



**GENERAL CHEMISTRY 2  
FINAL EXAM**

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

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

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

**Part 1** \_\_\_\_\_ (48 points)

**Part 2** \_\_\_\_\_ (64 points)

**Part 3** \_\_\_\_\_ (88 points)

**TOTAL** \_\_\_\_\_ (200 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) Which of the following methods for expressing concentration have no units?  
a) molality  
b) molarity  
**C** c) mole fraction  
d) Both a and b  
e) All of the above methods for expressing concentration have units
- 2) A solution is formed by adding 0.100 moles of a nonvolatile and nonionizing solute to 250.0 g of a volatile solvent. Compared to the pure solvent  
a) the boiling point of the solution will be higher than the boiling point of the pure solvent  
b) the freezing point of the solution will be higher than the freezing point of the pure solvent  
**A** c) the vapor pressure of the solution will be higher than the vapor pressure of the pure solvent  
d) Both a and b  
e) Both b and c
- 3) For a spontaneous reaction which of the following must be true?  
a)  $\Delta G_{\text{rxn}} < 0$   
b)  $\Delta S_{\text{rxn}} < 0$   
**A** c)  $\Delta S_{\text{rxn}} > 0$   
d) Both a and b  
e) Both a and c
- 4) For which of the following reactions would we expect  $\Delta S^{\circ}_{\text{rxn}}$  to be large and negative?  
a)  $\text{MgCO}_3(\text{s}) \rightarrow \text{MgO}(\text{s}) + \text{CO}_2(\text{g})$   
b)  $\text{C}_6\text{H}_6(\ell) \rightarrow \text{C}_6\text{H}_6(\text{g})$   
**C** c)  $\text{C}_3\text{H}_8(\text{g}) + 5 \text{O}_2(\text{g}) \rightarrow 3 \text{CO}_2(\text{g}) + 4 \text{H}_2\text{O}(\ell)$   
d) both a and b  
e) both a and c
- 5) Consider the reaction
- $$\text{I}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons 2 \text{ICl}(\text{g})$$
- A system containing  $\text{I}_2$ ,  $\text{Cl}_2$ , and  $\text{ICl}$  is initially at equilibrium at some temperature  $T$ . The volume of the system is decreased to half of its initial value while keeping temperature constant. Which of the following will occur as the system re-establishes equilibrium?  
a) The moles of  $\text{I}_2$  in the system will increase  
b) The moles of  $\text{Cl}_2$  in the system will increase  
**E** c) The moles of  $\text{ICl}$  in the system will increase  
d) Both a and b  
e) None of the above
- 6) Benzoic acid ( $\text{C}_6\text{H}_5\text{COOH}$ ) is a weak acid, with  $K_a = 6.5 \times 10^{-5}$  (at  $T = 25.^\circ\text{C}$ ). The  $\text{C}_6\text{H}_5\text{COO}^-$  ion is  
a) a strong acid  
b) a weak acid  
**D** c) a strong base  
d) a weak base  
e) None of the above, as ions have no acid or base properties

7) A Bronsted acid is

- a) a proton acceptor
- b) a proton donor
- B** c) an electron pair acceptor
- d) an electron pair donor
- e) both b and c

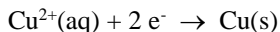
8) Consider the following three substances: HBr, H<sub>2</sub>S, and H<sub>2</sub>Se. Of these substances

- a) HBr is the strongest acid and H<sub>2</sub>S is the weakest acid
- b) HBr is the strongest acid and H<sub>2</sub>Se is the weakest acid
- A** c) H<sub>2</sub>S is the strongest acid and HBr is the weakest acid
- d) H<sub>2</sub>Se is the strongest acid and HBr is the weakest acid
- e) H<sub>2</sub>Se is the strongest acid and H<sub>2</sub>S is the weakest acid

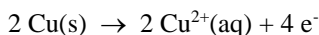
9) Which of the following aqueous solutions will be a buffer solution?

- a) A solution containing 0.100 M HBr (an acid) and 0.050 M NaBr.
- b) A solution containing 0.100 M HNO<sub>2</sub> (an acid) and 0.050 M NaNO<sub>2</sub>.
- E** c) A solution containing 0.100 M HNO<sub>2</sub> (an acid) and 0.050 M NaOH.
- d) Both a and b
- e) Both b and c

10) The standard reduction potential for the process



is  $E^{\circ} = + 0.34 \text{ v}$ . Based on this, we can say that the half-cell oxidation potential for the process



is

- a)  $E^{\circ} = + 0.68 \text{ v}$
- b)  $E^{\circ} = + 0.34 \text{ v}$
- D** c)  $E^{\circ} = 0.00 \text{ v}$
- d)  $E^{\circ} = - 0.34 \text{ v}$
- e)  $E^{\circ} = - 0.68 \text{ v}$

11) A chemical reaction obeys the rate law

$$\text{rate} = k [\text{A}] [\text{B}]^2$$

The overall order of the reaction is

- a) first order
- b) second order
- C** c) third order
- d) both a and b
- e) both a and b and c

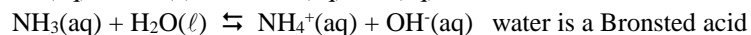
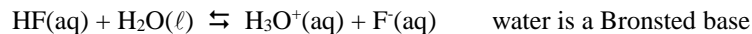
12) A catalyst

- a) changes the rate of reaction and also changes the equilibrium constant for a reaction
- b) changes the rate of reaction but does not change the equilibrium constant for a reaction
- B** c) does not change the rate of reaction but changes the equilibrium constant for a reaction
- d) does not change the rate of reaction and also does not change the equilibrium constant for a reaction
- e) cannot be present in a system at equilibrium

**Part 2. Short answer.**

1) Define the following terms [6 points each]

a) amphoteric – A substance that can act as either a Bronsted acid or a Bronsted base in an acid/base reaction. Example:



b) catalyst – A substance that when added to a system speeds up a chemical reaction without itself being produced or consumed. Enzymes are one example of biological catalysts.

2) 0.45 g of a nonvolatile pure chemical substance (a polymer) are dissolved in liquid benzene ( $\text{C}_6\text{H}_6$ , MW = 78.1 g/mol), to form a solution with final volume  $V = 200.0$  mL. The osmotic pressure of the solution, measured at  $T = 20.0$  °C, was 33.2 torr. Based on this information find the molecular weight of the polymer. [10 points]

$$\Pi = [\text{B}]RT \quad [\text{B}] = \frac{\Pi}{RT} = \frac{33.2 \text{ torr (1 atm/760 torr)}}{(0.08206 \text{ L}\cdot\text{atm/mol}\cdot\text{K})(293. \text{ K})} = 1.82 \times 10^{-3} \text{ mol/L}$$

$$\# \text{ moles} = (0.2000 \text{ L}) (1.82 \times 10^{-3} \text{ mol/L}) = 3.63 \times 10^{-4} \text{ mol}$$

$$\text{MW} = \frac{\text{mass}}{\text{moles}} = \frac{0.45 \text{ g}}{3.63 \times 10^{-4} \text{ mol}} = 1240. \text{ g/mol}$$

3) 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 with  $\Delta G^\circ_f = 0.0$  kJ/mol at  $T = 25.$  °C



b) The acid that is a polyprotic acid



c) The hydroxide compound that is a strong soluble base



d) The best indicator to use in the titration of a strong acid by a strong base



4) Equilibrium between sulfur oxides in the presence of molecular oxygen is difficult to study experimentally. Consider the following reaction



a) Give the expression for  $K_C$ , the equilibrium constant, in terms of reactant and product concentrations. [4 points]

$$K_C = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2 [\text{O}_2]}$$

b) For a particular system the initial concentrations of  $\text{SO}_3$  and  $\text{O}_2$  are both 0.0400 mol/L. No  $\text{SO}_2$  is initially present. Find the value for  $[\text{SO}_2]$ , the concentration of  $\text{SO}_2$ , when equilibrium is reached. [10 points]

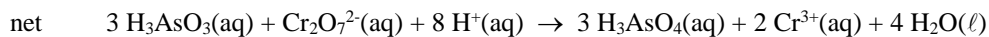
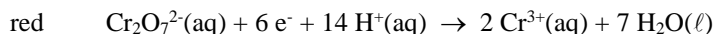
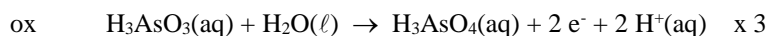
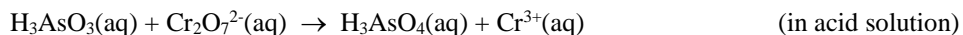
	Initial	Change	Equilibrium
$\text{SO}_2$	0.0000	2x	2x
$\text{O}_2$	0.0400	x	0.0400 + x
$\text{SO}_3$	0.0400	- 2x	0.0400 - 2x

So  $\frac{(0.0400 - 2x)^2}{(2x)^2 (0.0400 + x)} = 1.9 \times 10^{26}$  If we assume  $x \ll 0.0400$ , then

$$\frac{(0.0400)^2}{(4x^2)(0.0400)} = 1.9 \times 10^{26} \quad x^2 = 5.26 \times 10^{-29} \quad x = 7.25 \times 10^{-15}$$

So at equilibrium,  $[\text{SO}_2] = 2(7.25 \times 10^{-15}) = 1.45 \times 10^{-14}$  mol/L

5) Balance the following oxidation-reduction reaction for the indicated condition. [12 points each]

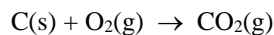


### Part 3. Problems.

1) Thermochemical data (at  $T = 25. \text{ }^\circ\text{C}$ ) for several substances is given below, and may be of use in doing the following problems, which also take place at  $T = 25. \text{ }^\circ\text{C}$ .

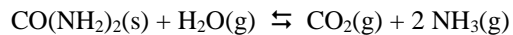
Substance	$\Delta H^\circ_f$ (kJ/mol)	$\Delta G^\circ_f$ (kJ/mol)	$S^\circ$ (J/mol·K)
C(s)	0.00	0.00	5.74
CO <sub>2</sub> (g)	- 393.51	- 394.36	213.74
CO(NH <sub>2</sub> ) <sub>2</sub> (s)	- 333.51	- 197.33	104.60
H <sub>2</sub> O(g)	- 241.82	- 228.57	188.83
NH <sub>3</sub> (g)	- 46.11	- 16.45	192.45
O <sub>2</sub> (g)	0.00	0.00	205.14

a) What is the value for  $\Delta S^\circ_{\text{rxn}}$  for the reaction [8 points]



$$\begin{aligned}\Delta S^\circ_{\text{rxn}} &= [ S^\circ(\text{CO}_2(\text{g})) ] - [ S^\circ(\text{C(s)}) + S^\circ(\text{O}_2(\text{g})) ] \\ &= [ 213.74 ] - [ (5.74) + (205.14) ] = 2.86 \text{ J/mol}\cdot\text{K}\end{aligned}$$

b) What are the values for  $\Delta G^\circ_{\text{rxn}}$  and K for the reaction [16 points]



$$\begin{aligned}\Delta G^\circ_{\text{rxn}} &= [ \Delta G^\circ_f(\text{CO}_2(\text{g})) + 2 \Delta G^\circ_f(\text{NH}_3(\text{g})) ] - [ \Delta G^\circ_f(\text{CO(NH}_2)_2(\text{s})) + \Delta G^\circ_f(\text{H}_2\text{O(g})) ] \\ &= [ (- 394.36) + 2 (- 16.45) ] - [ (- 197.33) + (- 228.57) ] = - 1.36 \text{ kJ/mol}\end{aligned}$$

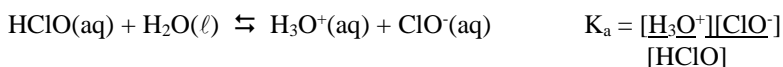
$$\ln K = - \frac{\Delta G^\circ_{\text{rxn}}}{RT} = - \frac{(- 1360. \text{ J/mol})}{(8.314 \text{ J/mol}\cdot\text{K})(298. \text{ K})} = 0.55$$

$$K = e^{0.55} = 1.73$$

2) Titration is a common method for finding the concentration of stock solutions of acids or bases. The following problem concerns a titration carried out at  $T = 25.^\circ\text{C}$ .

A student titrates a 25.00 mL sample of a 0.1814 M solution of hypochlorous acid ( $\text{HClO}$ ,  $K_a = 2.9 \times 10^{-8}$ ) with a stock solution of sodium hydroxide ( $\text{KOH}$ ), a strong soluble base.

a) What is the initial pH of the sample  $\text{HClO}$  solution? [8 points]



	Initial	Change	Equilibrium		
$\text{H}_3\text{O}^+$	0	x	x	$\frac{(x)(x)}{(0.1814 - x)}$	$= 2.9 \times 10^{-8}$ If we assume $x \ll 0.1814$
$\text{ClO}^-$	0	x	x		
$\text{HClO}$	0.1814	-x	0.1814 - x		

$$x^2 = (0.1814)(2.9 \times 10^{-8}) = 5.26 \times 10^{-9} \quad x = (5.26 \times 10^{-9})^{1/2} = 7.25 \times 10^{-5}$$

$$\text{pH} = -\log_{10}(7.25 \times 10^{-5}) = 4.14$$

b) After 38.17 mL of sodium hydroxide solution is added the equivalence point for the titration is reached. Based on this result, what is the concentration of the sodium hydroxide stock solution? [8 points]



Since equal amounts of acid and base react, then at equivalence point moles acid = moles base

$$\text{moles acid} = \text{moles base, and so } M_{\text{acid}} V_{\text{acid}} = M_{\text{base}} V_{\text{base}}$$

$$M_{\text{base}} = M_{\text{acid}} (V_{\text{acid}}/V_{\text{base}}) = (0.1814 \text{ M}) (25.00/38.17) = 0.1188 \text{ M}$$

c) In the above titration, what is the pH at the equivalence point (when 25.00 mL of stock  $\text{HClO}$  solution has been mixed with 38.17 mL of stock  $\text{NaOH}$  solution)? [12 points]

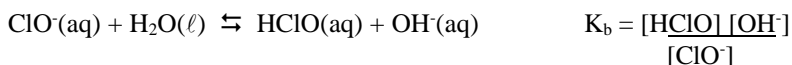
$$\text{The volume at this point is } V = 25.00 \text{ mL} + 38.17 \text{ mL} = 63.17 \text{ mL}$$

At this point, all the weak acid has been converted into weak base. So this is finding the pH of a weak base solution.

$$\text{The moles of } \text{ClO}^- \text{ is } n = (0.1188 \text{ M}) (0.03817 \text{ L}) = 4.54 \times 10^{-3} \text{ mol}$$

$$\text{The initial } \text{ClO}^- \text{ concentration is } [\text{ClO}^-] = (4.54 \times 10^{-3} \text{ mol})/(0.06317 \text{ L}) = 0.0718 \text{ M}$$

$$K_b = 1.0 \times 10^{-14}/K_a = (1.0 \times 10^{-14})/(2.9 \times 10^{-8}) = 3.45 \times 10^{-7}$$

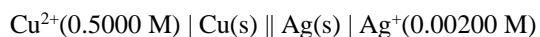


	Initial	Change	Equilibrium		
$\text{HClO}$	0	x	x	$\frac{(x)(x)}{(0.0718 - x)}$	$= 3.45 \times 10^{-7}$ If we assume $x \ll 0.0718$
$\text{OH}^-$	0	x	x		
$\text{ClO}^-$	0.0718	-x	0.0718 - x		

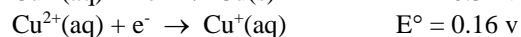
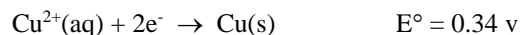
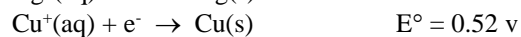
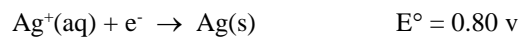
$$x^2 = (0.0718)(3.45 \times 10^{-7}) = 2.48 \times 10^{-8} \quad x = 1.57 \times 10^{-4} \quad \text{pOH} = 3.80 \quad \text{pH} = 10.20$$



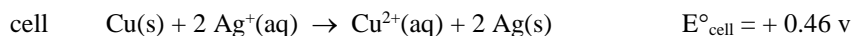
3) Consider the following galvanic cell (at T = 25. °C)



Find the following. You may need to use some of the reduction data given below in doing part of this problem



a) The half cell oxidation reaction, the half cell reduction, and the net cell reaction [5 points]



b)  $E^{\circ}_{\text{cell}}$  [5 points]

$$E^{\circ}_{\text{cell}} = 0.46 \text{ v (see above)}$$

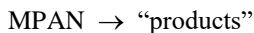
c)  $E_{\text{cell}}$  [6 points]

From Nernst

$$E_{\text{cell}} = E^{\circ}_{\text{cell}} - (RT/nF) \ln(Q) \quad Q = \frac{[\text{Cu}^{2+}]}{[\text{Ag}^{+}]^2} = \frac{(0.5000)}{(0.00200)^2} = 1.25 \times 10^5$$

$$E_{\text{cell}} = (0.46 \text{ v}) - \frac{(8.314 \text{ J/mol K})(298. \text{ K})}{(2)(96485 \text{ C/mol})} \ln(1.25 \times 10^5) = 0.31 \text{ v}$$

4) MPAN (peroxymethacryloyl nitrate) is one of a family of related compounds that are atmospheric pollutants. The reaction, given below, is for most conditions an irreversible first order reaction



The rate constant for the reaction is  $k = 5.6 \times 10^{-6} \text{ s}^{-1}$  at  $T = 0.0 \text{ }^\circ\text{C}$ , and  $k = 1.2 \times 10^{-2} \text{ s}^{-1}$  at  $T = 50.0 \text{ }^\circ\text{C}$

Find the following

a) The value for  $t_{1/2}$  for MPAN at  $T = 0.0 \text{ }^\circ\text{C}$ . [5 points]

$$t_{1/2} = \frac{\ln(2)}{(5.6 \times 10^{-6} \text{ s}^{-1})} = 1.24 \times 10^5 \text{ s}$$

b) The value for A and  $E_a$ , the Arrhenius parameters, for the above reaction (including correct units) [15 points]

$$\ln(k_2/k_1) = - (E_a/R) \{ (1/T_2) - (1/T_1) \}$$

$$E_a = - \frac{R \ln(k_2/k_1)}{\{ (1/T_2) - (1/T_1) \}} = - \frac{(8.314 \text{ J/mol}\cdot\text{K}) \ln(1.2 \times 10^{-2}/5.6 \times 10^{-6})}{\{ (1/323. \text{ K}) - (1/273 \text{ K}) \}} = 112.5 \text{ kJ/mol}$$

We may use the rate constant at  $0.0 \text{ }^\circ\text{C}$  to find A

$$k = A \exp(-E_a/RT)$$

$$\begin{aligned} A &= k \exp(E_a/RT) = (5.6 \times 10^{-6} \text{ s}^{-1}) \exp[(112500. \text{ J/mol})/(8.314 \text{ J/mol}\cdot\text{K})(273. \text{ K})] \\ &= (5.6 \times 10^{-6} \text{ s}^{-1}) e^{49.57} = 1.9 \times 10^{16} \text{ s}^{-1} \end{aligned}$$