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]

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

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

$1\ atm = 760\ torr = 760\ mm\ Hg$

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

$R = 8.314\ J/mol{\bullet}K$

$°C = (^5/_9)\ (°F - 32)$

$°C = K - 273.15$

$1\ atm = 1.013\ bar$

$1\ L{\bullet}atm = 101.3\ J$

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

$°F = (^9/_5)(°C) + 32$

$K = °C + 273.15$

$pV = nRT$

$p_A = X_A\ p_A°$

$\Delta T_b = K_b\ m_B$

$[B] = k\ p_B$

$\Delta T_f = K_f\ m_B$

$\Delta p_A = X_B p_A°$

$\Pi = [B]RT$

$H = U + pV$

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

$G = H - TS$

$\ln K = -\Delta G°_{rxn}/RT$

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

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

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

$pH = pK_a + \log_{10}\{[base]/[acid]\}$

GENERAL CHEMISTRY 2
THIRD HOUR EXAM
NOVEMBER 2, 2018

Name _____________Key – Version 3_____________________

Panthersoft ID ____

Signature ____

Part 1 ________________ **(20 points)**

Part 2 ________________ **(32 points)**

Part 3 ________________ **(28 points)**

TOTAL ________________ **(80 points)**

Do all of the following problems. <u>Show your work.</u>
Note: Unless otherwise stated you may assume T = 25.0 °C and aqueous solutions in the problems below.

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]

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Values for K_b for three weak bases are given below and may be useful in answering questions 1 and 2.

aniline ($C_6H_5NH_2$, K_b = 2.34 x 10^{-5}) methylamine (CH_3NH_2, K_b = 2.70 x 10^{-11}) pyridine (C_5H_5N, K_b = 5.62 x 10^{-6})
****

1) For the weak bases aniline ($C_6H_5NH_2$), methylamine (CH_3NH_2) and pyridine (C_5H_5N)

a) $C_6H_5NH_2$ is the strongest base and CH_3NH_2 is the weakest base
b) $C_6H_5NH_2$ is the strongest base and C_5H_5N is the weakest base
A c) CH_3NH_2 is the strongest base and $C_6H_5NH_2$ is the weakest base
d) CH_3NH_2 is the strongest base and C_5H_5N is the weakest base
e) C_5H_5N is the strongest base and $C_6H_5NH_2$ is the weakest base

2) For the cations $C_6H_5NH_3^+$, $CH_3NH_3^+$, and $C_5H_5NH^+$

a) $C_6H_5NH_3^+$ is the strongest acid and $CH_3NH_3^+$ is the weakest acid
b) $C_6H_5NH_3^+$ is the strongest acid and $C_5H_5NH^+$ is the weakest acid
C c) $CH_3NH_3^+$ is the strongest acid and $C_6H_5NH_3^+$ is the weakest acid
d) $CH_3NH_3^+$ is the strongest acid and $C_5H_5NH^+$ is the weakest acid
e) $C_5H_5NH^+$ is the strongest acid and $C_6H_5NH_3^+$ is the weakest acid

3) Which of the following salts will form an acidic solution when added to water?

a) the salt of a strong acid and a strong base
b) the salt of a strong acid and a weak base
B c) the salt of a weak acid and a strong base
d) both a and b
e) both a and c

4) A Lewis base is

a) an electron pair donor
b) a proton donor
A c) a proton acceptor
d) both a and b
e) both a and c

5) A small amount (1 drop, 0.1 mL) of a 0.100 M solution of sodium hydroxide (NaOH, a strong base) is added to 250.0 mL of a buffer solution with an initial pH = 5.00 After addition of the drop of sodium hydroxide solution

a) the pH of the solution will decrease by a large amount (more than 0.1 pH unit)
b) the pH of the solution will decrease by a small amount (less than 0.1 pH unit)
D c) the pH of the solution will be exactly the same as before addition of the drop of strong base solution
d) the pH of the solution will increase by a small amount (less than 0.1 pH unit)
e) the pH of the solution will increase by a large amount (more than 0.1 pH unit)

Version 1 D, B, A, A, B Version 2 C, A, B, C, E

Part 2. Short answer.

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

a) The substance expected to be the strongest acid

H_2S H_2Se HCl **<u>HBr</u>**

b) A pH where a mixture of acetic acid (CH_3COOH, $K_a = 1.8 \times 10^{-5}$) and sodium acetate ($NaCH_3COO$) could be used to make a good buffer.

<u>pH = 4.5</u> pH = 6.5 pH = 8.5 pH = 10.5

2) What is the difference (if any) between the end point and the equivalence point of a titration? [4 points]

The equivalence point in a titration is the point where sufficient titrant has been added for the neutralization reaction to be complete, with no excess acid or base. The end point of the titration is where the indicator being used to follow the reaction changes color. Indicators are chosen to make the end point as close as possible to te equivalence point.

3) Methyl red is a weak acid ($K_a = 8.1 \times 10^{-6}$) often used as an indicator in acid-base titrations. The acid form of the indicator (HInd) is red, and the base form of the indicator (Ind^-) is yellow.

a) Methyl red would be a <u>bad</u> choice as an indicator for which of the following types of titrations (circle the correct answer) [4 points]

<u>titration of a weak acid with a strong base</u> titration of a weak base with a strong acid titration of a strong acid with a strong base

b) One drop (0.1 mL) of a solution containing methyl red is added to 250.0 mL of a pH = 4.50 buffer solution. What percentage of the methyl red molecules will be in the acid (HInd) form? [8 points]

$HInd(aq) + H_2O(\ell) \leftrightarrows H_3O^+(aq) + Ind^-(aq)$ $K_{Ind} = \dfrac{[H_3O^+]\,[Ind^-]}{[Hind]}$

So $\dfrac{[Ind^-]}{[HInd]} = \dfrac{K_{Ind}}{[H_3O^+]}$ But $K_{Ind} = 8.1 \times 10^{-6}$

$[H_3O^+] = 10^{-pH} = 10^{-4.50} = 3.16 \times 10^{-5}$ M

Since the solution is a buffer, the pH can be assumed constant. So

$\dfrac{[Ind^-]}{[H_{Ind}]} = \dfrac{8.1 \times 10^{-6}}{3.16 \times 10^{-5}} = 0.256$ so $[Ind^-] = 0.256\,[HInd]$

$$\%\text{ acid form} = \frac{[HInd]}{[HInd] + [Ind^-]} \times 100\,\% = \frac{[HInd]}{[HInd] + 0.256\,[HInd]} \times 100\,\%$$

$$= \frac{1}{1 + 0.256} \times 100\,\% = 80\,\%$$

Version 1 38 % Version 2 66 %

4) A 20.00 mL sample of a stock solution of a weak monoprotic acid HA is titrated with a 0.1826 M solution of potasssium hydroxide (KOH), a strong soluble base. After the addition of 15.26 mL of the KOH solution the equivalence point of the titration is reached. What is the concentration of weak acid in the weak acid stock soution? [8 points]

Reaction is $HA(aq) + KOH(aq) \rightarrow KA(aq) + H_2O(\ell)$

moles KOH = $0.01526\ \text{L}\ \dfrac{0.1826\ \text{mol KOH}}{\text{L soln}} = 2.786 \times 10^{-3}$ mol KOH

Based on the balanced reaction, moles HA = moles KOH = 2.786×10^{-3} moles

So $[HA] = \dfrac{2.786 \times 10^{-3}\ \text{mol}}{0.02000\ \text{L}} = 0.1393$ M

Version 1 0.1564 M Version 2 0.1469 M

Part 3. Problems.

1) Propionic acid (C_3H_5COOH, $K_a = 1.32 \times 10^{-5}$) is a monoprotic weak acid

a) Give the formula for the conjugate base of propionic acid (including correct charge). [4 points]

$C_3H_5COO^-$

b) Find the pH for a 0.0758 M solution of propionic acid. [12 points]

The reaction is $C_3H_5COOH(aq) + H_2O(\ell) \leftrightarrows H_3O^+(aq) + C_3H_5COO^-(aq)$

$$K_a = \frac{[H_3O^+][C_3H_5COO^-]}{[C_3H_5COOH]} = 1.32 \times 10^{-5}$$

	Initial	Change	Equilibrium
H_3O^+	0	x	x
$C_3H_5COO^-$	0	x	x
C_3H_5COOH	0.0758	- x	0.0758 – x

$$\frac{(x)(x)}{(0.0758 - x)} = 1.32 \times 10^{-5}$$

Assume x << 0.0758 then $\dfrac{x^2}{0.0758} = 1.32 \times 10^{-5}$ $x^2 = (1.32 \times 10^{-5})(0.0758) = 1.00 \times 10^{-6}$

$x = (1.00 \times 10^{-6})^{1/2} = 1.00 \times 10^{-3}$ The assumption that x << 0.0758 is correct

So $[H_3O^+] = x = 1.00 \times 10^{-3}$ M pH = $-\log_{10}(1.00 \times 10^{-3}) = 3.00$

2) Pyruvic acid ($C_3H_4O_3$, MW = 88.1 g/mol, K_a = 3.2 x 10^{-3}) is a weak monoprotic acid, and sodium pyruvate ($NaC_3H_3O_3$, MW = 110.1 g/mol) is the sodium salt of the conjugate base of pyruvic acid.

A solution is formed by dissolving 1.418 g of pyruvic acid and 3.715 g of sodium pyruvate in water. The final volume of the solution is 500.0 mL. What is the pH of the solution that forms? [12 points]

$$\text{moles pyruvic acid} = 1.418\text{ g}\ \frac{1\text{ mol}}{88.1\text{ g}} = 1.610 \times 10^{-2}\text{ mol pyruvic acid}$$

Sodium pyruvate is a strong electrolyte and a soluble ionic compound, reaction by the process

$$NaC_3H_3O_3(s) \rightarrow Na^+(aq) + C_3H_3O_3^-(aq)$$

So moles pyruvate (the conjugate acid of pyruvic acid) = moles sodium pyrutave

$$= 3.715\text{ g}\ \frac{1\text{ mol}}{110.1\text{ g}} = 3.374 \times 10^{-2}\text{ mol pyruvate}$$

From the Henderson equation

$$pH = pK_a + \log_{10}\{[\text{base}]/\text{acid}]\}$$

Note that $\frac{[\text{base}]}{[\text{acid}]} = \frac{\text{moles base/volume}}{\text{moles acid/volume}} = \frac{\text{moles base}}{\text{moles acid}}$

Since the volume is the same for the acid and conjugate base, the ratio of concentrations is the same as the ratio of moles.

So $$pH = -\log_{10}(3.2 \times 10^{-3}) + \log_{10}\{(3.374 \times 10^{-2}\text{ mol})/(1.610 \times 10^{-2}\text{ mol})\}$$

$$= 2.495 + 0.321 = 2.82$$

Version 1 pH = 2.65 Version 2 pH = 2.17