) + H_2(g)$

For which of the above reactions will the numerical value for K_C and K_p be equal?

a) Reaction I only.
b) Reaction II only.
D c) Reaction III only.
d) Both reaction I and reaction II
e) Both reaction I and reaction III

3) Which of the following hydroxide compounds is a strong soluble base?

a) KOH (potassium hydroxide)
b) AgOH (silver hydroxide)
A c) $Ni(OH)_2$ (nickel II hydroxide)
d) Both a and b
e) Both a and b and c

4) From the substances HI, H_2S, and H_2Se

a) HI is the strongest acid and H_2Se is the weakest acid
b) HI is the strongest acid and H_2S is the weakest acid
B c) H_2S is the strongest acid and HI is the weakest acid
d) H_2S is the strongest acid and H_2Se is the weakest acid
e) H_2Se is the strongest acid and H_2S is the weakest acid

5) In the reaction

$$Al(H_2O)_6^{3+}(aq) + H_2O(\ell) \leftrightarrows Al(H_2O)_5OH^{2+}(aq) + H_3O^+(aq)$$

the $Al(H_2O)_6^{3+}$ ion functions as

a) the conjugate base of H_2O
b) the conjugate acid of H_2O
D c) a Bronsted base
d) a Bronsted acid
e) none of the above

Version 1: C, E, C, E, B Version 3: A, E, B, D, A Version 4: C, D, B, A, C

Part 2. Short answer.

1) Consider the following chemical reaction

$CO(g) + H_2(g) \leftrightarrows H_2CO(g)$ $\Delta H°_{rxn} = +30.4$ kJ/mol

A system at constant volume containing CO, H_2, and H_2CO is initially at equilibrium. For each of the following changes to the system indicate whether the number of moles of H_2CO in the system will increase, remain the same, or decrease as the system returns to equilibrium. Circle your answer. [4 points each]

a) 0.0200 moles of CO(g) is added to the system

moles of H_2CO increases	moles of H_2CO remains the same	moles of H_2CO decreases

b) The temperature of the system is increased by 20.0 °C

moles of H_2CO increases	moles of H_2CO remains the same	moles of H_2CO decreases

2) Values for K_b for several weak bases are given below, at T = 25. °C.

NH_3 $K_b = 1.8 \times 10^{-5}$ $(C_2H_5)_2NH$ $K_b = 5.4 \times 10^{-4}$

C_5H_5N $K_b = 1.7 \times 10^{-9}$ $C_6H_5NH_2$ $K_b = 3.8 \times 10^{-10}$

From the lists below circle the correct answer. There is one and only one correct answer per problem. [4 points each]

a) The strongest weak base

NH_3 **$(C_2H_5)_2NH$** C_5H_5N $C_6H_5NH_2$

b) The strongest conjugate acid

NH_4^+ $(C_2H_5)_2NH_2^+$ $C_5H_5NH^+$ **$C_6H_5NH_3^+$**

3) An aqueous solution of a weak acid has pH = 5.18 at T = 25. °C. What are the values for pOH and $[H_3O^+]$ for the solution? [4 points each]

pOH = _____8.82_____ $[H_3O^+]$ = _____6.6×10^{-6} M_____

Version 1: pOH = 8.12, $[H_3O^+] = 1.3 \times 10^{-6}$ M
Version 3: pOH = 9.75, $[H_3O^+] = 5.6 \times 10^{-5}$ M
Version 4: pOH = 9.28, $[H_3O^+] = 1.9 \times 10^{-5}$ M

4) Rubidium hydroxide (RbOH) is a strong soluble base. Find the pH of a 0.014 M aqueous solution of rubidium hydroxide at T = 25. °C. [8 points]

$$[OH^-] = 0.\frac{014 \text{ mol RbOH}}{\text{L}} \quad \frac{1 \text{ mol } OH^-}{1 \text{ mol RbOH}} = 0.014 \text{ M}$$

$$pOH = - \log_{10}[OH-] = - \log_{10}(0.014) = 1.85$$

$$pH = 14.00 - pOH = 14.00 - 1.85 = 12.15$$

Version 1: pH = 12.73 Version 3: pH = 12.89 Version 4: pH = 12.58

Part 3. Problems.

1) Using the information given below find the numerical values for $\Delta G°_{rxn}$ and K for the following reaction. You may assume that T = 25. °C. [16 points]

$$H_2(g) + I_2(g) \leftrightarrows 2\ HI(g)$$

Substance	$\Delta H°_f$ (kJ/mol)	$\Delta G°_f$ (kJ/mol)	S° (J/mol·K)
$H_2(g)$	0.00	0.00	130.68
HI(g)	26.48	1.70	206.59
$I_2(g)$	62.44	19.33	260.69

$$\Delta G°_{rxn} = [2\ \Delta G°_f(HI(g))\ ] - [\ \Delta G°_f(H_2(g)) + \Delta G°_f(I_2(g))\ ]$$

$$= [\ 2\ (1.70)\ ] - [\ 0.00 + 19.33\ ] = - 15.93 \text{ kJ/mol}$$

$$\ln K = - \frac{\Delta G°_{rxn}}{RT} = - \frac{(\ - 15.93 \text{ kJ/mol})\ (1000 \text{ J/1 kJ})}{(8.314 \text{ J/mol·K})(298.\text{ K})} = 6.43$$

$$K = e^{6.43} = 620.$$

2) Hypochlorous acid (HOCl) is a weak acid, with $K_a = 3.5 \times 10^{-8}$ at T = 25. °C.

a) Give the conjugate base of HOCl (correct formula and charge) [4 points]

_____OCl^-_____

Version 1: OBr^- Version 3: OCl^- Version 4: OBr-

b) What is the pH and the percent dissociation for a 0.00900 M aqueous solution of HOCl at T = 25. °C? [12 points]

Reaction is $HOCl(aq) + H_2O(\ell) \leftrightarrows H_3O^+(aq) + OCl^-(aq)$

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

	Initial	Change	Equilibrium
H_3O^+	0	x	x
OCl^-	0	x	x
HOCl	0.00900	- x	0.00900 - x

So $\frac{(x)\,(x)}{(0.00900 - x)} = 3.5 \times 10^{-8}$

If we assume x << 0.00900, then we get

$\frac{x^2}{(0.00900)} = 3.5 \times 10^{-8}$ $\quad x^2 = (3.5 \times 10^{-8})\,(0.00900) = 3.15 \times 10^{-10}$

$x = (3.15 \times 10^{-10})^{1/2} = 1.78 \times 10^{-5}$

$pH = - \log_{10}(1.78 \times 10^{-5}) = 4.75$

$$\% \text{ ionization} = \frac{[OCl^-]_{eq}}{[HOCl]_{initial}} \times 100\% = \frac{(1.78 \times 10^{-5})}{(0.00900)} \times 100\ \% = 0.20\ \%$$

Version 1: pH = 5.32, % dissociation = 0.05 %
Version 3: pH = 5.08, % dissociation = 0.42 %
Version 4: pH = 5.65, % dissociation = 0.11 %

3) Because the F-F single bond in F_2 is a weak bond, diatomic fluorine will dissociate at high temperatures. The reaction may be written as

$F_2(g) \leftrightarrows 2\ F(g)$ $\quad K_C = 0.064$ at T = 1500. K

A closed system at T = 1500. K initially has $[F_2] = 0.1400$ mol/L. No fluorine atoms are initially present in the system. What will be the value for [F], the concentration of fluorine atoms in the system, when equilibrium is reached? [16 points]

$$K_C = \frac{[F]^2}{[F_2]} = 0.064$$

	Initial	Change	Equilibrium
F	0	2x	2x
F_2	0.1400	- x	0.1400 - x

So $\quad \frac{(2x)^2}{(0.1400 - x)} = 0.064$

If we assume $x << 0.1400$, then

$$\frac{4x^2}{0.1400} = 0.064 \qquad x^2 = \frac{(0.064)\ (.1400)}{4} = 2.24 \times 10^{-3} \qquad x = (2.24 \times 10^{-3})^{1/2} = 0.047$$

But 0.047 is not small compared to 0.1400 (it is not at least 10 times smaller), so we will have to use another method to find x

$$\frac{(2x)^2}{(0.1400 - x)} = 0.064 \qquad 4x^2 = (0.064)\ (0.1400 - x) = 0.00896 - 0.064\ x$$

$$4x^2 + 0.064\ x - 0.00896 = 0$$

So $\quad x = - 0.064 \pm [\ (0.064)^2 - 4\ (4)\ (- 0.00896)\ ]^{1/2} \ \Big/ \ 2\ (4) = - 0.056\ ,\ + 0.040$

The underlined root gives positive concentrations for F_2 and F.

Therefore $\quad [F] = 2x = 2\ (0.040) = 0.080$ M

Version 1: [F] = 0.073 M $\quad$ Version 3: [F] = 0.086 M $\quad$ Version 4: [F] = 0.093 M