

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]

$$N_A = 6.022 \times 10^{23}$$

$$1 \text{ amu} = 1.661 \times 10^{-27} \text{ kg}$$

$$1 \text{ atm} = 760 \text{ torr} = 760 \text{ mm Hg}$$

$$R = 0.08206 \text{ L}\cdot\text{atm}/\text{mol}\cdot\text{K}$$

$$R = 8.314 \text{ J}/\text{mol}\cdot\text{K}$$

$$^{\circ}\text{C} = (5/9)(^{\circ}\text{F} - 32)$$

$$^{\circ}\text{C} = \text{K} - 273.15$$

$$1 \text{ atm} = 1.013 \text{ bar}$$

$$1 \text{ L}\cdot\text{atm} = 101.3 \text{ J}$$

$$1 \text{ J} = 1 \text{ kg}\cdot\text{m}^2/\text{s}^2$$

$$^{\circ}\text{F} = (9/5)(^{\circ}\text{C}) + 32$$

$$\text{K} = ^{\circ}\text{C} + 273.15$$

$$pV = nRT$$

$$p_A = X_A p_A^{\circ}$$

$$\Delta T_b = K_b m_B$$

$$H = U + pV$$

$$\Delta G_{\text{rxn}} = \Delta G^{\circ}_{\text{rxn}} + RT \ln Q$$

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

$$K_a \cdot K_b = K_w$$

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

$$[B] = k p_B$$

$$\Delta T_f = K_f m_B$$

$$G = H - TS$$

$$\ln K = -\Delta G^{\circ}_{\text{rxn}}/RT$$

$$\Delta p_A = X_B p_A^{\circ}$$

$$\Pi = M_B RT$$

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

$$\text{pH} + \text{pOH} = \text{p}K_w$$

$$\text{pH} + \text{pOH} = 14.00 \text{ (at } T = 25. ^{\circ}\text{C)}$$

**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. Show your work.

Unless otherwise stated, you may assume $T = 25. \text{ }^\circ\text{C}$ 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).



A system initially at equilibrium contains $\text{SO}_2(\text{g})$, $\text{Cl}_2(\text{g})$, and $\text{SO}_2\text{Cl}_2(\text{g})$. Which of the following changes will cause the number of moles of $\text{SO}_2(\text{g})$ in the system to increase?

- a) Add 0.100 moles of $\text{Cl}_2(\text{g})$ to the system
- b) Add 0.100 moles of $\text{SO}_2\text{Cl}_2(\text{g})$ to the system
- E** c) Increase the temperature of the system by $40.0 \text{ }^\circ\text{C}$
- 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?

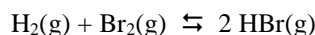
- a) Na_2O
- b) SO_2
- A** c) N_2O_5
- d) Both b and c
- e) Both a and b and c

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

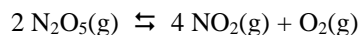


is $K_C = 2.0 \times 10^9$ at $T = 25.^\circ\text{C}$.

For a particular system at equilibrium at $T = 25.^\circ\text{C}$ $[\text{Br}_2] = 4.0 \times 10^{-5} \text{ M}$ and $[\text{HBr}] = 0.164 \text{ M}$. Based on this information, what is the value for $[\text{H}_2]$, the concentration of H_2 present in the system? [6 points]

$$K_C = \frac{[\text{HBr}]^2}{[\text{H}_2][\text{Br}_2]} \quad \text{and so } [\text{H}_2] = \frac{[\text{HBr}]^2}{K_C [\text{Br}_2]} = \frac{(0.164)^2}{(2.0 \times 10^9)(4.0 \times 10^{-5})} = 3.4 \times 10^{-7} \text{ M}$$

2) The equilibrium constant for the reaction



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

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

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

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

b) A particular system has the following initial concentrations: $[\text{N}_2\text{O}_5] = 0.0160 \text{ M}$; $[\text{O}_2] = 0.0500 \text{ M}$. There is initially no NO_2 present in the system. Give an ICE table for this system and initial concentrations, but do not use the ICE table to find the equilibrium concentrations that are present. [6 points]

$$K_C = \frac{[\text{NO}_2]^4 [\text{O}_2]}{[\text{N}_2\text{O}_5]^2}$$

	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: $\text{HI}(\text{aq}) + \text{C}_5\text{H}_5\text{N}(\text{aq}) \rightarrow \text{C}_5\text{H}_5\text{NH}^+(\text{aq}) + \text{I}^-(\text{aq})$

$\text{C}_5\text{H}_5\text{N}$ $\text{C}_5\text{H}_5\text{NH}^+$ HI I^-

b) The hydroxide compound that is a strong soluble base

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

c) The strongest weak acid

NH_3 H_2O H_2S 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 $[\text{H}_3\text{O}^+]$ 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

$[\text{H}_3\text{O}^+] = 10^{-\text{pH}} = 10^{-4.17} = 6.8 \times 10^{-5} \text{ M}$

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

For a weak acid, $\text{HA}(\text{aq}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{A}^-(\text{aq})$

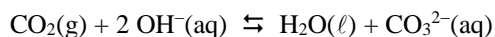
percent dissociation = $\frac{\text{molarity of conjugate base formed}}{\text{initial molarity of weak acid}} \times 100 \%$

But at equilibrium $[\text{A}^-] = [\text{H}_3\text{O}^+] = 6.8 \times 10^{-5} \text{ M}$

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

Part 3. Problems.

1) When carbon dioxide (CO₂) is bubbled through an aqueous solution of a strong base, the following reaction will take place



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

$$K = \frac{[\text{CO}_3^{2-}]}{p_{\text{CO}_2} [\text{OH}^-]^2}$$

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

substance	ΔH°_f (kJ/mol)	ΔG°_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 ₂ O(ℓ)	- 285.8	- 237.1	70.0
OH ⁻ (aq)	- 230.0	- 157.2	- 10.8

$$\begin{aligned}\Delta G^\circ_{\text{rxn}} &= [\Delta G^\circ_f(\text{H}_2\text{O}(\ell)) + \Delta G^\circ_f(\text{CO}_3^{2-}(\text{aq}))] - [\Delta G^\circ_f(\text{CO}_2(\text{g})) + 2 \Delta G^\circ_f(\text{OH}^-(\text{aq}))] \\ &= [(- 237.1) + (- 527.8)] - [(- 394.4) + 2 (- 157.2)] = - 56.1 \text{ kJ/mol}\end{aligned}$$

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

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

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

CH ₃ COOH	K _a = 1.8 x 10 ⁻⁵	HOCN	K _a = 3.5 x 10 ⁻⁴
HClO	K _a = 4.0 x 10 ⁻⁸	N ₂ H ₄	K _a = 7.9 x 10 ⁻⁹
HN ₃	K _a = 2.5 x 10 ⁻⁵	HIO	K _a = 3.2 x 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]

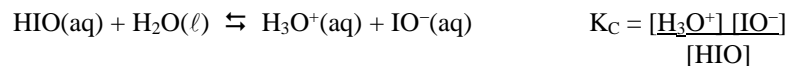
CH₃COOH HClO **HN₃** N₂H₄

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

CH₃COO⁻ ClO⁻ N₃⁻ **N₂H₃⁻**

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

The reaction that occurs is



	Initial	Change	Equilibrium
H ₃ O ⁺	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 $x \ll 0.060$, then

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

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

$$[\text{H}_3\text{O}^+] = x = 1.39 \times 10^{-6} \text{ M} \quad \text{pH} = -\log_{10}[\text{H}_3\text{O}^+] = -\log_{10}(1.39 \times 10^{-6}) = 5.86$$