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

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

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

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

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

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

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

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

GENERAL CHEMISTRY 2
SECOND HOUR EXAM
OCTOBER 22, 2021

Name _____

Panthersoft ID _____

Signature _____

Part 1 _____ **(20 points)**

Part 2 _____ **(46 points)**

Part 3 _____ **(34 points)**

TOTAL_____ **(100 points)**

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

Unless otherwise stated, you may assume T = 25. °C in all problems.

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) The numerical value for the equilibrium constant depends on which of the following?

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

2) The gas phase equilibrium for carbon dioxide (CO_2), carbon disulfide (CS_2), and carbonyl sulfide (COS) is described by the following reaction:

$$CO_2(g) + CS_2(g) \leftrightarrows 2\ COS(g)$$

0.010 moles of $CS_2(g)$ is added to a system initially at equilibrium, while keeping temperature and volume constant. As the system returns to equilibrium, which of the following will occur?

a) moles of CO_2 in the system will increase
b) moles of COS in the system will increase
B c) moles of COS in the system will decrease
d) Both a and b
e) Both a and c

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

a) AgOH (silver hydroxide)
b) CsOH (cesium hydroxide)
D c) NaOH (sodium hydroxide)
d) Both b and c
e) Both a and b and c

4) An aqueous solution has pH = 6.18 Based on this information, which of the following can be found?

a) $[H_3O^+]$, the concentration of hydronium ion in the solution
b) $[OH^-]$ the concentration of hydroxide ion in the solution
E c) pOH
d) Both a and b
e) Both a and b and c

5) The salt of a strong acid and a weak base is

a) a strong acid
b) a weak acid
B c) a strong base
d) a weak base
e) none of the baove

Part 2. Short answer.

1) For the chemical reaction

$$Ba(s) + 2\ H_2O(\ell) \leftrightarrows Ba^{2+}(aq) + 2\ OH^-(aq) + H_2(g)$$

give the expressions for K_C, K_p, and K. If an expression for one or more of these equilibrium constants cannot be given, put n/a (not applicable) as your answer. [9 points]

$K_C = [Ba^{2+}]\ [OH^-]^2\ [H_2]$ $K_p =$ n/a $K = [Ba^{2+}]\ [OH^-]^2\ (p_{H2})$

2) Thermochemical data can be used to find the value for an equilibrium constants for reactions that are difficult or dangerous to study in the laboratory. For example, consider the following reaction involving chlorine oxides, compounds found in the stratosphere of the Earth.

$$2\ ClO(g) + O_2(g) \leftrightarrows 2\ ClO_2(g)$$

Based on the information below, find the numerical value for K, the thermodynamic equilibrium constant, for the above reaction. [10 points]

substance	$\Delta H°_f$ (kJ/mol)	$\Delta G°_f$ (kJ/mol)	S° (J/mol·K)
ClO(g)	101.8	98.1	226.6
ClO_2(g)	89.1	105.0	263.7
O_2(g)	0.0	0.0	205.0

$\Delta G°_{rxn} = [\ 2\ \Delta G°_f(ClO_2(g))\ ] - [\ 2\ \Delta G°_f(ClO(g)) + \Delta G°_f(O_2(g))\ ]$

$= [\ 2\ (105.0)\ ] - [2\ (98.1) + 0.0\ ] = 13.8$ kJ/mol

$$\ln K = -\frac{\Delta G°_{rxn}}{RT} = -\frac{(13800.\ J/mol)}{(8.314\ J/mol·K)\ (298.\ K)} = -5.57$$

$K = e^{-5.57} = 3.8 \times 10^{-3}$

3) Define the following term – polyprotic acid [4 points]

A polyprotic acid is an acid that has two or more donatable protons. Examples: H_2SO_4, H_3PO_4

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

a) A value for K_C that greatly favors formation of products instead of reactants

K_C much less than 1	K_C approximately equal to 1	**K_C much greater than 1**

b) The pH that is closest to that for a neutral solution?

pH = 3.00	**pH = 6.00**	pH = 9.00

c) The strongest weak acid?

$HBrO_3$	**$HBrO_4$**	HIO_4

5) Hydrogen peroxide (H_2O_2) is a weak monoprotic acid, with $K_a = 2.4 \times 10^{-12}$. Aqueous solutions of hydrogen peroxide are often used as antiseptics.

a) What is the conjugate base of hydrogen peroxide? [4 points]

conjugate base = HO_2^-

b) A 3 % solution of hydrogen peroxide (available for purchase in most drug stores) has $[H_2O_2] = 0.80$ M. What is the pH of a 3 % solution of hydrogen peroxide? [10 points]

Reaction is $H_2O_2(aq) + H_2O(\ell) \leftrightarrows H_3O^+(aq) + HO_2^-(aq)$ $\quad K_a = \dfrac{[H_3O^+]\,[HO_2^-]}{[H_2O_2]} = 2.4 \times 10^{-12}$

	Initial	Change	Equilibrium
H_3O^+	0	x	x
HO_2^-	0	x	x
H_2O_2	0.80	– x	0.80 – x

So $\dfrac{(x)\,(x)}{(0.80 - x)} = \dfrac{x^2}{(0.80 - x)} = 2.4 \times 10^{-12}$

If we assume $x << 0.80$, then

$\dfrac{x^2}{(0.80 - x)} = \dfrac{x^2}{(.080)} = 2.4 \times 10^{-12}$ $\qquad x^2 = (2.4 \times 10^{-12})\,(0.80) = 1.92 \times 10^{-12}$

$x = (1.92 \times 10^{-12})^{1/2} = 1.39 \times 10^{-6}$

So $x << 0.80$ was a good approximation. And so

$[H_3O^+] = x = 1.39 \times 10^{-6}$ M $\qquad pH = -\log_{10}(1.39 \times 10^{-6}) = 5.86$

Part 3. Problems.

1) Nitrogen trifluoride (NF_3) is a gas used in the manufacture of light emitting diodes and photovoltaic cells. It is also a potent greenhouse gas. Nitrogen trifluoride exists in equilibrium with nitrogen (N_2) and hydrogen (F_2).

$$N_2(g) + 3\ F_2(g) \leftrightarrows 2\ NF_3(g) \qquad K_C = 5.8 \times 10^{31}$$

In a particular closed system maintained at a constant temperature the initial concentrations of nitrogen and nitrogen trifluoride are $[N_2] = 0.0320$ M, $[NF_3] = 0.0840$ M. There is no fluorine (F_2) initially present in the system.

a) Give an ICE table corresponding to the above reaction and initial conditions. [8 points]

$$K_C = \frac{[NF_3]^2}{[N_2]\,[F_2]^3} = 5.8 \times 10^{31}$$

	Initial	Change	Equilibrium
NF_3	0.0840	$-2x$	$0.0840 - 2x$
N_2	0.0320	x	$0.0320 + x$
F_2	0	$3x$	$3x$

b) Find the concentration of F_2 present in the system when equilibrium is reached. Give your final answer in terms of molarity. [10 points]

Substituting, we get $\dfrac{(0.0840 - 2x)^2}{(0.0320 + x)\,(3x)^3} = 5.8 \times 10^{31}$

Assume $x << 0.032$, then $\dfrac{(0.0840)^2}{(0.0320)\,(3x)^3} = 5.8 \times 10^{31}$ $\quad x^3 = \dfrac{(0.0840)^2}{(0.0320)\,(27)\,(5.8 \times 10^{31})} = 1.41 \times 10^{-34}$

$$x = (1.41 \times 10^{-34})^{1/3} = 5.20 \times 10^{-12}$$

So assuming $x << 0.032$ was a good assumption. Therefore

$$[F_2] = 3x = 3\,(5.20 \times 10^{-12}) = 1.6 \times 10^{-11}\ \text{M}$$

2) A chemist prepares an aqueous solution of potassium hydroxide (KOH, MW = 56.11 g/mol), a strong soluble base. The pH and final volume of the solution are pH = 12.44 and V = 250.0 mL.

a) What is the concentration of hydronium ion (H_3O^+) in the solution. [4 points]

$[H_3O^+] = 10^{-pH} = 10^{-12.44} = 3.6 \times 10^{-13}$

b) The chemist preparing the above solution forgot to write down how much KOH was used in its preparation. Based on the information in the problem, find the number of grams of potassium hydroxide in the solution. [12 points]

KOH is a strong soluble base, and so react as follows

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

Based on this reaction, we can say the concentration of KOH is the same as the concentration of OH^- ions

$pOH = 14.00 - pH = 14.00 - 12.44 = 1.56$

$[OH^-] = 10^{-pOH} = 10^{-1.56} = 0.0275$ M

So [KOH] = 0.0275 M

$$\text{mol KOH} = \frac{0.0275 \text{ mol}}{\text{L}} (0.2500 \text{ L}) = 6.89 \times 10^{-3} \text{ mol}$$

$$\text{grams KOH} = 6.89 \times 10^{-3} \text{ mol} \ \frac{56.11 \text{ g}}{\text{mol}} = 0.386 \text{ g KOH}$$