

Chemistry 112, Fall 2006, Section 1 (Garman and Heuck)  
Final Exam A (100 points)  
19 Dec 2006

Name: KEY A

**YOU MUST:**

Put your **name** and **student ID** on the bubble sheet correctly.

Put the exam version on the bubble sheet on the upper left side above the word "NAME". **This is Final Exam A.**

Put **all** your answers on the bubble sheet.

**Please sign the statement on the last page of the exam.**

Please make sure your exam has **9 pages** (plus this one and 3 reference pages at the back).

Please keep your eyes on your own paper and your answers covered.

Use the exam as scratch paper. We will not grade anything on the exam itself.

Turn in both the exam and bubble sheet when you are done. **Good luck!**

- 1) (4 points) If a person records a blood alcohol level of 0.0133 M (or 0.08% by volume), what was the person's blood alcohol level 2.5 hours before this measurement? The zero order rate constant for the oxidation of ethanol in the liver is 0.00425 M/hour.

- A) 0.00268 M (= 0.0161% by volume)  
B) 0.0106 M (= 0.0638% by volume)  
C) 0.0134 M (= 0.0806% by volume)  
D) 0.0216 M (= 0.130% by volume)  
**E) 0.0239 M (= 0.144% by volume)**

$$A_0 - A = kt$$

$$A_0 = kt + A$$

$$= (0.00425 \text{ M/hr}) (2.5 \text{ hr}) + 0.0133 \text{ M}$$

$$= 0.0239 \text{ M}$$

- 2) (4 points) How much  $N_2$  gas dissolves in the tissues of a diver who experiences 5.00 atm (=3800 mm Hg) of  $N_2$  pressure during a dive? Assume the diver has 50L of fluid in her tissues.

- A) 0.00320 g  
B) 0.00589 g  
C) 0.0896 g  
D) 0.160 g  
**E) 4.48 g**

$$S_g = k_H A_g$$

$$= (8.42 \times 10^{-7} \text{ M/mm Hg}) (3800 \text{ mm Hg})$$

$$= 0.00320 \text{ M}$$

$$= 0.00320 \frac{\text{mole } N_2}{L} \times 50 L \times \frac{28.0 \text{ g } N_2}{\text{mole } N_2} = 4.48 \text{ g}$$

- 3) (4 points) What is the boiling point of an ideal solution where 100g of  $MgCl_2$  is dissolved in 0.250 kg of water, and the final volume of the solution is 265ml?

- A) 6.45°C  
B) 102.03°C  
C) 102.15°C  
D) 106.09°C  
**E) 106.45°C**

$$\Delta T = k \cdot m \cdot i$$

$$= (+0.512^\circ \text{C/m}) (4.20 \text{ m}) (3)$$

$$= 6.45^\circ \text{C}$$

$$BP_{\text{soln}} = 100^\circ \text{C} + \Delta T$$

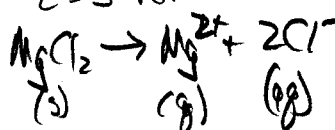
$$= 106.45^\circ \text{C}$$

$$m = \frac{\text{moles}}{\text{kg } H_2O}$$

$$= \frac{1.05 \text{ moles } MgCl_2}{0.250 \text{ kg } H_2O}$$

$$= 4.20 \text{ m}$$

$$i = 3 \text{ for}$$



$$\frac{Mg}{2 \times Cl} = \frac{24.31}{70.90}$$

$$MgCl_2 = 95.21 \text{ g/mole}$$

$$100 \text{ g } MgCl_2 \times \frac{1 \text{ mole}}{95.21 \text{ g}}$$

$$= 1.05 \text{ moles } MgCl_2$$

- 4) (4 points) Ethylene glycol ( $\text{HOCH}_2\text{CH}_2\text{OH}$ , molecular weight 62.1 g/mole) is a non-electrolyte commonly used in automobile radiators to prevent overheating. If 50.0 g of ethylene glycol is added to 50.0 g of water, what is the vapor pressure of the resulting solution at  $100^\circ\text{C}$ ?

- A) 0.225 mm Hg  
B) 0.775 mm Hg  
C) 171 mm Hg  
☒ D) 589 mm Hg  
E) None of the above

$$P_A = X_A P_A^\circ \quad X_{\text{H}_2\text{O}} = \frac{\text{moles H}_2\text{O}}{\text{moles H}_2\text{O} + \text{moles EG}}$$

$$= (0.775)(760 \text{ mm Hg}) = \frac{2.78}{2.78 + 0.805} = 589 \text{ mm Hg}$$

$$\text{moles H}_2\text{O} = 50 \text{ g} \times \frac{1 \text{ mole}}{18.0 \text{ g}} = 2.78 \text{ moles}$$

$$\text{moles EG} = 50 \text{ g} \times \frac{1 \text{ mole}}{62.1 \text{ g}} = 0.805 \text{ moles}$$

- 5) (4 points) Radioactive iodine,  $^{125}\text{I}$ , is used to diagnose and cure thyroid problems in people. The half life for the first order radioactive decay of  $^{125}\text{I}$  is 63 days. If you ingest 0.200 g of  $^{125}\text{I}$ , how long will it take for the amount of  $^{125}\text{I}$  to decay to 0.020 g?

- A) 63 days  
B) 189 days  
☒ C) 209 days  
D) 252 days  
E) 4090 days

$$\ln \frac{N}{N_0} = -kt$$

$$t = \frac{\ln \frac{N}{N_0}}{-k} = \frac{\ln \left( \frac{0.020}{0.200} \right)}{-0.011 \text{ day}^{-1}} = 209 \text{ days}$$

$$t_{1/2} = \frac{0.693}{k}$$

$$k = \frac{0.693}{t_{1/2}} = \frac{0.693}{63 \text{ d}} = 0.011 \text{ day}^{-1}$$

- 6) (3 points) Which of the following plots do you expect to be linear for the first order reaction for the decomposition of  $\text{SO}_2\text{Cl}_2$  according to the reaction:



- A)  $[\text{SO}_2\text{Cl}_2]$  vs. time  
☒ B)  $\ln [\text{SO}_2\text{Cl}_2]$  vs. time  
C)  $1/[\text{SO}_2\text{Cl}_2]$  vs. time  
D)  $[\text{SO}_2\text{Cl}_2]$  vs. temperature  
E)  $\ln [\text{SO}_2\text{Cl}_2]$  vs. temperature

0 order: linear in  $[\text{SO}_2\text{Cl}_2]$  v. time  
→ 1st order: linear in  $\ln [\text{SO}_2\text{Cl}_2]$  v. time  
2nd order: linear in  $1/[\text{SO}_2\text{Cl}_2]$  v. time

The next two problems refer to the following data, collected for the reaction of nitrogen and hydrogen to make ammonia:

Experiment	$[N_2]$	$[H_2]$	initial rate of appearance of $NH_3$
1	0.030 M	0.010 M	$4.21 \times 10^{-5}$ M/min
2	0.060 M	0.010 M	$1.68 \times 10^{-4}$ M/min
3	0.030 M	0.020 M	$3.37 \times 10^{-4}$ M/min

doubling  $[N_2]$  increases  
rate 4x, so  
rate  $\propto [N_2]^2$

doubling  $[H_2]$  increases  
rate 8x, so  
rate  $\propto [H_2]^3$

7) (4 points) From the above data, the rate equation for this reaction is:

- A) rate =  $k[N_2][H_2]^2$   
B) rate =  $k[N_2][H_2]^3$   
C) rate =  $k[N_2]^2[H_2]$   
D) rate =  $k[N_2]^2[H_2]^2$   
E) rate =  $k[N_2]^2[H_2]^3$

$$\text{rate} = k [N_2]^2 [H_2]^3$$

8) (3 points) From the above data, the rate constant for this reaction is:

- A)  $k = 4.68 \text{ M}^{-2} \text{ min}^{-1}$   
B)  $k = 14.0 \text{ M}^{-2} \text{ min}^{-1}$   
C)  $k = 4.68 \times 10^2 \text{ M}^{-3} \text{ min}^{-1}$   
D)  $k = 1.40 \times 10^3 \text{ M}^{-3} \text{ min}^{-1}$   
E)  $k = 4.68 \times 10^4 \text{ M}^{-4} \text{ min}^{-1}$

$$k = \frac{\text{rate}}{[N_2]^2 [H_2]^3} = \frac{4.21 \times 10^{-5} \text{ M/min}}{[0.030 \text{ M}]^2 [0.010 \text{ M}]^3} = 4.68 \times 10^4 \text{ M}^{-4} \text{ min}^{-1}$$

9) (5 points) What is the activation energy for a reaction if the rate constant  $k$  goes from  $2.00 \times 10^1$  to  $1.60 \times 10^2$  when the temperature is raised from 400K to 800K?

- A)  $4.32 \times 10^{-5} \text{ kJ/mol}$   
B)  $5.32 \times 10^{-2} \text{ kJ/mol}$   
C)  $0.137 \text{ kJ/mol}$   
D)  $13.8 \text{ kJ/mol}$   
E) None of the above

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

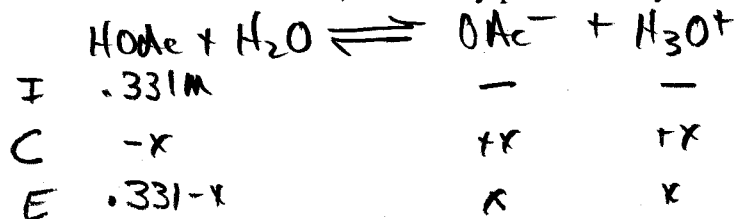
$$E_a = \frac{-R \ln \frac{k_2}{k_1}}{\frac{1}{T_2} - \frac{1}{T_1}} = \frac{-(8.31 \text{ J/mol K}) \left( \ln \frac{160}{20} \right)}{\frac{1}{800 \text{ K}} - \frac{1}{400 \text{ K}}} = 13824 \text{ J/mol} = 13.8 \text{ kJ/mol}$$

The next four problems refer to the following titration: A 24.8 mL sample of a 0.331 M aqueous acetic acid (HAcO) solution is titrated with a 0.415 M aqueous potassium hydroxide solution.

$$K_a (\text{acetic acid}) = 1.8 \times 10^{-5}$$

10) (5 points) What is the pH at the start of the titration, before any potassium hydroxide (KOH) has been added?

- A) 9.0
- ☒ B) 2.6
- C) 11.4
- D) 4.7
- E) cannot tell



$$K_a = \frac{[\text{OAc}^-][\text{H}_3\text{O}^+]}{[\text{HAcO}]} = \frac{(x)(x)}{(.331-x)} = 1.8 \times 10^{-5}$$

$$x^2 = 5.96 \times 10^{-6}$$

$$x = 2.44 \times 10^{-3} = [\text{H}_3\text{O}^+]$$

$$\text{pH} = -\log [\text{H}_3\text{O}^+] = 2.6$$

11) (5 points) What is the pH at the half-point of the titration?

- A) 9.0
- B) 2.6
- C) 11.4
- ☒ D) 4.7
- E) cannot tell

At the midpoint of a titration,  $\text{pH} = \text{pK}_a$

$$\begin{aligned} \text{pK}_a &= -\log K_a \\ &= -\log 1.8 \times 10^{-5} \\ &= 4.7 \end{aligned}$$

12) (3 points) What is the concentration of potassium ions ( $\text{K}^+$ ) at the equivalence point?

- A) 0.194 M
- B) 0.174 M
- ☒ C) 0.184 M
- D) cannot tell

$$24.8 \text{ mL} = 0.0248 \text{ L}$$

$$0.0248 \text{ L} \times \frac{0.331 \text{ moles}}{\text{L}} = 0.00821 \text{ moles acid}$$

$$\begin{aligned} \text{At equivalence, moles KOH added} &= \text{moles acid} \\ &= 0.00821 \text{ moles} \end{aligned}$$

$$\text{Volume base added} = \frac{0.00821 \text{ moles}}{0.415 \text{ moles/L}} = 0.0198 \text{ L}$$

$$\begin{aligned} \text{Total volume} &= \text{volume acid} + \text{volume base added} \\ &= 0.0248 \text{ L} + 0.0198 \text{ L} \\ &= 0.0446 \text{ L} \end{aligned}$$

$$[\text{K}^+] = \frac{\text{moles}}{\text{L}} = \frac{0.00821 \text{ moles}}{0.0446 \text{ L}} = 0.184 \text{ M}$$

(continued from previous page)

13) (3 points) What is the pH at the equivalence point?  $K_b(\text{acetate}, \text{AcO}^-) = 5.56 \times 10^{-10}$

- ☒ A) 9.0
- ☐ B) 2.6
- ☐ C) 11.4
- ☐ D) 4.7
- ☐ E) cannot tell

At equivalence, all of the HOAc has been neutralized by KOH



I 0.184M

C -x

E 0.184-x

	+	+
x	x	x

$$K_b = \frac{[\text{HOAc}][\text{OH}^-]}{[\text{OAc}^-]} = \frac{(x)(x)}{0.184-x} = 5.56 \times 10^{-10}$$

$$\begin{aligned} \text{pOH} &= -\log [\text{OH}^-] \\ &= -\log 1.01 \times 10^{-5} \\ &= 4.99 \end{aligned}$$

$$14 - \text{pOH} = \text{pH} = 9.01$$

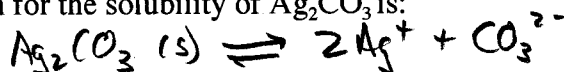
$$\begin{aligned} &= \frac{x^2}{0.184} = 5.56 \times 10^{-10} \\ x^2 &= 1.02 \times 10^{-10} \\ x &= 1.01 \times 10^{-5} = [\text{OH}^-] \end{aligned}$$

14) (3 points) For one mole at 298 K, which of the following compounds will have the higher entropy?

- ☐ A)  $\text{CH}_4$
- ☐ B)  $\text{CH}_3\text{CH}_3$
- ☐ C)  $\text{CH}_3\text{CH}_2\text{CH}_3$
- ☒ D)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$
- ☐ E) cannot tell

15) (3 points) The equilibrium constant expression for the solubility of  $\text{Ag}_2\text{CO}_3$  is:

- ☐ A)  $K_{sp} = 2[\text{Ag}^+][\text{CO}_3^{2-}]$
- ☐ B)  $K_{sp} = [\text{Ag}^+]^3[\text{CO}_3^{2-}]^2$
- ☒ C)  $K_{sp} = [\text{Ag}^+]^2[\text{CO}_3^{2-}]$
- ☐ D)  $K_{sp} = [\text{Ag}^+][\text{CO}_3^{2-}]/[\text{Ag}_2\text{CO}_3]$
- ☐ E) none of the above



$$K_{sp} = [\text{Ag}^+]^2[\text{CO}_3^{2-}]$$

16) (3 points) For a reversible reaction at the equilibrium

- ☐ A) The concentration of reactants equals the concentration of products.
- ☒ B) The forward and reverse reactions still occur.
- ☐ C) The rates of the forward and reverse reactions are equal to zero.
- ☐ D) The concentrations of products is always higher than the concentrations of reactants
- ☐ E) None of the above.

17) (3 points) In the following reaction



- ☐ A)  $\text{HPO}_4^{2-}$  is an acid and  $\text{H}_2\text{O}$  is its conjugate base.
- ☒ B)  $\text{HPO}_4^{2-}$  is an acid and  $\text{PO}_4^{3-}$  is its conjugate base.
- ☐ C)  $\text{H}_3\text{O}^+$  is an acid and  $\text{HPO}_4^{2-}$  is its conjugate base.
- ☐ D)  $\text{H}_2\text{O}$  is an acid and  $\text{PO}_4^{3-}$  is its conjugate base.
- ☐ E)  $\text{H}_3\text{O}^+$  is an acid and  $\text{PO}_4^{3-}$  is its conjugate base.

18) (3 points) If  $Q > K$  for the following reaction  $2A + B \rightleftharpoons 3C$ , in order to reach equilibrium

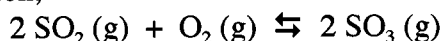
- A) more C will be produced
- ☒ B) more A will be produced
- C) the concentration of A will decrease by 1/2
- D) the concentration of B will decrease by 3/2
- E) none of the above

$Q > K$  means reaction will shift to the left to reach equilibrium

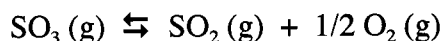
19) (3 points) For the titration of a monoprotic acid with a strong base, which of the following statements is always true?

- A) The pH at the equivalence point is equal to 7.0
- B) The pH at the equivalence point depends on the initial concentration of acid
- C) The pH at the equivalence point is lower than pH at the half point of the titration
- ☒ D) The pH at the equivalence point is higher than pH at the half point of the titration
- E) None of the above

20) (6 points) For the following reaction,



the equilibrium constant,  $K_p$ , is 0.758 at 627 °C. What is the equilibrium constant at 627 °C for the reaction below?



- A) 0.660
- B) 0.871
- ☒ C) 1.15
- D) 1.32
- E) none of the above

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

$$\sqrt{K_p} = \sqrt{\frac{[\text{SO}_3]^2}{[\text{SO}_2]^2 [\text{O}_2]}} = \frac{[\text{SO}_3]}{[\text{SO}_2] [\text{O}_2]^{1/2}}$$

$$\frac{1}{\sqrt{K_p}} = \frac{[\text{SO}_2] [\text{O}_2]^{1/2}}{[\text{SO}_3]} = K \text{ for 2nd reaction}$$

$$\frac{1}{\sqrt{K_p}} = \frac{1}{\sqrt{0.758}} = 1.15$$

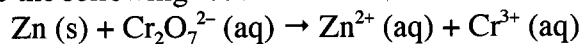
Without doing any calculations, match the following thermodynamic properties with their appropriate numerical sign for the following exothermic reaction.



- 21) (3 points)  $\Delta H_{\text{rxn}}$  **B**                      A)  $> 0$   
 22) (3 points)  $\Delta S_{\text{rxn}}$  **A**                      B)  $< 0$   
 23) (2 points)  $\Delta G_{\text{rxn}}$  **B**                      C)  $> 0$  low T,  $< 0$  high T  
 24) (2 points)  $\Delta S_{\text{universe}}$  **A**                      D)  $< 0$  low T,  $> 0$  high T

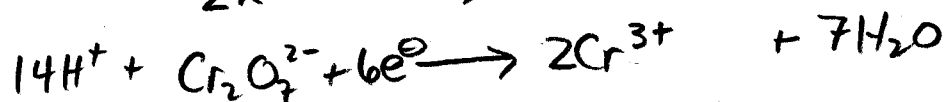
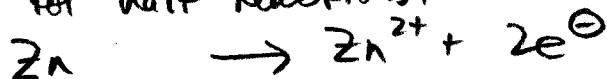
- exothermic;  $\Delta H$  is  $\ominus$
- 9 moles  $\rightarrow$  10 moles means  $\Delta S$  is  $\oplus$
- if  $\Delta H$  is  $\ominus$  and  $\Delta S$  is  $\oplus$   $\Delta G$  will be  $\ominus$  at all temperatures
- $\Delta S_{\text{univ}}$  is  $\oplus$  for spontaneous reactions

25) (6 points) Balance the following redox reaction in a basic solution:

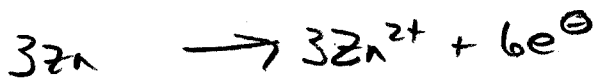


- A)  $14\text{H}^+ + \text{Zn} + \text{Cr}_2\text{O}_7^{2-} \rightarrow \text{Zn}^{2+} + 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$   
 B)  $14\text{H}^+ + 3\text{Zn} + \text{Cr}_2\text{O}_7^{2-} \rightarrow 3\text{Zn}^{2+} + 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$   
 C)  $7\text{H}_2\text{O} + \text{Zn} + \text{Cr}_2\text{O}_7^{2-} \rightarrow \text{Zn}^{2+} + 2\text{Cr}^{3+} + 14\text{OH}^-$   
 D)  $7\text{H}_2\text{O} + 3\text{Zn} + \text{Cr}_2\text{O}_7^{2-} \rightarrow 3\text{Zn}^{2+} + \text{Cr}^{3+} + 14\text{OH}^-$   
 E)  $7\text{H}_2\text{O} + 3\text{Zn} + \text{Cr}_2\text{O}_7^{2-} \rightarrow 3\text{Zn}^{2+} + 2\text{Cr}^{3+} + 14\text{OH}^-$

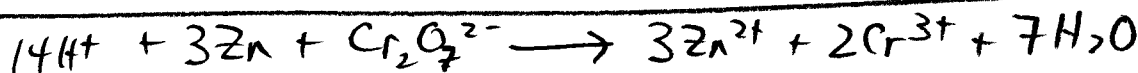
• Balance masses for half reactions:



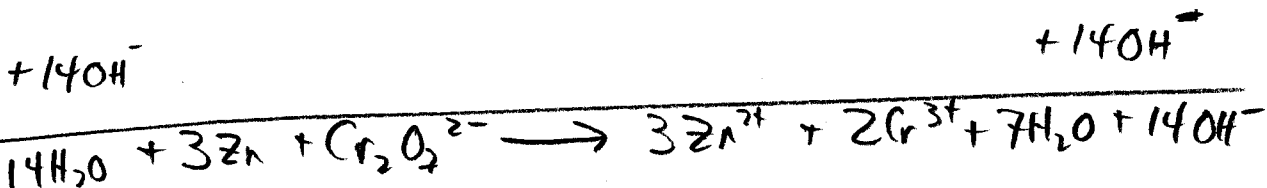
• Balance electrons:



• All half reactions



• Add  $\text{OH}^-$



• remove  $7\text{H}_2\text{O}$  from each side



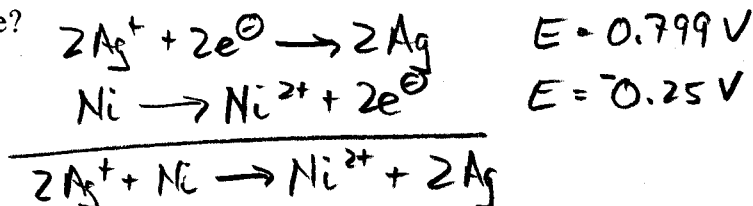


The next 3 questions refer to the following electrochemical cell:

A nickel electrode is put into a solution that contains 1.00 M  $\text{Ni}^{2+}$  ions, and a silver electrode is put into a solution that contains 1.00 M  $\text{Ag}^+$  ions. The electrodes are connected by a wire, and the solutions are connected by a salt bridge. The entire cell is placed at room temperature.

26) (3 points) What is the overall reaction that takes place?

- A)  $2\text{Ag}^+(\text{aq}) + 2\text{Ag}(\text{s}) \rightleftharpoons \text{Ni}^{2+}(\text{aq}) + \text{Ni}(\text{s})$
- B)  $\text{Ni}^{2+}(\text{aq}) + \text{Ni}(\text{s}) \rightleftharpoons 2\text{Ag}^+(\text{aq}) + 2\text{Ag}(\text{s})$
- C)  $\text{Ni}^{2+}(\text{aq}) + 2\text{Ag}(\text{s}) \rightleftharpoons 2\text{Ag}^+(\text{aq}) + \text{Ni}(\text{s})$
- ☒ D)  $2\text{Ag}^+(\text{aq}) + \text{Ni}(\text{s}) \rightleftharpoons \text{Ni}^{2+}(\text{aq}) + 2\text{Ag}(\text{s})$
- E) None of these occurs



27) (3 points) What is the voltage produced by this cell?

- A) -1.049 V
- B) -0.549 V
- C) 0.549 V
- ☒ D) 1.049 V
- E) 1.848 V

$$\begin{aligned} E_{\text{cell}}^{\circ} &= E_{\text{cathode}}^{\circ} - E_{\text{anode}}^{\circ} \\ &= 0.799 \text{ V} - (-0.25 \text{ V}) \\ &= 1.049 \text{ V} \end{aligned}$$

28) (4 points) What is the voltage produced by this cell if the concentrations of the  $\text{Ni}^{2+}$  and  $\text{Ag}^+$  ions are each reduced to 0.0100 M?

- A) 0.931 V
- ☒ B) 0.990 V
- C) 1.049 V
- D) 1.108 V
- E) None of these is correct

$$\begin{aligned} E &= E^{\circ} - \frac{0.0257}{n} \ln Q \\ &= 1.049 - \frac{0.0257}{2} \ln 100 \\ &= 1.049 - 0.0592 \\ &= 0.990 \text{ V} \end{aligned}$$

$$\begin{aligned} Q &= \frac{[\text{Ni}^{2+}]}{[\text{Ag}^+]^2} \\ &= \frac{[0.01]}{[0.01]^2} \\ &= 100 \end{aligned}$$

$n = 2$  for this reaction where 2 electrons are transferred

**Extra credit problems:**

29) (5 points) 5.00 g of an unknown non-electrolyte compound is used to make 100ml of a solution. The solution exerts a pressure of 1250 mm Hg at room temperature. What is the molecular weight of the unknown compound?

- A) 74.4 g/mole  
☒ B) 744 g/mole  
 C)  $7.53 \times 10^4$  g/mole  
 D)  $5.65 \times 10^5$  g/mole  
 E) None of these is correct

$$\Pi = CRT$$

$$C = \frac{\Pi}{RT} = \frac{(1250 \text{ mm Hg})(1 \text{ atm}/760 \text{ mm Hg})}{(0.0821 \text{ L-atm/mol K})(298 \text{ K})}$$

$$= 0.672 \text{ moles/L}$$

$$0.672 \text{ moles/L} \times 0.100 \text{ L} = 0.0672 \text{ moles}$$

$$\frac{5 \text{ g}}{0.0672 \text{ moles}} = 744 \text{ g/mole}$$

30) (5 points) For the reaction:  $\text{NH}_4\text{Cl (aq)} \longrightarrow \text{NH}_3 \text{ (g)} + \text{HCl (aq)}$   
 $\Delta H^\circ = 86.4 \text{ kJ/mol}$  and  $\Delta S^\circ = 79.1 \text{ J/(mol K)}$  (Assume that  $\Delta H^\circ$  and  $\Delta S^\circ$  are independent of temperature.)

The equilibrium constant for this reaction at 299 K is:

- A) 0.975  
 B)  $5.57 \times 10^{-26}$   
 C)  $1.79 \times 10^{25}$   
 D)  $9.28 \times 10^{10}$   
☒ E)  $1.09 \times 10^{-11}$

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$

$$= (86.4 \text{ kJ/mole}) - (299 \text{ K}) \left( \frac{0.0791 \text{ kJ}}{\text{mol K}} \right)$$

$$= 62.7 \text{ kJ/mole}$$

$$= 62700 \text{ J/mole}$$

$$\Delta G = -RT \ln K$$

$$\ln K = \frac{\Delta G}{-RT} = \frac{62700 \text{ J/mole}}{-(8.31 \text{ J/mole K})(299 \text{ K})}$$

$$= -25.25$$

$$K = 1.08 \times 10^{-11}$$

Please sign the following statement at the completion of the exam:

I did not cheat on this exam. \_\_\_\_\_ (name)

\_\_\_\_\_ (signature)

# PERIODIC TABLE OF THE ELEMENTS

1A	2A	3B	4B	5B	6B	7B	8B	8B	8B	1B	2B	3A	4A	5A	6A	7A	8A	
1 H 1.008																		2 He 4.003
3 Li 6.939	4 Be 9.012											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 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.71	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	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 (99)	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	57 La 138.9	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 226.0	89 Ac 227.0	104 Unq (261)	105 Unp (262)	106 Unh (263)	107 Uns (262)	108 Uno (265)	109 Une (266)										

**USEFUL INFORMATION:**
**Constants**

1 atm = 760 mm Hg	T (°C) + 273 = T (K)	$k_H$ for N <sub>2</sub> = $8.42 \times 10^{-7}$ M/mm Hg
R = 0.0821 (L•atm)/(mol•K) = 8.31 J/(mol•K) = $8.31 \times 10^{-3}$ kJ/(mol•K)	Room Temperature = 25°C = 298K	P° (H <sub>2</sub> O, 100°C) = 760 mm Hg
K <sub>bp</sub> for water: +0.512°C/m	K <sub>fp</sub> for water: -1.86°C/m	
K <sub>w</sub> = $1 \times 10^{-14}$ , 25 °C	$\Delta H_{\text{vap}}$ for water = 40.7 kJ/mol	F = 96,485 coulombs/mole e <sup>-</sup> = 96,485 J/(V•mole)

**Formulae:**

PV = nRT	$\ln P = (-\Delta H/RT) + c$	$\ln (P_2/P_1) = (\Delta H/R)(1/T_1 - 1/T_2)$
$\Delta T = K m_i$	$P_A = X_A P_A^\circ$	$\Pi = cRT$
$S_g = k_H P_g$	Molarity (M) = moles/L solution	molality (m) = moles/kg H <sub>2</sub> O
$\ln (A/A_0) = -kt$	$1/A - 1/A_0 = kt$	$A_0 - A = kt$
$t_{1/2} = 0.693/k$	$\ln (k_2/k_1) = (-E_a/R)(1/T_2 - 1/T_1)$	$k = A e^{-E_a/RT}$
$ax^2 + bx + c = 0$	$x = [-b \pm \sqrt{b^2 - 4ac}]/(2a)$	
pX = -log X	$pK_w = pK_a + pK_b$	$pK_w = pH + pOH$
pH = pK <sub>a</sub> + log ([Conjugate Base]/[Acid])	pOH = pK <sub>b</sub> + log ([Conjugate Acid]/[Base])	
$\Delta G^\circ_{\text{rxn}} = \Delta H^\circ_{\text{rxn}} - T\Delta S^\circ_{\text{rxn}}$	$\Delta S = q_{\text{rev}}/T$	$\Delta S_{\text{sys}} = \Delta S_{\text{fus}} = \Delta H_{\text{fus}}/T_{\text{fus}}$
$\Delta S_{\text{surr}} = -\Delta H_{\text{sys}}/T = -\Delta H_{\text{rxn}}/T$	$\Delta S_{\text{sys}} = \Delta S_{\text{vap}} = \Delta H_{\text{vap}}/T_{\text{vap}}$	$\Delta S_{\text{univ}} = \Delta S_{\text{sys}} + S_{\text{surr}}$
$\Delta G = \Delta H - T\Delta S$	$\Delta G^\circ = -RT \ln K$	$\Delta G = \Delta G^\circ + RT \ln Q$
$E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$	$E = E^\circ - (0.0257/n) \ln Q$ (at 25°C)	$\ln K_{\text{eq}} = nE^\circ/0.0257$ (at 25°C)
$\Delta G^\circ = -nFE^\circ$	Current I (Amperes, A) = electric charge (coulombs, C) / time (sec)	

**Table 20.1** Standard Reduction Potentials in Aqueous Solution at 25 °C\*

Reduction Half-Reaction	$E^\circ$ (V)
$F_2(g) + 2 e^- \longrightarrow 2 F^-(aq)$	+2.87
$H_2O_2(aq) + 2 H^+(aq) + 2 e^- \longrightarrow 2 H_2O(l)$	+1.77
$PbO_2(s) + SO_4^{2-}(aq) + 4 H^+(aq) + 2 e^- \longrightarrow PbSO_4(s) + 2 H_2O(l)$	+1.685
$MnO_4^-(aq) + 8 H^+(aq) + 5 e^- \longrightarrow Mn^{2+}(aq) + 4 H_2O(l)$	+1.51
$Au^{3+}(aq) + 3 e^- \longrightarrow Au(s)$	+1.50
$Cl_2(g) + 2 e^- \longrightarrow 2 Cl^-(aq)$	+1.36
$Cr_2O_7^{2-}(aq) + 14 H^+(aq) + 6 e^- \longrightarrow 2 Cr^{3+}(aq) + 7 H_2O(l)$	+1.33
$O_2(g) + 4 H^+(aq) + 4 e^- \longrightarrow 2 H_2O(l)$	+1.229
$Br_2(l) + 2 e^- \longrightarrow 2 Br^-(aq)$	+1.08
$NO_3^-(aq) + 4 H^+(aq) + 3 e^- \longrightarrow NO(g) + 2 H_2O(l)$	+0.96
$OCl^-(aq) + H_2O(l) + 2 e^- \longrightarrow Cl^-(aq) + 2 OH^-(aq)$	+0.89
$Hg^{2+}(aq) + 2 e^- \longrightarrow Hg(l)$	+0.855
$Ag^+(aq) + e^- \longrightarrow Ag(s)$	+0.799
$Hg_2^{2+}(aq) + 2 e^- \longrightarrow 2 Hg(l)$	+0.789
$Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$	+0.771
$I_2(s) + 2 e^- \longrightarrow 2 I^-(aq)$	+0.535
$O_2(g) + 2 H_2O(l) + 4 e^- \longrightarrow 4 OH^-(aq)$	+0.40
$Cu^{2+}(aq) + 2 e^- \longrightarrow Cu(s)$	+0.337
$Sn^{4+}(aq) + 2 e^- \longrightarrow Sn^{2+}(aq)$	+0.15
$2 H^+(aq) + 2 e^- \longrightarrow H_2(g)$	0.00
$Sn^{2+}(aq) + 2 e^- \longrightarrow Sn(s)$	-0.14
$Ni^{2+}(aq) + 2 e^- \longrightarrow Ni(s)$	-0.25
$V^{3+}(aq) + e^- \longrightarrow V^{2+}(aq)$	-0.255
$PbSO_4(s) + 2 e^- \longrightarrow Pb(s) + SO_4^{2-}(aq)$	-0.356
$Cd^{2+}(aq) + 2 e^- \longrightarrow Cd(s)$	-0.40
$Fe^{2+}(aq) + 2 e^- \longrightarrow Fe(s)$	-0.44
$Zn^{2+}(aq) + 2 e^- \longrightarrow Zn(s)$	-0.763
$2 H_2O(l) + 2 e^- \longrightarrow H_2(g) + 2 OH^-(aq)$	-0.8277
$Al^{3+}(aq) + 3 e^- \longrightarrow Al(s)$	-1.66
$Mg^{2+}(aq) + 2 e^- \longrightarrow Mg(s)$	-2.37
$Na^+(aq) + e^- \longrightarrow Na(s)$	-2.714
$K^+(aq) + e^- \longrightarrow K(s)$	-2.925
$Li^+(aq) + e^- \longrightarrow Li(s)$	-3.045

\* In volts (V) versus the standard hydrogen electrode.