

Read questions carefully to understand what is being asked, before answering. No outside paper is allowed. Use the reverse side of your answer paper as scratch. Use the important equation table and periodic table provided. (Total points = 56 + (18x3=)54 = 110).

Show your calculation first with set up equation. Then use the raw data with units in the equation in the equation and then complete the calculation.

1) Benzoic acid is a monoprotic acid. A student dissolves 0.25g of benzoic acid ( $C_6H_5CO_2H$ ) in 100.00 mL of water. The student titrates the benzoic acid solution with 0.15M NaOH solution. What is the pH of the solution at the equivalence point? ( $K_a = 6.4 \times 10^{-5}$ ) (10 pts.) 1) \_\_\_\_\_

2) The  $K_{sp}$  for  $Zn(OH)_2$  is  $5.0 \times 10^{-17}$ . Determine the molar solubility of  $Zn(OH)_2$  in a buffer solution with a pH of 11.5 (6 pts.). 2) \_\_\_\_\_

3) The following information is available for the reaction at 25°C:

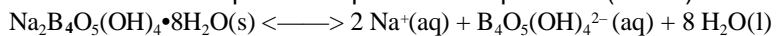
	$\text{CaCO}_3 (\text{s}) \rightleftharpoons \text{CaO} (\text{s}) + \text{CO}_2 (\text{g})$		
$\Delta G_f^\circ$ (kJ/mol)	-1129.16	-603.42	-394.36
$\Delta H_f^\circ$ (kJ/mol)	-1207.6	-635.09	-393.51
$S_f^\circ$ (J/K.mol)	91.7	38.2	213.74

3) \_\_\_\_\_

(a) Calculate the Gibbs free energy change of the reaction (3pts.) .

(b) Calculate the temperature in °C when the reaction will be favorable (5 pts.).

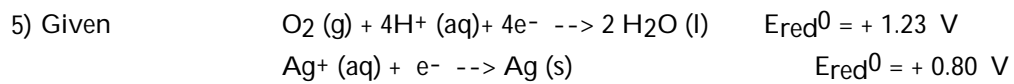
4) A nonlinear best fit plot of  $K_{eq}$  versus Temperature (Kelvin) of tetraborate equilibrium:



gives  $\Delta H^\circ = 96 \text{ kJ/mol}$  and  $\Delta S^\circ = 300 \text{ J/mol}$ . From this data calculate the  $K_{eq}$  at 25° C .

Show set up, raw data and units. (8 pts.)

4) \_\_\_\_\_



5) \_\_\_\_\_

For redox reaction:  $4\text{Ag} (\text{s}) + \text{O}_2 (\text{g}) + 4\text{H}^+ (\text{aq}) \rightarrow 4 \text{Ag}^+ (\text{aq}) + 2 \text{H}_2\text{O} (\text{l})$

(i) Write the cathode reaction (2 pts.):

(ii) Write the anode reaction (2 pts.):

iii) Show set up and all your work to calculate the standard free energy change for the reaction at 25°C (4 pts.)

(iv) Show set up and all your work to calculate the equilibrium constant for the reaction at 25°C (8 pts.)

6) How many seconds are required to produce 4.00 g of aluminum metal from the electrolysis of molten  $\text{AlCl}_3$  with an electrical current of 12.0 A? Show set up and all your work. (8 pts.)

6) \_\_\_\_\_

MULTIPLE CHOICE. Show your work to select the one response that best completes the statement or answers the question (3 pts each).

- 7) In which of the following aqueous solutions would you expect  $\text{PbCl}_2$  to have the lowest solubility? 7) \_\_\_\_\_
- A) 0.015 M NaCl
  - B) 0.020 M  $\text{BaCl}_2$
  - C) pure water
  - D) 0.015 M  $\text{PbNO}_3$
  - E) 0.020 M KCl
- 8) Which below best describe(s) the behavior of an amphoteric hydroxide in water? 8) \_\_\_\_\_
- A) With conc. aq. HCl, its suspension dissolves.
  - B) With conc. aq. HCl, its clear solution forms a precipitate.
  - C) With conc. aq. NaOH, its clear solution forms a precipitate.
  - D) With conc. aq. NaOH, its suspension dissolves.
  - E) With both conc. aq. NaOH and conc. aq. HCl, its suspension dissolves.
- 9) What is the oxidation number of sulfur in the  $\text{HSO}_4^-$  ion? 9) \_\_\_\_\_
- A) +2                      B) +4                      C) +6                      D) +1                      E) -2
- 10) Which transformation could take place at the anode of an electrochemical cell? 10) \_\_\_\_\_
- A)  $\text{O}_2 \rightarrow \text{H}_2\text{O}_2$
  - B)  $\text{H}_2\text{AsO}_4 \rightarrow \text{H}_3\text{AsO}_3$
  - C)  $\text{VO}_2^+ \rightarrow \text{VO}^{2+}$
  - D)  $\text{NO} \rightarrow \text{NO}_3^-$
  - E)  $\text{CO}_2 \rightarrow \text{C}_2\text{O}_4^{2-}$
- 11) Which transformation could take place at the cathode of an electrochemical cell? 11) \_\_\_\_\_
- A)  $\text{Mn}^{2+} \rightarrow \text{MnO}_4^-$
  - B)  $\text{MnO}_2 \rightarrow \text{MnO}_4^-$
  - C)  $\text{Br}_2 \rightarrow \text{BrO}_3^-$
  - D)  $\text{HSO}_4^- \rightarrow \text{H}_2\text{SO}_3$
  - E)  $\text{NO} \rightarrow \text{HNO}_2$

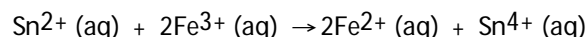
Table 20.2

Half-reaction	$E^\circ$ (V)
$\text{Cr}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Cr}(\text{s})$	-0.74
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Fe}(\text{s})$	-0.440
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightarrow \text{Fe}^{2+}(\text{aq})$	+0.771
$\text{Sn}^{4+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Sn}^{2+}(\text{aq})$	+0.154

12) Which of the following reactions will occur spontaneously as written? 12) \_\_\_\_\_

- A)  $3\text{Sn}^{4+}(\text{aq}) + 2\text{Cr}(\text{s}) \rightarrow 2\text{Cr}^{3+}(\text{aq}) + 3\text{Sn}^{2+}(\text{aq})$   
 B)  $3\text{Fe}(\text{s}) + 2\text{Cr}^{3+}(\text{aq}) \rightarrow 2\text{Cr}(\text{s}) + 3\text{Fe}^{2+}(\text{aq})$   
 C)  $3\text{Fe}^{2+}(\text{aq}) \rightarrow \text{Fe}(\text{s}) + 2\text{Fe}^{3+}(\text{aq})$   
 D)  $\text{Sn}^{4+}(\text{aq}) + \text{Fe}^{3+}(\text{aq}) \rightarrow \text{Sn}^{2+}(\text{aq}) + \text{Fe}^{2+}(\text{aq})$   
 E)  $\text{Sn}^{4+}(\text{aq}) + \text{Fe}^{2+}(\text{aq}) \rightarrow \text{Sn}^{2+}(\text{aq}) + \text{Fe}(\text{s})$

13) The standard cell potential ( $E^\circ_{\text{cell}}$ ) for the voltaic cell based on the reaction below is \_\_\_\_\_ V. 13) \_\_\_\_\_

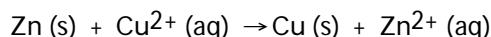


- A) +1.21                  B) +0.617                  C) +0.46                  D) +1.39                  E) -0.46

14) The reduction half reaction occurring in the standard hydrogen electrode is \_\_\_\_\_. 14) \_\_\_\_\_

- A)  $\text{H}_2(\text{g}, 1 \text{ atm}) \rightarrow 2\text{H}^+(\text{aq}, 1 \text{ M}) + 2\text{e}^-$   
 B)  $2\text{H}^+(\text{aq}) + 2\text{OH}^- \rightarrow \text{H}_2\text{O}(\text{l})$   
 C)  $2\text{H}^+(\text{aq}, 1 \text{ M}) + \text{Cl}_2(\text{aq}) \rightarrow 2\text{HCl}(\text{aq})$   
 D)  $2\text{H}^+(\text{aq}, 1 \text{ M}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g}, 1 \text{ atm})$   
 E)  $\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}(\text{l})$

15) The standard cell potential ( $E^\circ_{\text{cell}}$ ) for the reaction below is +1.10 V. The cell potential for this reaction is \_\_\_\_\_ V when the concentration of  $[\text{Cu}^{2+}] = 1.0 \times 10^{-5} \text{ M}$  and  $[\text{Zn}^{2+}] = 1.0 \text{ M}$ . 15) \_\_\_\_\_



- A) 0.95                  B) 0.80                  C) 1.25                  D) 1.10                  E) 1.40

16) The thermodynamic quantity that expresses the degree of disorder in a system is \_\_\_\_\_. 16) \_\_\_\_\_

- A) bond energy  
 B) entropy  
 C) internal energy  
 D) enthalpy  
 E) heat flow

17) The normal boiling point of water is  $100.0^\circ\text{C}$  and its molar enthalpy of vaporization is  $40.67 \text{ kJ/mol}$ . What is the change in entropy in the system in  $\text{J/K}$  when  $39.3 \text{ grams}$  of steam at  $1 \text{ atm}$  condenses to a liquid at the normal boiling point? 17) \_\_\_\_\_

- A) 373                  B) 88.8                  C) -40.7                  D) -88.8                  E) -238

- 18)  $\Delta S$  is positive for the reaction \_\_\_\_\_. 18) \_\_\_\_\_
- A)  $2\text{NO}_2(\text{g}) \rightarrow \text{N}_2\text{O}_4(\text{g})$
  - B)  $2\text{Hg}(\text{l}) + \text{O}_2(\text{g}) \rightarrow 2\text{HgO}(\text{s})$
  - C)  $\text{BaF}_2(\text{s}) \rightarrow \text{Ba}^{2+}(\text{aq}) + 2\text{F}^{-}(\text{aq})$
  - D)  $\text{CO}_2(\text{g}) \rightarrow \text{CO}_2(\text{s})$
  - E)  $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{O}(\text{g})$

- 19) Of the following, the entropy of \_\_\_\_\_ is the largest. 19) \_\_\_\_\_
- A)  $\text{HCl}(\text{s})$
  - B)  $\text{HCl}(\text{g})$
  - C)  $\text{HCl}(\text{l})$
  - D)  $\text{HBr}(\text{g})$
  - E)  $\text{HI}(\text{g})$

TRUE/FALSE. Select A in the scantron if the statement is TRUE and B if the statement is FALSE (3 pts).

- 20) The solubility of slightly soluble salts containing basic anions is proportional to the pH of the solution. T or F
- 21) The vaporization of a substance at its boiling point is an isothermal process T or F
- 22) The entropy of a pure crystalline substance at  $0^\circ\text{C}$  is zero. T or F
- 23) The standard reduction potential,  $E^\circ_{\text{red}}$ , is proportional to the stoichiometric coefficient. T or F
- 24) The standard reduction potential of X is 1.23 V and that of Y is -0.44 V therefore X is oxidized by Y. T or F

MULTIPLE CHOICE. Show your work to select the one response that best completes the statement or answers the question (3 pts each).

- 25) EXTRA POINT QUESTION The standard Gibbs free energy of formation of \_\_\_\_\_ is zero. 25) \_\_\_\_\_
- (a)  $\text{H}_2\text{O}(\text{l})$
  - (b)  $\text{Na}(\text{s})$
  - (c)  $\text{H}_2(\text{g})$
- A) (a) only
  - B) (b) only
  - C) (c) only
  - D) (b) and (c)
  - E) (a), (b), and (c)