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]

$N_A = 6.022 \times 10^{23}$ $\quad$ $°C = (^5/_9)(°F - 32)$ $\quad$ $°F = (^9/_5)(°C) + 32$

1 amu = 1.661×10^{-27} kg $\quad$ $°C = K - 273.15$ $\quad$ $K = °C + 273.15$

1 atm = 760 torr = 760 mm Hg $\quad$ 1 atm = 1.013 bar $\quad$ $pV = nRT$

$R = 0.08206$ L·atm/mol·K $\quad$ 1 L·atm = 101.3 J

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

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

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

$H = U + pV$ $\quad$ $G = H - TS$

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

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

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

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

GENERAL CHEMISTRY 2
SECOND HOUR EXAM
OCTOBER 20, 2022

Name _____**Version 3 solutions**_____

Panthersoft ID _____

Signature _____

Part 1 _____ **(20 points)**

Part 2 _____ **(44 points)**

Part 3 _____ **(36 points)**

TOTAL_____ **(100 points)**

Unless otherwise stated, you may assume T = 25.0 °C in all of the problems below.

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) Which of the following will cause a change in the numerical value for K_C?

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

2) Consider the following three reactions

i. $SO_2(g) + H_2O(\ell) \leftrightarrows H_2SO_3(aq)$
ii. $Cl_2(g) + F_2(g) \leftrightarrows 2\ ClF(g)$
iii. $MgCO_3(s) \leftrightarrows MgO(s) + CO_2(g)$

For which of these reactions is it possible to write an expression for K_p?

a) Reaction i.
b) Reaction ii.
D c) Reaction iii.
d) Both reaction ii. and reaction iii.
e) Both reaction i. and reaction ii. and reaction iii.

3) An Arrhenius acid

a) forms $H^+(aq)$ when added to liquid water
b) forms $OH^-(aq)$ when added to liquid water
A c) donates a proton in an acid-base reaction
d) accepts a proton in an acid-base reaction
e) is an electron pair donor

4) Which of the following solids is a strong soluble base?

a) AgOH(s)
b) $Sr(OH)_2(s)$
B c) $Fe(OH)_3(s)$
d) Both b and c
e) Both a and b and c

5) The numerical value for the equilibrium constant for the autoionization reaction of water is $K_w = 5.5 \times 10^{-14}$, at T = 50. °C. What is the value for pH for a neutral aqueous solution at this temperature?

a) 14.00
b) 13.26
D c) 7.00
d) 6.63
e) Cannot tell from the information given

Version 1: C, D, B, C, D **Version 2: B, D, E, B, A** **Version 4: B, D, D, C, A**

Part 2. Short answer.

1) For the chemical reaction

$SrF_2(s) \leftrightarrows Sr^{2+}(aq) + 2\ F^-(aq)$

$\Delta H°_{rxn} = +\ 5.3$ kJ/mol $\quad \Delta S°_{rxn} = -\ 142.3$ J/mol·K $\quad \Delta G°_{rxn} = +\ 47.7$ kJ/mol

Based on the above information, find the numerical value for K for the above reaction. Assume T = 25. °C. [8 points]

$$\ln K = -\frac{\Delta G°_{rxn}}{RT} = -\frac{(47.7\ \text{kJ/mol})(1000\ \text{J/kJ})}{(8.314\ \text{J/mol·K})(298.\ \text{K})} = -19.25$$

So $K = e^{-19.25} = 4.4 \times 10^{-9}$

2) Consider the following chemical reaction

$CO_2(g) + H_2(g) \leftrightarrows CO(g) + H_2O(g) \qquad \Delta H°_{rxn} = +\ 41.2$ kJ/mol

A system containing CO(g), CO_2(g), H_2(g), and H_2O(g) in a container of fixed volume is initially at equilibrium at T = 25. °C. For each of the following changes, indicate whether the moles of CO(g) will increase, stay the same, or decrease when equilibrium is reestablished. [4 points each]

a) Add 0.0200 moles of H_2 to the system.

moles CO(g) will increase	moles CO(g) will stay the same	moles CO(g) will decrease

b) Increase the volume of the container.

moles CO(g) will increase	**moles CO(g) will stay the same**	moles CO(g) will decrease

c) Change the temperature of the system to T = 60. °C while keeping volume constant.

moles CO(g) will increase	moles CO(g) will stay the same	moles CO(g) will decrease

3) An aqueous solution has pH = 9.46 Based on this, find the values for $[H_3O^+]$ and $[OH^-]$ for the solution. [4 points each]

$[H_3O^+]$ = ___3.5 x 10^{-10} M_____ $[OH^-]$ = ___2.9 x 10^{-5} M_____

pH + pOH = 14.00 and so pOH = 14.00 – pH = 14.00 – 9.46 = 4.54

$[H_3O^+] = 10^{-pH} = 10^{-9.46} = 3.5 \times 10^{-10}$ M $[OH^-] = 10^{-pOH} = 10^{-4.54} = 2.9 \times 10^{-5}$ M

Version 1: $[H_3O^+] = 8.3 \times 10^{-10}$ M $[OH^-] = 1.2 \times 10^{-5}$ M

Version 2: $[H_3O^+] = 2.3 \times 10^{-10}$ M $[OH^-] = 14.3 \times 10^{-5}$ M

Version 4: $[H_3O^+] = 1.5 \times 10^{-10}$ M $[OH^-] = 6.5 \times 10^{-5}$ M

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

a) The strongest acid.

H_3P H_2S **<u>H_2Se</u>**

b) A monoprotic strong acid

$HClO_2$ HNO_2 **<u>HNO_3</u>**

c) The pH of a 0.040 M aqueous solution of barium nitrite, $Sr(NO_2)_2$, the salt of a weak acid and a strong soluble base.

pH < 7.0 pH = 7.0 **<u>pH > 7.0</u>**

d) The oxide compound expected to form a base when added to water

<u>Na_2O</u> N_2O_5 SO_2

Part 3. Problems.

1) In the presence of molecular oxygen (O_2) nitrogen monoxide and nitrogen dioxide will establish an equilibrium by the process

$$2\ NO_2(g) \leftrightarrows 2\ NO(g) + O_2(g) \qquad K_C = 2.4 \times 10^{-14}$$

A system initially has $[NO_2] = 6.1 \times 10^{-3}$ M and $[O_2] = 0.52$ M. There is initially no NO(g) in the system.

a) Give an appropriate ICE table for the above system. [8 points]

$$K_C = \frac{[NO]^2\,[O_2]}{[NO_2]^2} = 2.4 \times 10^{-14}$$

	Initial	Change	Equilibrium
NO	0	2x	2x
O_2	0.52	x	0.52 + x
NO_2	6.1×10^{-3}	– 2x	$6.1 \times 10^{-3} - 2x$

b) What is the [NO], the concentration of NO(g), when the above system reaches equilibrium. [8 points]

Based on the ICE table and the expression for K_C

$$\frac{(2x)^2\,(0.52 + x)}{(6.1 \times 10^{-3} - 2x)^2} = 2.4 \times 10^{-14} \qquad \text{Assume } x << 6.1 \times 10^{-3}$$

Then $$\frac{(4x^2)\,(0.52)}{(6.1 \times 10^{-3})^2} = 2.4 \times 10^{-14}$$

$$x^2 = (2.4 \times 10^{-14})\,\frac{(6.1 \times 10^{-3})^2}{4\,(0.52)} = 4.29 \times 10^{-19}$$

$x = (4.29 \times 10^{-19})^{1/2} = 6.55 \times 10^{-10}$ Our assumption that $x << 6.1 \times 10^{-3}$ was good

So $[NO] = 2x = 1.3 \times 10^{-9}$ M

Version 1: 1.3×10^{-9} M **Version 2: 6.3×10^{-10} M** **Version 4: 8.0×10^{-10} M**

2) Find the pH for the following

a) A 0.026 M solution of sodium hydroxide (NaOH, MW = 40.00 g/mol), a strong soluble base. [8 points]

NaOH is a strong soluble base, and reacts by the process

$NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$

Since the base is soluble and strong the reaction goes to completion.

Therefore $[OH^-] = \frac{0.026 \text{ mol NaOH}}{\text{L soln}} \frac{1 \text{ mol } OH^-}{1 \text{ mol NaOH}} = \frac{0.026 \text{ mol } OH^-}{\text{L soln}}$

$pOH = -\log_{10}[OH^-] = -\log_{10}(0.026) = 1.59$

$pH + pOH = 14.00$ and so $pH = 14.00 - pOH = 14.00 - 1.59 = 12.41$

Version 1: pH = 12.81 **Version 2: pH = 12.62** **Version 4: pH = 12.95**

b) A 3.6×10^{-2} M solution of phenol (C_6H_5OH, MW = 94.11 g/mol). Phenol is a weak monoprotic acid, with $K_a = 1.1 \times 10^{-10}$ [12 points]

C_6H_5OH is a weak monoprotic acid, so

$C_6H_5OH(aq) + H_2O(\ell) \leftrightarrows H_3O^+(aq) + C_6H_5O^-(aq)$ $K_a = \frac{[H_3O^+][C_6H_5O^-]}{[C_6H_5OH]} = 1.1 \times 10^{-10}$

Now we need the ICE table

	Initial	Change	Equilibrium
$C_6H_5O^-$	0	x	x
H_3O^+	0	x	x
C_6H_5OH	1.6×10^{-2}	– x	$3.6 \times 10^{-2} - x$

And so $\frac{(x)(x)}{(3.6 \times 10^{-2} - x)} = 1.1 \times 10^{-10}$ Assume $x << 3.6 \times 10^{-2}$

Then $\frac{x^2}{(3.6 \times 10^{-2})} = 1.1 \times 10^{-10}$ $x^2 = (1.1 \times 10^{-10})(3.6 \times 10^{-2}) = 3.96 \times 10^{-12}$

$x = (3.96 \times 10^{-12})^{1/2} = 1.99 \times 10^{-6}$ Our assumption that $x << 3.6 \times 10^{-2}$ was good

So $[H_3O^+] = 1.99 \times 10^{-6}$ M $pH = -\log_{10}[H_3O^+] = -\log_{10}(1.99 \times 10^{-6}) = 5.70$

Version 1: pH = 5.49 **Version 2: pH = 5.59** **Version 4: pH = 5.55**