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]

$N_A = 6.022 \times 10^{23}$
$1 \text{ amu} = 1.661 \times 10^{-27}$ kg
1 atm = 760 torr = 760 mm Hg
R = 0.08206 L•atm/mol•K
R = 8.314 J/mol•K

$°C = (^5/_9)\,(°F - 32)$
°C = K - 273.15
1 atm = 1.013 bar
1 L•atm = 101.3 J
$1\text{ J} = 1 \text{ kg}\cdot\text{m}^2/\text{s}^2$

$°F = (^9/_5)(°C) + 32$
K = °C + 273.15
pV = nRT

$p_A = X_A\, p_A°$
$\Delta T_b = K_b\, m_B$

$[B] = k\, p_B$
$\Delta T_f = K_f\, m_B$

$\Delta p_A = X_B p_A°$
$\Pi = [B]RT$

$K_p = K_C\, (RT)^{\Delta n}$

H = E + pV
$\Delta G_{rxn} = \Delta G°_{rxn} + RT \ln Q$

G = H - TS
$\ln K = - \Delta G°_{rxn}/RT$

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

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

GENERAL CHEMISTRY 2
SECOND HOUR EXAM (Sample)

Name ____

Panthersoft ID ____

Signature ____

Part 1 ______________ **(20 points)**

Part 2 ______________ **(32 points)**

Part 3 ______________ **(48 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) For which of the following reactions can an expression be written for both K_C and K_p?

a) $2\ H_2(g) + C_2H_2(g) \leftrightarrows C_2H_6(g)$
b) $MgCO_3(s) \leftrightarrows MgO(s) + CO_2(g)$
D c) $HNO_2(aq) + H_2O(\ell) \leftrightarrows H_3O^+(aq) + NO_2^-(aq)$
d) Both a and b
e) Both a and b and c

2) Consider the following chemical reaction at T =25. °C.

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

The equilibrium constant for this reaction at this temperature is $K_C = 0.0046$

For a closed system with an initial value for reaction quotient $Q_C = 1.00$ at T = 25. °C, which of the following will occur as the system approaches equilibrium?

a) Moles of N_2O_4 will increase
b) Moles of NO_2 will decrease
D c) Moles of NO_2 will increase
d) Both a and b
e) Both a and c

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

a) $Ba(OH)_2$
b) $Co(OH)_2$
A c) $Fe(OH)_3$
d) Both a and b
e) Both a and b and c

4) Which of the following substances is classified as a salt?

a) NaCl
b) $NaNO_3$
D c) NaOH
d) Both a and b
e) Both a and b and c

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

Part 2. Short answer.

1) A system containing the gases Cl_2, NO, and NOCl will achieve equilibrium. The process that takes place is

$$2\ NOCl(g) \leftrightarrows 2\ NO(g) + Cl_2(g)$$

Consider a system initially at equilibrium. For each of the changes given below, indicate (by circling the correct answer) whether the change will lead to an increase, decrease, or no change in the number of moles of Cl_2 in the system. In all cases temperature is held constant at T = 500. K. [4 points each]

Add 0.20 moles of of NOCl to the system under conditions of constant volume

moles of Cl_2 will increase	moles of Cl_2 will remain constant	moles of Cl_2 will decrease

Double the volume of the system

moles of Cl_2 will increase	moles of Cl_2 will remain constant	moles of Cl_2 will decrease

Addition of a catalyst to the system

moles of Cl_2 will increase	**moles of Cl_2 will remain constant**	moles of Cl_2 will decrease

2) The equilibrium constant for the reaction

$$F_2(g) \leftrightarrows 2\ F(g)$$

is $K_C = 8.1 \times 10^{-24}$ at T = 25. °C.

A system initially contains 0.0840 mol/L of $F_2(g)$ at T = 25. °C. No F(g) is initially present in the system. What will the concentration of F(g) be in the system when equilibrium is reached? [10 points]

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

	Initial	Change	Equilibrium
F	0.0	x	x
F_2	0.084	- x/2	0.084 - x/2

Substituting, we get $\dfrac{(x)^2}{(0.084 - x/2)} = 8.1 \times 10^{-24}$ If we assume x << 0.084, then

$$\frac{(x)^2}{(0.084)} = 8.1 \times 10^{-24} \qquad x^2 = (0.084)(8.1 \times 10^{-24}) = 6.8 \times 10^{-25}$$

$$x = (6.8 \times 10^{-25})^{1/2} = 8.2 \times 10^{-13}$$

Therefore, at equilibrium $[F] = 8.2 \times 10^{-13}$ mol/L

3) Define the following [5 points each]

amphoteric - A substance that can act as either a Bronsted acid or a Bronsted base

Lewis base - An electron pair donor

Part 3. Problems.

1) Thermodynamic data are given below (at T = 25. °C) and may be of use in doing this problem.

Substance	ΔH°_f (kJ/mol)	ΔG°_f (kJ/mol)	S° (J/mol•K)
$Br_2(g)$	30.907	3.110	245.46
$Cl_2(g)$	0.00	0.00	223.07
$CH_3Br(g)$	- 35.4	- 26.3	246.4
$CH_3Cl(g)$	- 81.9	- 58.4	234.6

What are ΔG°_{rxn} and K_{eq} for the following reaction, at T = 25. °C [12 points]

$2\ CH_3Cl(g) + Br_2(g) \leftrightarrows 2\ CH_3Br(g) + Cl_2(g)$

$$\Delta G^\circ_{rxn} = [\ 2\ \Delta G^\circ_f(CH_3Br(g)) + \Delta G^\circ_f(Cl_2(g))\ ] - [\ 2\ \Delta G^\circ_f(CH_3Cl(g)) + \Delta G^\circ_f(Br_2(g))\ ]$$

$$= [\ 2\ (-26.3) + (0.0)\ ] - [\ 2\ (-58.4) + (3.110)\ ] = 61.1 \text{ kJ/mol}$$

$$\ln K = -\frac{\Delta G^\circ_{rxn}}{RT} = -\frac{(61100.\ \text{J/mol})}{(8.314\ \text{J/mol•K})\ (298.2\ \text{K})} = -24.64$$

$K = e^{-24.64} = 2.0 \times 10^{-11}$

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

$Br_2(g) + Cl_2(g) \leftrightarrows 2\,BrCl(g)$

at T = 25. °C is K_C = 7.90

a) What is the numerical value for K_p for the above reaction at T = 25. °C? [4 points]

Since Δn = change in moles of gas per mole reaction = 0, then $K_p = K_C = 7.9$

b) A system at T = 25. °C initially has 0.100 mol/L $Cl_2(g)$ and 0.360 mol/L BrCl(g). No $Br_2(g)$ is initially present in the system. What will be the concentrations of BrCl, Br_2, and Cl_2 when the system reaches equilibrium? [14 points]

$$K_C = \frac{[BrCl]^2}{[Br_2]\,[Cl_2]}$$

	Initial	Change	Equilibrium
Br_2	0	x	x
Cl_2	0.100	x	0.100 + x
BrCl	0.360	- 2x	0.360 - 2x

So $$\frac{(0.360 - 2x)^2}{(x)\,(0.100 + x)} = 7.9$$

If we assume x << 0.100, then $$\frac{(0.360)^2}{(x)\,(0.100)} = 7.9\ ; \qquad x = \frac{(0.360)^2}{(0.100)\,(7.9)} = 0.164$$

So the assumption that x << 0.100 is not valid. We therefore need to do the problem using a different approach.

$(0.360 - 2x)^2 = (x)\,(0.100 + x)\,(7.9)$

$0.1296 - 1.44\,x + 4\,x^2 = 7.9\,x^2 + 0.79\,x$

$3.9\,x^2 + 2.23\,x - 0.1296 = 0$ $$x = \frac{(-2.23) \pm [\,(2.23)^2 - 4\,(3.9)\,(-0.1296)]^{1/2}}{2\,(3.9)}$$

x = <u>0.053</u>, - 0.625

The underlined root is the only one that gives all positive final concentrations, and so is the correct answer.

So $[Br_2]$ = 0.053 mol/L $[Cl_2]$ = 1.53 mol/L [BrCl] = 0.254 mol/L

3) Find the pH of the following two solutions (both at T = 25. °C).

a) 6.44 g of potassium hydroxide (KOH, MW = 56.11 g/mol), a strong soluble base, dissolved in water, to form a solution of final volume V = 400.0 mL. [8 points]

$KOH(s) \rightarrow K^+(aq) + OH^-(aq)$

moles KOH = $6.44\text{ g}\ \frac{1\text{ mol}}{56.11\text{ g}} = 0.1148\text{ mol}$

molarity KOH = $\frac{0.1148\text{ mol}}{0.4000\text{ L}} = 0.287\text{ mol/L KOH}$ A strong soluble base, so $[OH^-] = 0.287$ mol/L

pOH = $-\log_{10}[OH-] = -\log_{10}(0.287) = 0.54$ pH = 14.00 - pOH = 14.00 - 0.54 = 13.46

b) A 0.0800 M solution of propionic acid, a weak monoprotic acid, with $K_a = 1.4 \times 10^{-5}$. [10 points]

Let HA = weak monoprotic acid. Then

$HA(aq) + H_2O(\ell) \leftrightarrows H_3O^+(aq) + A^-(aq)$ $K_a = \frac{[H_3O^+]\,[A^-]}{[HA]} = 1.4 \times 10^{-5}$

	Initial	Change	Equilibrium
HA	0.0800	-x	0.0800 - x
H_3O^+	0	x	x
A^-	0	x	x

$\frac{(x)(x)}{(0.0800 - x)} = 1.4 \times 10^{-5}$

Assume x < 0.0800, then $\frac{x^2}{(0.0800)} = 1.4 \times 10^{-5}$ $x^2 = (0.0800)(1.8 \times 10^{-5}) = 1.12 \times 10^{-6}$

$x = (1.12 \times 10^{-6})^{1/2} = 1.06 \times 10^{-3}$ (so x is small)

$[H_3O^+] = x = 1.20 \times 10^{-3}$ pH = $-\log_{10}[H_3O^+] = -\log_{10}(1.06 \times 10^{-3}) = 2.98$