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 $x = \dfrac{-b \pm [b^2 - 4ac]^{1/2}}{2a}$

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

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

GENERAL CHEMISTRY 2
SECOND HOUR EXAM
MARCH 18, 2022

Name _____

Panthersoft ID _____

Signature _____

Part 1 _____ **(20 points)**

Part 2 _____ **(42 points)**

Part 3 _____ **(38 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) For a system at equilibrium which of the following could be true?

a) $Q_C > K_C$
b) $Q_C = K_C$
B c) $Q_C < K_C$
d) Both a and c
e) Both a and b and c

2) In the gas phase sulfur dioxide (SO_2) and chlorine (Cl_2) will react to form sulfuryl dichloride (SO_2Cl_2).

$SO_2(g) + Cl_2(g) \leftrightarrows SO_2Cl_2(g)$ $\Delta H°_{rxn} = -67.2$ kJ/mol $\Delta G°_{rxn} = -19.9$ kJ/mol $\Delta S°_{rxn} = -159.2$ J/mol·K

A system initially at equilibrium contains $SO_2(g)$, $Cl_2(g)$, and $SO_2Cl_2(g)$. Which of the following changes will cause the number of moles of $SO_2(g)$ in the system to increase?

a) Add 0.100 moles of $Cl_2(g)$ to the system
b) Add 0.100 moles of $SO_2Cl_2(g)$ to the system
E c) Increase the temperature of the system by 40.0 °C
d) Both a and c
e) Both b and c

3) Potassium nitrite (KNO_2) is the salt of a weak acid and a strong soluble base. KNO_2

a) is a strong acid
b) is a weak acid
D c) is a strong base
d) is a weak base
e) has no acid or base properties

4) Which of the following oxides is expected to form a base when added to liquid water?

a) Na_2O
b) SO_2
A c) N_2O_5
d) Both b and c
e) Both a and b and c

5) A Lewis acid

a) is a proton donor
b) is an electron pair donor
D c) is a proton acceptor
d) is an electron pair acceptor
e) none of the above

Part 2. Short answer.

1) The equilibrium constant for the reaction

$$H_2(g) + Br_2(g) \leftrightarrows 2\ HBr(g)$$

is $K_C = 2.0 \times 10^9$ at T = 25. °C.

For a particular system at equilibrium at T = 25. °C $[Br_2] = 4.0 \times 10^{-5}$ M and [HBr] = 0.164 M. Based on this information, what is the value for $[H_2]$, the concentration of H_2 present in the system? [6 points]

$$K_C = \frac{[HBr]^2}{[H_2]\,[Br_2]} \quad \text{and so } [H_2] = \frac{[HBr]^2}{K_C\,[Br_2]} = \frac{(0.164)^2}{(2.0 \times 10^9)\,(4.0 \times 10^{-5})} = 3.4 \times 10^{-7}\ M$$

2) The equilibrium constant for the reaction

$$2\ N_2O_5(g) \leftrightarrows 4\ NO_2(g) + O_2(g)$$

is $K_C = 8.0 \times 10^{-6}$ at T = 25. °C.

a) What is the numerical value for K_p for the above reaction? [4 points]

$K_p = K_C\,(RT)^{\Delta ng}$ $\quad \Delta n_g = 5 - 2 = 3$, and so

$K_p = (8.0 \times 10^{-6})\,[\,(0.08206)\,(298.)\,]^3 = 0.117$

b) A particular system has the following initial concentrations: $[N_2O_5] = 0.0160$ M; $[O_2] = 0.0500$ M. There is initially no NO_2 present in the system. Give an ICE table for this system and initial concentations, but do not use the ICE table to find the equilibrium concentrations that are present. [6 points]

$$K_C = \frac{[NO_2]^4\,[O_2]}{[N_2O_5]^2}$$

	Initial	Change	Equilibrium
NO_2	0	4x	4x
O_2	0.0500	x	0.0500 + x
N_2O_5	0.0160	– 2x	0.0160 – 2x

Note that there are other ICE tables that could be given that would also be correct.

3) Define the following term: amphoteric [5 points]

Amphoteric refers to a substance that can act as either a Bronsted acid or a Bronsted base in a chemical reaction. Water (H_2O), for example, is amphoteric.

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

a) The conjugate base in the reaction: $HI(aq) + C_5H_5N(aq) \rightarrow C_5H_5NH^+(aq) + I^-(aq)$

C_5H_5N $C_5H_5NH^+$ HI **$\underline{I^-}$**

b) The hydroxide compound that is a strong soluble base

AgOH **$\underline{CsOH}$** $Cu(OH)_2$ $Fe(OH)_3$

c) The strongest weak acid

NH_3 H_2O H_2S **$\underline{H_2Se}$**

5) The pH of a 0.0270 M solution of a weak monoprotic acid HA is pH = 4.17

a) What are the values for pOH and $[H_3O^+]$ for the solution? [6 points]

At T = 25. °C, pH + pOH = 14.00 , and so pOH = 14.00 – pH = 14.00 – 4.17 = 9.83

$[H_3O^+] = 10^{-pH} = 10^{-4.17} = 6.8 \times 10^{-5}$ M

b) What is the value for the percent dissociation for HA in the above solution? [6 points]

For a weak acid, $HA(aq) + H_2O(\ell) \leftrightarrows H_3O^+(aq) + A^-(aq)$

$$\text{percent dissociation} = \frac{\text{molarity of conjugate base formed}}{\text{initial molarity of weak acid}} \times 100\ \%$$

But at equilibrium $[A^-] = [H_3O^+] = 6.8 \times 10^{-5}$ M

and so $$\text{percent dissociation} = \frac{6.8 \times 10^{-5}}{0.0270} \times 100\% = 0.25\ \%$$

Part 3. Problems.

1) When carbon dioxide (CO_2) is bubbled through an aqueous solution of a strong base, the following reaction will take place

$$CO_2(g) + 2\ OH^-(aq) \leftrightarrows H_2O(\ell) + CO_3^{2-}(aq)$$

a) Give the expression for K, the thermodynamic equilibrium constant, for the above reaction. [5 points]

$$K = \frac{[CO_3^{2-}]}{p_{CO2}\,[OH^-]^2}$$

b) Using the thermodynamic data below, find the numerical value for K for the above reaction. [12 points]

substance	$\Delta H°_f$ (kJ/mol)	$\Delta G°_f$ (kJ/mol)	$S°$ (J/mol·K)
$CO_2(g)$	– 393.5	– 394.4	213.8
$CO_3^{2-}(aq)$	– 677.1	– 527.8	– 56.9
$H_2O(\ell)$	– 285.8	– 237.1	70.0
$OH^-(aq)$	– 230.0	– 157.2	– 10.8

$$\Delta G°_{rxn} = [\ \Delta G°_f(H_2O(\ell)) + \Delta G°_f(CO_3^{2-}(aq))\ ] - [\ \Delta G°_f(CO_2(g)) + 2\ \Delta G°_f(OH^-(aq))\ ]$$

$$= [\ (-237.1) + (-527.8)\ ] - [\ (-394.4) + 2\ (-157.2)\ ] = -56.1\ \text{kJ/mol}$$

And so $$\ln K = -\frac{\Delta G°_{rxn}}{RT} = -\frac{(-56100.\ \text{J/mol})}{(8.3145\ \text{J/mol·K})\ (298.2\ \text{K})} = 22.63$$

$$k = e^{22.63} = 6.7 \times 10^9$$

2) Data for several weak monoprotic acids are given below and may be used in doing the following problem.

CH_3COOH	$K_a = 1.8 \times 10^{-5}$	HOCN	$K_a = 3.5 \times 10^{-4}$
HClO	$K_a = 4.0 \times 10^{-8}$	N_2H_4	$K_a = 7.9 \times 10^{-9}$
HN_3	$K_a = 2.5 \times 10^{-5}$	HIO	$K_a = 3.2 \times 10^{-11}$

a) Give the conjugate base of cyanic acid (HOCN). [3 points]

conjugate base of HOCN = _____**OCN^-**_____

b) The strongest acid from the following list (circle the correct answer). [3 points]

CH_3COOH HClO **HN_3** N_2H_4

c) The strongest base from the following list (circle the correct answer). [3 points]

CH_3COO^- ClO^- N_3^- **$N_2H_3^-$**

d) What is the pH of a 0.0600 M aqueous solution of hypoiodous acid (HIO)? [12 points]

The reaction that occurs is

$$HIO(aq) + H_2O(\ell) \leftrightarrows H_3O^+(aq) + IO^-(aq) \qquad K_C = \frac{[H_3O^+]\,[IO^-]}{[HIO]}$$

	Initial	Change	Equilibrium
H_3O^+	0	x	x
IO^-	0	x	x
HIO	0.0600	– x	0.0600 – x

So $\frac{(x)\,(x)}{(0.0600 - x)} = K_a = 3.2 \times 10^{-11}$ If we assume $x << 0.060$, then

$\frac{x^2}{0.0600} = 3.2 \times 10^{-11}$ $\quad x^2 = (0.0600)\,(3.2 \times 10^{-11}) = 1.92 \times 10^{-12}$

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

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