

**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]																																								
<table border="1"> <tr> <td>57 La 138.9</td> <td>58 Ce 140.1</td> <td>59 Pr 140.9</td> <td>60 Nd 144.2</td> <td>61 Pm [145]</td> <td>62 Sm 150.4</td> <td>63 Eu 152.0</td> <td>64 Gd 157.2</td> <td>65 Tb 158.9</td> <td>66 Dy 162.5</td> <td>67 Ho 164.9</td> <td>68 Er 167.3</td> <td>69 Tm 168.9</td> <td>70 Yb 173.0</td> </tr> <tr> <td>89 Ac [227]</td> <td>90 Th 232.0</td> <td>91 Pa 231.0</td> <td>92 U 238.0</td> <td>93 Np [237]</td> <td>94 Pu [244]</td> <td>95 Am [243]</td> <td>96 Cm [247]</td> <td>97 Bk [247]</td> <td>98 Cf [251]</td> <td>99 Es [252]</td> <td>100 Fm [257]</td> <td>101 Md [258]</td> <td>102 No [259]</td> </tr> </table>																		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]
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$$N_A = 6.022 \times 10^{23}$$

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

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

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

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

$$p_A = X_A p_A^\circ$$

$$\Delta T_b = K_b m_B$$

$$H = U + pV$$

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

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

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

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

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

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

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

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

$$[B] = k p_B$$

$$\Delta T_f = K_f m_B$$

$$G = H - TS$$

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

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

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

$$pV = nRT$$

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

$$\Pi = M_B RT$$

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

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

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

**GENERAL CHEMISTRY 2  
SECOND HOUR EXAM**

**Name** \_\_\_\_\_

**Panthersoft ID** \_\_\_\_\_

**Signature** \_\_\_\_\_

**Part 1** \_\_\_\_\_ (20 points)

**Part 2** \_\_\_\_\_ (43 points)

**Part 3** \_\_\_\_\_ (37 points)

**TOTAL** \_\_\_\_\_ (100 points)

**Do all of the following problems. Show your work.**

**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 for the reaction  $A_2(g) + 2 B(g) \rightleftharpoons 2 AB(g)$  is  $K_C = 25$ . The numerical value for the equilibrium constant for the reaction  $2 AB(g) \rightleftharpoons A_2(g) + 2 B(g)$ , measured at the same temperature, is

- a)  $K_C = 0.040$
- b)  $K_C = 0.20$
- A** c)  $K_C = 5.0$
- d)  $K_C = 25$ .
- e) Cannot tell from the information given

2) Consider the following chemical reaction.



A system containing  $PCl_3$ ,  $PCl_5$ , and  $Cl_2$  at a fixed temperature is initially at equilibrium. Which of the following changes will lead to an increase in the number of moles of  $PCl_3$  in the system?

- a) Addition of 0.100 moles of  $Cl_2$  into the system
- b) Addition of 0.100 moles of  $PCl_5$  into the system
- B** c) Decreasing the volume of the system by 2.00 L
- d) Both a and c
- e) Both b and c

3) A Bronsted base is

- a) a proton acceptor
- b) a proton donor
- A** c) an electron pair acceptor
- d) an electron pair donor
- e) any ionic compound that will dissolve in water

4) Which of the following is a polyprotic acid?

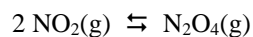
- a)  $HClO_2$
- b)  $HClO_3$
- E** c)  $HI$
- d)  $HNO_3$
- e)  $H_2SO_3$

5) 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

**Part 2. Short answer.**

1) The free energy change for the reaction

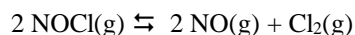


is  $\Delta G^\circ_{\text{rxn}} = -5.3 \text{ kJ/mol}$  at  $T = 25.^\circ\text{C}$ . Based on this information, find the numerical value for  $K$ , the equilibrium constant, for this reaction. [8 points]

$$\ln K = -\frac{\Delta G^\circ_{\text{rxn}}}{RT} = -\frac{(-5300. \text{ J/mol})}{(8.314 \text{ J/mol}\cdot\text{K})(298. \text{ K})} = 2.14$$

$$K = e^{2.14} = 8.5$$

2) A system containing the gases  $\text{Cl}_2$ ,  $\text{NO}$ , and  $\text{NOCl}$  will achieve equilibrium. The process that takes place is



At  $T = 500. \text{ K}$ , the partial pressures of gas present at equilibrium are  $p(\text{Cl}_2) = 0.608 \text{ atm}$ ,  $p(\text{NO}) = 0.240 \text{ atm}$ , and  $p(\text{NOCl}) = 1.36 \text{ atm}$ .

a) What is the numerical value for  $K_p$  for the above reaction at  $T = 500. \text{ K}$ ? [5 points]

$$K_p = \frac{[p(\text{NO})]^2 \cdot p(\text{Cl}_2)}{[p(\text{NOCl})]^2} = \frac{(0.240)^2 (0.608)}{(1.36)^2} = 0.0189$$

b) What is the numerical value for  $K_C$  for the above reaction at  $T = 500. \text{ K}$ ? [5 points]

$$K_p = K_C (RT)^{\Delta n} \qquad \Delta n = 3 - 2 = 1$$

$$K_C = \frac{K_p}{(RT)^{\Delta n}} = \frac{0.0189}{[(0.08206)(500.)]} = 4.6 \times 10^{-4}$$

(Note we do not include units for  $R$  or  $T$  because equilibrium constants do not have units).

3) The pH of an aqueous solution is  $\text{pH} = 8.82$  at  $T = 25\text{ }^\circ\text{C}$ . Find  $[\text{H}_3\text{O}^+]$ ,  $[\text{OH}^-]$ , and the pOH for the solution. [9 points total]

$$\text{pOH} = 14.00 - \text{pH} = 5.18$$

$$[\text{H}_3\text{O}^+] = 10^{-\text{pH}} = 10^{-8.82} = 1.5 \times 10^{-9} \text{ M}$$

$$[\text{OH}^-] = 10^{-\text{pOH}} = 10^{-5.18} = 6.6 \times 10^{-6} \text{ M}$$

4) What is the pH of a 0.0385 M aqueous solution of sodium hydroxide (NaOH), at  $T = 25\text{ }^\circ\text{C}$ ? [8 points]

The reaction is  $\text{NaOH(s)} \rightarrow \text{Na}^{\text{+}}(\text{aq}) + \text{OH}^{\text{-}}(\text{aq})$

$$[\text{OH}^-] = \frac{0.0385 \text{ mol NaOH}}{\text{L soln}} \frac{1 \text{ mol OH}^-}{1 \text{ mol NaOH}} = 0.0385 \text{ mol/L OH}^-$$

$$\text{pOH} = -\log_{10}(0.0385) = 1.41$$

$$\text{pH} = 14.00 - 1.41 = 12.59$$

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

A weak acid

HI

HBr

HCl

**HF**

A strong soluble base

AgOH

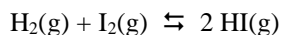
$\text{Cu}(\text{OH})_2$

**$\text{Ba}(\text{OH})_2$**

$\text{Fe}(\text{OH})_3$

### Part 3. Problems.

1) The numerical value for the equilibrium constant for the reaction



is  $K_C = 57.0$  at  $T = 700. \text{ K}$ .

The initial concentration of  $\text{H}_2$  and  $\text{I}_2$  in a system at  $T = 700. \text{ K}$  are  $[\text{H}_2] = 0.2000 \text{ mol/L}$  and  $[\text{I}_2] = 0.1000 \text{ mol/L}$ . No  $\text{HI}$  is initially present in the system. What are the concentrations of  $\text{H}_2$ ,  $\text{I}_2$ , and  $\text{HI}$  that are present when the system reaches equilibrium? [16 points]

	Initial	Change	Equilibrium
$\text{H}_2$	0.200 0	- x	0.2000 - x
$\text{I}_2$	0.1000	- x	0.1000 - x
$\text{HI}$	0.0000	2x	2x

$$K_C = \frac{[\text{HI}]^2}{[\text{H}_2][\text{I}_2]} = 57.0 = \frac{(2x)^2}{(0.2000 - x)(0.1000 - x)} = \frac{4x^2}{x^2 - 0.300x + 0.0200}$$

$$57.0x^2 - 17.1x + 1.140 = 4x^2$$

$$53.0x^2 - 17.1x + 1.140 = 0$$

Using the quadratic equation, we get

$$x = \frac{17.1 \pm [(17.1)^2 - 4(53.0)(1.140)]^{1/2}}{2(53.0)} = \frac{17.1 \pm 7.12}{106.0} = 0.2285, \underline{0.09412}$$

The underlined root is correct (the other root would give negative concentrations for  $\text{H}_2$  and  $\text{I}_2$ ) and so

$$[\text{H}_2] = 0.200 - 0.09412 = 0.1059 \text{ mol/L}$$

$$[\text{I}_2] = 0.100 - 0.09412 = 0.0059 \text{ mol/L}$$

$$[\text{HI}] = 2(0.09412) = 0.1882 \text{ mol/L}$$

As a check, if we insert these values into the expression for  $K_C$ , we get

$$K_C = \frac{(0.1882)^2}{(0.1059)(0.0059)} = 56.7, \text{ the value initially given (to within roundoff error)}$$

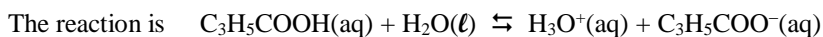
Note that if we do the calculation by assuming that  $x \ll 0.1000$ , we do not get the correct value for  $x$ . This means that the assumption that  $x \ll 0.1000$  is not correct in this problem.

2) Propionic acid ( $\text{C}_3\text{H}_5\text{COOH}$ ,  $K_a = 1.32 \times 10^{-5}$  at  $T = 25.^\circ\text{C}$ ) is a monoprotic weak acid

a) Give the formula for the conjugate base of propionic acid (including correct charge). [5 points]



b) Find the pH for a 0.0898 M aqueous solution of propionic acid at  $T = 25.^\circ\text{C}$ . [16 points]



$$K_a = \frac{[\text{H}_3\text{O}^+][\text{C}_3\text{H}_5\text{COO}^-]}{[\text{C}_3\text{H}_5\text{COOH}]} = 1.32 \times 10^{-5}$$

	Initial	Change	Equilibrium	
$\text{H}_3\text{O}^+$	0	x	x	
$\text{C}_3\text{H}_5\text{COO}^-$	0	x	x	$\frac{(x)(x)}{(0.0898 - x)} = 1.32 \times 10^{-5}$
$\text{C}_3\text{H}_5\text{COOH}$	0.0898	-x	$0.0898 - x$	

Assume  $x \ll 0.0898$  then  $\frac{x^2}{0.0898} = 1.32 \times 10^{-5}$   $x^2 = (1.32 \times 10^{-5})(0.0898) = 1.19 \times 10^{-6}$

$x = (1.19 \times 10^{-6})^{1/2} = 1.09 \times 10^{-3}$  The assumption that  $x \ll 0.0898$  is correct

So  $[\text{H}_3\text{O}^+] = x = 1.09 \times 10^{-3} \text{ M}$   $\text{pH} = -\log_{10}(1.09 \times 10^{-3}) = 2.96$