



7. (12 pts) For the chemical reaction,  $\text{NH}_3(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{NH}_4^+(\text{aq}) + \text{OH}^-(\text{aq})$ ,  
 a. Calculate  $\Delta G^\circ$  (in kJ) AND the equilibrium constant, K, at 25° C.  $\Delta S^\circ = 143.3 \text{ J/K}$  and  $\Delta H^\circ = 176.4 \text{ kJ}$

$$\Delta G^\circ = +133.7 \text{ kJ} \quad K = 3.66 \times 10^{-24}$$

- b. Calculate  $\Delta G$  at 298 K, when  $[\text{NH}_4^+] = 0.20 \text{ M}$ ,  $[\text{OH}^-] = 0.10 \text{ M}$  and  $[\text{NH}_3] = 0.050 \text{ M}$ .

$$\Delta G = +131.4 \text{ kJ}$$

Is this reaction spontaneous? **YES** **NO** (circle one and show all work to receive credit!)

8. (6 pts) Rubidium has a heat of vaporization of 69.0 kJ/mol and an entropy of vaporization of 71.9 J/mol K. Calculate the boiling point of rubidium. (*Hint: what is  $\Delta G$  during a phase change?*)

$$T = \Delta H / \Delta S = 959 \text{ K}$$

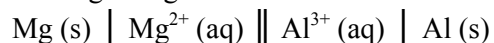
**For the following Electrochemistry problems, refer to the Reduction Potential Table on the last page of the exam.**

9. (5 pts) Given the reduction potentials on the last page of the exam, determine which combination of metal electrodes will produce a battery with the largest voltage.  
 a. Ag (s) and Fe (s)      b. Zn (s) and Sn (s)      c. Mg (s) and Al (s)      d. Cu (s) and Zn (s)
10. (5 pts) Circle the substance that is the strongest oxidizing agent:  
 a. Ni (s)      b.  $\text{Mg}^{2+}$  (aq)      c.  $\text{Cu}^{2+}$  (aq)      d. Ag (s)
11. (6 pts) Assign oxidation numbers for every atom in the reaction. Write the number under each atom  
 $5 \text{H}_2\text{C}_2\text{O}_4(\text{aq}) + 2 \text{MnO}_4^-(\text{aq}) + 6 \text{H}^+(\text{aq}) \rightarrow 10 \text{CO}_2(\text{g}) + 2 \text{Mn}^{2+}(\text{aq}) + 8 \text{H}_2\text{O}(\text{l})$

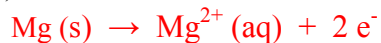
What is the oxidizing agent?  $\text{MnO}_4^-$       What is the reducing agent?  $\text{H}_2\text{C}_2\text{O}_4$

12. (5 pts) Which of the following are true if  $\Delta G$  has a negative value?  
 a.  $E^\circ_{\text{cell}}$  is (+) and  $K < 1$   
 b.  $E^\circ_{\text{cell}}$  is (+) and  $K > 1$   
 c.  $E^\circ_{\text{cell}}$  is (-) and  $K < 1$   
 d.  $E^\circ_{\text{cell}}$  is (-) and  $K > 1$   
 e.  $E^\circ_{\text{cell}}$  is zero and  $K = 1$
13. (5 pts)  $E^\circ_{\text{cell}} = 0.60 \text{ V}$  for the spontaneous reaction  $\text{Ni}(\text{s}) + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Ni}^{2+}(\text{aq}) + \text{Cu}(\text{s})$   
 Which statement is **False** regarding this cell?  
 a. The reduction half reaction is  $\text{Cu}^{2+}(\text{aq}) + 2 \text{e}^- \rightarrow \text{Cu}(\text{s})$   
 b. The electrons are flowing from the copper metal to the nickel metal through an external wire.  
 c. Cations from the salt bridge move towards the compartment containing the Cu.  
 d. The mass of the nickel electrode is decreasing as the nickel atoms become nickel ions.

14. (12 pts) Answer the following questions regarding the short-hand cell notation:



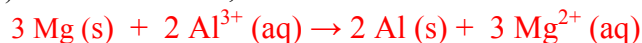
a. (1 pt) Write the oxidation  $\frac{1}{2}$  reaction:



b. (1 pt) Write the reduction  $\frac{1}{2}$  reaction:



c. (1 pt) Write the overall, balanced reaction:



d. (1 pt) What is the anode? Mg

e. (1 pt) What is the cathode? Al

f. (2 pts) Calculate the total cell potential ( $E^{\circ}_{\text{cell}}$ ) for this reaction. **0.71 V**

g. (5 pts) Calculate the EMF for the cell, E, when 0.100 M  $\text{Mg}(\text{NO}_3)_2$  and 0.0100 M  $\text{Al}(\text{NO}_3)_3$  are used at 25°C.

$$E = 0.70 \text{ V}$$

15. (8 pts) Calculate  $\Delta G^{\circ}$  for the galvanic cell composed of Fe in  $\text{Fe}(\text{NO}_3)_2$  solution and Sn in  $\text{Sn}(\text{NO}_3)_4$  solution.

$$\Delta G^{\circ} = (4 \text{e}^{-})(96500)(0.60 \text{ V}) = -230 \text{ kJ}$$

Reduction half-reaction	$E^{\circ}, \text{V}$
$\text{Ag}^{+} \text{ (aq)} + \text{e}^{-} \rightarrow \text{Ag (s)}$	0.80
$\text{Cu}^{2+} \text{ (aq)} + 2\text{e}^{-} \rightarrow \text{Cu (s)}$	0.34
$\text{Sn}^{4+} \text{ (aq)} + 4\text{e}^{-} \rightarrow \text{Sn (s)}$	0.15
$2\text{H}^{+} \text{ (aq)} + 2\text{e}^{-} \rightarrow \text{H}_2 \text{ (g)}$	0
$\text{Ni}^{2+} \text{ (aq)} + 2\text{e}^{-} \rightarrow \text{Ni (s)}$	-0.26
$\text{Fe}^{2+} \text{ (aq)} + 2\text{e}^{-} \rightarrow \text{Fe (s)}$	-0.45
$\text{Zn}^{2+} \text{ (aq)} + 2\text{e}^{-} \rightarrow \text{Zn (s)}$	-0.76
$\text{Al}^{3+} \text{ (aq)} + 3\text{e}^{-} \rightarrow \text{Al (s)}$	-1.66
$\text{Mg}^{2+} \text{ (aq)} + 2\text{e}^{-} \rightarrow \text{Mg (s)}$	-2.37

**Extra credit: (5 pts)**

Calculate the pH and percent ionization of a 0.300 M ammonia solution?  $K_b = 1.75 \times 10^{-5}$  (show work on back)