

FORMULA SHEET (tear off)

|                   |                   |                    |                    |                    |                    |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                    |                    |                    |
|-------------------|-------------------|--------------------|--------------------|--------------------|--------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|--------------------|--------------------|--------------------|
| 1A                |                   |                    |                    |                    |                    |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   | 8A                |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                    |                    |                    |
| 1<br>H<br>1.01    | 2A                |                    |                    |                    |                    |                   |                   |                   |                   |                   | 3A                |                   | 4A                | 5A                | 6A                | 7A                | 2<br>He<br>4.00   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                    |                    |                    |
| 3<br>Li<br>6.94   | 4<br>Be<br>9.01   |                    |                    |                    |                    |                   |                   |                   |                   |                   |                   | 5<br>B<br>10.81   | 6<br>C<br>12.01   | 7<br>N<br>14.01   | 8<br>O<br>16.00   | 9<br>F<br>19.00   | 10<br>Ne<br>20.18 |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                    |                    |                    |
| 11<br>Na<br>22.99 | 12<br>Mg<br>24.31 |                    |                    |                    |                    |                   |                   |                   |                   |                   |                   | 13<br>Al<br>26.98 | 14<br>Si<br>28.09 | 15<br>P<br>30.97  | 16<br>S<br>32.07  | 17<br>Cl<br>35.45 | 18<br>Ar<br>39.95 |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                    |                    |                    |
| 19<br>K<br>39.10  | 20<br>Ca<br>40.08 | 21<br>Sc<br>44.96  | 22<br>Ti<br>47.87  | 23<br>V<br>50.94   | 24<br>Cr<br>52.00  | 25<br>Mn<br>54.94 | 26<br>Fe<br>55.85 | 27<br>Co<br>58.93 | 28<br>Ni<br>58.69 | 29<br>Cu<br>63.55 | 30<br>Zn<br>65.41 | 31<br>Ga<br>69.72 | 32<br>Ge<br>72.64 | 33<br>As<br>74.92 | 34<br>Se<br>78.96 | 35<br>Br<br>79.90 | 36<br>Kr<br>83.80 |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                    |                    |                    |
| 37<br>Rb<br>85.47 | 38<br>Sr<br>87.62 | 39<br>Y<br>88.91   | 40<br>Zr<br>91.22  | 41<br>Nb<br>92.91  | 42<br>Mo<br>95.94  | [98]              | 43<br>Tc<br>[98]  | 44<br>Ru<br>101.1 | 45<br>Rh<br>102.9 | 46<br>Pd<br>106.4 | 47<br>Ag<br>107.9 | 48<br>Cd<br>112.4 | 49<br>In<br>114.8 | 50<br>Sn<br>118.7 | 51<br>Sb<br>121.8 | 52<br>Te<br>127.6 | 53<br>I<br>126.9  | 54<br>Xe<br>131.3 |                   |                   |                   |                   |                   |                   |                   |                   |                   |                    |                    |                    |
| 55<br>Cs<br>132.9 | 56<br>Ba<br>137.3 | 71<br>Lu<br>175.0  | 72<br>Hf<br>178.5  | 73<br>Ta<br>181.0  | 74<br>W<br>183.8   | 75<br>Re<br>186.2 | 76<br>Os<br>190.2 | 77<br>Ir<br>192.2 | 78<br>Pt<br>195.1 | 79<br>Au<br>197.0 | 80<br>Hg<br>200.6 | 81<br>Tl<br>204.4 | 82<br>Pb<br>207.2 | 83<br>Bi<br>209.0 | 84<br>Po<br>[209] | 85<br>At<br>[210] | 86<br>Rn<br>[222] |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                    |                    |                    |
| 87<br>Fr<br>[223] | 88<br>Ra<br>[226] | 103<br>Lr<br>[262] | 104<br>Rf<br>[261] | 105<br>Db<br>[262] | 106<br>Sg<br>[266] |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                    |                    |                    |
|                   |                   |                    |                    |                    |                    |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   | 57<br>La<br>138.9 | 58<br>Ce<br>140.1 | 59<br>Pr<br>140.9 | 60<br>Nd<br>144.2 | 61<br>Pm<br>[145] | 62<br>Sm<br>150.4 | 63<br>Eu<br>152.0 | 64<br>Gd<br>157.2 | 65<br>Tb<br>158.9 | 66<br>Dy<br>162.5 | 67<br>Ho<br>164.9 | 68<br>Er<br>167.3  | 69<br>Tm<br>168.9  | 70<br>Yb<br>173.0  |
|                   |                   |                    |                    |                    |                    |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   | 89<br>Ac<br>[227] | 90<br>Th<br>232.0 | 91<br>Pa<br>231.0 | 92<br>U<br>238.0  | 93<br>Np<br>[237] | 94<br>Pu<br>[244] | 95<br>Am<br>[243] | 96<br>Cm<br>[247] | 97<br>Bk<br>[247] | 98<br>Cf<br>[251] | 99<br>Es<br>[252] | 100<br>Fm<br>[257] | 101<br>Md<br>[258] | 102<br>No<br>[259] |

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

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

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

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

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

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

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

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

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

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

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

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

$$pV = nRT$$

$$p_A = X_A p_A^\circ$$

$$\Delta T_b = K_b m_B$$

$$[B] = k p_B$$

$$\Delta T_f = K_f m_B$$

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

$$\Pi = [B]RT$$

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

$$H = E + pV$$

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

$$G = H - TS$$

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

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

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

**GENERAL CHEMISTRY 2  
SECOND HOUR EXAM (Sample)**

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

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

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

**Part 1** \_\_\_\_\_ (24 points)

**Part 2** \_\_\_\_\_ (50 points)

**Part 3** \_\_\_\_\_ (26 points)

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

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**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  $AB(g) \rightleftharpoons \frac{1}{2} A_2(g) + B(g)$ , measured at the same temperature, is

- a)  $K_C = 0.040$
- b)  $K_C = 0.20$
- B** 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) Ammonium perchlorate ( $NH_4ClO_4$ ) is a soluble salt formed by the reaction of a strong acid with a weak base. The pH of a 0.100 M solution of ammonium perchlorate, measured at  $T = 25.^\circ C$ , is expected to be

- a) exactly equal to 7.0
- b) approximately equal to 7.0
- D** c) significantly larger than 7.0
- d) significantly smaller than 7.0
- e) undefined, because the concept of pH does not apply to solutions of salts

5) Hypoiodous acid (HOI) is a weak acid, with  $K_a = 3.5 \times 10^{-8}$  (at  $T = 25.^\circ C$ ).  $OI^-$  ion is

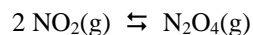
- a) a weak acid
- b) a strong acid
- C** c) a weak base
- d) a strong base
- e) None of the above, as ions have no acid or base properties

6) Which of the following is the strongest oxyacid?

- a)  $HIO_2$
- b)  $HIO_3$
- E** c)  $HBrO$
- d)  $HBrO_2$
- e)  $HBrO_3$

**Part 2. Short answer.**

1) The free energy change for the reaction

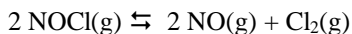


is  $\Delta G^\circ_{\text{rxn}} = -5.3 \text{ kJ/mol}$  at  $T = 25.^\circ\text{C}$ . Based on this information, find the numerical value for  $K$ , the equilibrium constant, for this reaction. [8 points]

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

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

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. [8 points]

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

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

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

4) Answer each of the following questions by filling in the blank. [4 points each]

a) The conjugate base of  $\text{HCO}_3^-$ . \_\_\_\_\_  $\text{CO}_3^{2-}$  \_\_\_\_\_

b) The value for  $K_b$  for  $\text{NO}_2^-$ , at  $T = 25\text{ }^\circ\text{C}$  \_\_\_\_\_  $2.2 \times 10^{-11}$  \_\_\_\_\_  
(Note  $K_a = 4.5 \times 10^{-4}$  for  $\text{HNO}_2$  at  $T = 25\text{ }^\circ\text{C}$ )

c) The pH of pure water at  $T = 50\text{ }^\circ\text{C}$ . \_\_\_\_\_ 6.63 \_\_\_\_\_  
(Note  $K_w = 5.5 \times 10^{-14}$  at  $T = 50\text{ }^\circ\text{C}$ )

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

The weakest acid

HI                                      HBr                                      HCl                                      **HF**

A strong soluble base

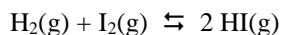
AgOH                                      Cu(OH)<sub>2</sub>                                      **Ba(OH)<sub>2</sub>**                                      Fe(OH)<sub>3</sub>

An example of a polyprotic acid

HBr                                      HF                                      HNO<sub>2</sub>                                      **H<sub>2</sub>SO<sub>4</sub>**

### 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 HI is initially present in the system. What are the concentrations of  $\text{H}_2$ ,  $\text{I}_2$ , and 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  |
| 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

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

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

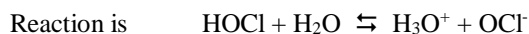
$$[\text{HI}] = 2(0.09412) = 0.1882 \text{ mol/L}$$

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) A chemist prepares 500.0 mL of a 0.0200 M aqueous solution of hypochlorous acid (HOCl,  $K_a = 3.5 \times 10^{-8}$ ). What is the pH of the above solution? [10 points]



$$K_a = \frac{[\text{H}_3\text{O}^+][\text{OCl}^-]}{[\text{HOCl}]} = 3.5 \times 10^{-8}$$

|                        | Initial | Change | Equil.     |
|------------------------|---------|--------|------------|
| HOCl                   | 0.0200  | -x     | 0.0200 - x |
| $\text{H}_3\text{O}^+$ | 0       | x      | x          |
| $\text{OCl}^-$         | 0       | x      | x          |

So  $\frac{(x)(x)}{(0.0200 - x)} = 3.5 \times 10^{-8}$  Assume  $x \ll 0.0200$ , then

$$\frac{x^2}{0.0200} = 3.5 \times 10^{-8} \quad x^2 = (0.0200)(3.5 \times 10^{-8}) = 7.0 \times 10^{-10}$$

$$x = [\text{H}_3\text{O}^+] = (7.0 \times 10^{-10})^{1/2} = 2.65 \times 10^{-5} \text{ M (Note that } x \text{ is small is a correct assumption)}$$

$$\text{pH} = -\log_{10}(2.65 \times 10^{-5}) = 4.58$$