

KEY

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 = 58 + (20x3)=60 = 118).

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) How many moles of ^{(con) acid} NH_4Cl must be added to 2.0 L of 0.10 M ammonia (^{weak base} NH_3) to form a buffer, whose $\text{pH}=9.0$? Assume that no volume change happens when NH_4Cl is added into the solution). K_b of NH_3 is 1.8×10^{-5} (8 pts). 1) _____

$$K_a = \frac{K_w}{K_b} = \frac{10^{-14}}{1.8 \times 10^{-5}} = 5.555 \times 10^{-10}$$

$$\text{pH} = \text{p}K_a + \log \frac{[\text{Base}]}{[\text{Acid}]}$$

$$\text{p}K_a = -\log K_a = 9.25527$$

$$9.0 = \cancel{9.25527} + \log \frac{[0.10]}{[\text{Acid}]} \quad 10^{-0.25527} = \log \frac{[0.10]}{[\text{Acid}]}$$

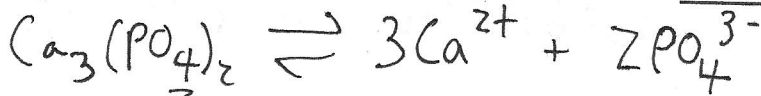
$$\frac{[0.10]}{[\text{Acid}]} = 0.5555 \quad [\text{Acid}] = 0.18 \text{ M} \quad 0.18 \text{ M } \text{NH}_4\text{Cl} \times 2.0 \text{ L} = 0.36 \text{ moles } \text{NH}_4\text{Cl}$$

0.36 moles NH_4Cl

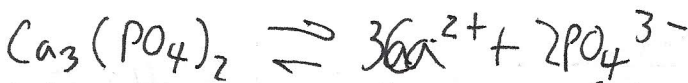
$$M = \frac{\text{mol}}{L}$$

- 2) If K_{sp} of calcium phosphate, $\text{Ca}_3(\text{PO}_4)_2$ in water is 1.0×10^{-33} , then what is its solubility in water in gram/L (10 pts)? 2) _____

$$MW = 310.174 \text{ g/mol}$$



$$K_{sp} = [\text{Ca}^{2+}]^3 [\text{PO}_4^{3-}]^2 = 1.0 \times 10^{-33}$$



I	initial amt	\emptyset	\emptyset
C	-S	+3S	+2S
E	initial amt - S	3S	2S

$$S = \frac{9.85 \times 10^{-8}}{2.26703} \times 10^{-7} \text{ mol/L}$$

$$= \frac{9.85 \times 10^{-8}}{2.26703} \times 10^{-7} \frac{\text{mol}}{L} \times 310.174 \frac{\text{g}}{\text{mol}} =$$

$$1.0 \times 10^{-33} = (3S)^3 \times (2S)^2 = 36S^5$$

$$27(9S)^3 \times 4S^2 = 108S^5$$

$$\frac{3.805 \times 10^{-5} \text{ g}}{L} = 3.05 \times 10^{-5} \frac{\text{g}}{L}$$

$$S = (1.0 \times 10^{-33} / 108)^{1/5} = 9.85 \times 10^{-8} \frac{\text{mol}}{L}$$

Ca 40.078
P 30.974
O 15.999

-3

$$\Delta G_{rxn}^{\circ} = \sum n \Delta G_f^{\circ} (\text{Products}) - \sum n \Delta G_f^{\circ} (\text{Reactants})$$

$$\Delta H_{rxn}^{\circ} = \sum n \Delta H_f^{\circ} (\text{Products}) - \sum n \Delta H_f^{\circ} (\text{Reactants})$$

$$\Delta S_{rxn}^{\circ} = \sum n S^{\circ} (\text{Products}) - \sum n S^{\circ} (\text{Reactants})$$

$$\frac{\Delta H}{\Delta S} = T \Delta S$$

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

	CaCO ₃ (s)	CaO (s)	CO ₂ (g)
ΔG_f° (kJ/mol)	-1129.16	-603.42	-394.36
ΔH_f° (kJ/mol)	-1207.6	-635.09	-393.51
S_f° (J/K.mol)	91.7	38.2	213.74

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

$$\Delta G_{rxn}^{\circ} = (-394.36 - 603.42) - (-1129.16) = 131.38 \text{ kJ/mol}$$

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

$$0 = \Delta G = \Delta H - T \Delta S$$

$$T = \frac{\Delta H}{\Delta S} = \frac{179 \times 10^3 \text{ J/mol}}{160.24 \text{ J/mol}\cdot\text{K}} = 1117.07 \text{ K}$$

$$\Delta H_{rxn}^{\circ} = (-393.51 - 635.09) - (-1207.6)$$

$$\Delta H_{rxn}^{\circ} = 179 \text{ kJ/mol}$$

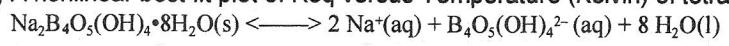
$$\Delta S_{rxn}^{\circ} = (213.74 + 38.2) - (91.7)$$

$$\Delta S_{rxn}^{\circ} = 160.24 \text{ J/mol}\cdot\text{K}$$

$$1117.07 \text{ K} - 273.15^{\circ}\text{C} = 843.92^{\circ}\text{C}$$

This reaction will be favorable above 843.92°C

4) A nonlinear best fit plot of Keq 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 Keq at 25°C.

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

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

$$\Delta G_{rxn}^{\circ} = -RT \ln K$$

$$\Delta G = \Delta H - T \Delta S = 96 \times 10^3 \text{ J/mol} - (298.15 \text{ K} \times 300 \text{ J/mol}\cdot\text{K})$$

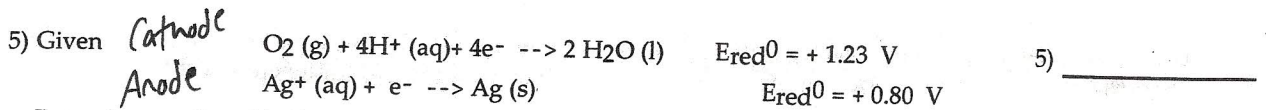
$$\Delta G = 6555 \text{ J/mol or } 6.555 \text{ kJ/mol}$$

$$6555 \text{ J/mol} = -8.314 \text{ J/mol}\cdot\text{K} \cdot 298.15 \text{ K} \cdot \ln K$$

$$\frac{6555 \text{ J/mol}}{-2478.819 \text{ J/mol}} = \ln K = -2.6444043$$

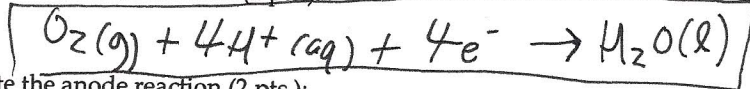
$$e^{-2.6444043} = K_{eq} = 7.104766 \times 10^{-2}$$

$$K_{eq} = 7.105 \times 10^{-2}$$

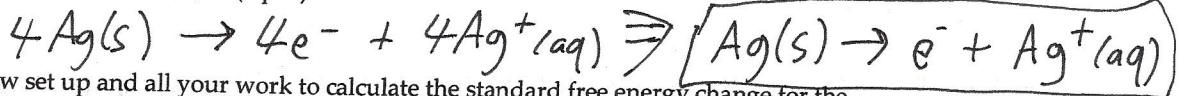


For redox reaction: $4\text{Ag}(\text{s}) + \text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) \rightarrow 4\text{Ag}^+(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$

(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.)

$n = 4 \text{ mol e}^-$
 $F = \frac{96,485 \text{ C}}{\text{mol e}^-}$

$$\Delta G^{\circ} = -nFE^{\circ}_{\text{cell}} \quad E^{\circ}_{\text{cell}} = E^{\circ}_{\text{cathode}} - E^{\circ}_{\text{anode}}$$

$$E^{\circ}_{\text{cell}} = +1.23 \text{ V} - (+0.80 \text{ V}) = 0.43 \text{ V}$$

$$\Delta G^{\circ} = -4 \text{ mol e}^- \times \frac{96,485 \text{ C}}{\text{mol e}^-} \times 0.43 \frac{\text{J}}{\text{C}} = -165954.2 \text{ J/mol}$$

$$\Delta G^{\circ} = -165,954.2 \frac{\text{kJ}}{\text{mol}}$$

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

Used this approach

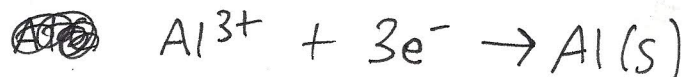
$$\Delta G^{\circ}_{\text{rxn}} = -RT \ln K \quad \text{OR} \quad E^{\circ}_{\text{cell}} = \frac{0.0592 \text{ V}}{n} \log K$$

$$-165954.2 \text{ J/mol} = -8.314 \text{ J/mol}\cdot\text{K} \times 298.15 \text{ K} \cdot \ln K$$

$$\frac{-165954.2 \text{ J/mol}}{-2478.8191 \text{ J/mol}} = \ln K = 66.94889514$$

$$e^{66.94889514} = K_{\text{eq}} = 1.18997 \times 10^{29}$$

6) How many seconds are required to produce 4.00 g of aluminum metal from the electrolysis of molten AlCl_3 with an electrical current of 12.0 A? Show set up and all your work. (8 pts.)



MW 26.9827 g/mol

$$\frac{4.00 \text{ g Al}}{26.9827 \text{ g/mol}} = 0.148247 \text{ mol Al} \times \frac{3 \text{ mol e}^-}{1 \text{ mol Al}} = 0.444741 \text{ mol e}^-$$

$$0.444741 \text{ mol e}^- \times \left(\frac{96,485 \text{ C}}{\text{mol e}^-} \right) = 42910.82931 \text{ C}$$

$$\frac{42910.82931 \text{ C}}{12.0 \text{ C/s}} = 3575.9 \text{ seconds}$$

$$12.0 \text{ A} = \frac{12 \text{ C}}{3 \text{ s}}$$

MULTIPLE CHOICE. On the scantron fill the bubble with number same as the question number. Show your work to select the one response that best completes the statement or answers the question (3 pts each).

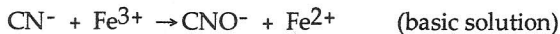
- 7) A solution containing which one of the following pairs of substances will be a buffer solution? 7) B
- A) KBr, HBr
 - B) CsF, HF
 - C) NaI, HI
 - D) RbCl, HCl
 - E) none of the above

- 8) In which of the following aqueous solutions would you expect PbCl₂ to have the lowest solubility? 8) B
- A) 0.015 M NaCl 0.015 Cl
 - B) 0.020 M BaCl₂ 0.040 Cl
 - C) pure water
 - D) 0.015 M PbNO₃ ~~0.015~~ 0.015 Pb
 - E) 0.020 M KCl 0.020 Cl

- 9) Which below best describe(s) the behavior of an amphoteric hydroxide in water? 9) E
- 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.

- 10) What is the oxidation number of nitrogen in the HNO₃? 10) C
- +1 +5 -6
- A) -1
 - B) +1
 - C) +5
 - D) +7
 - E) +3

- 11) What is the coefficient of Fe³⁺ when the following equation is balanced? 11) B



- A) 1
- B) 2
- C) 3
- D) 4
- E) 5

- 12) Which transformation could take place at the cathode of an electrochemical cell? 12) D

- A) $\overset{+2}{\text{Mn}^{2+}} \rightarrow \overset{+7}{\text{MnO}_4^-}$
- B) $\overset{+4}{\text{MnO}_2} \rightarrow \overset{+7}{\text{MnO}_4^-}$
- C) $\text{Br}_2 \rightarrow \overset{+3}{\text{BrO}_3^-}$
- D) $\overset{+6}{\text{HSO}_4^-} \rightarrow \overset{+4}{\text{H}_2\text{SO}_3}$
- E) $\text{NO} \rightarrow \text{HNO}_2$

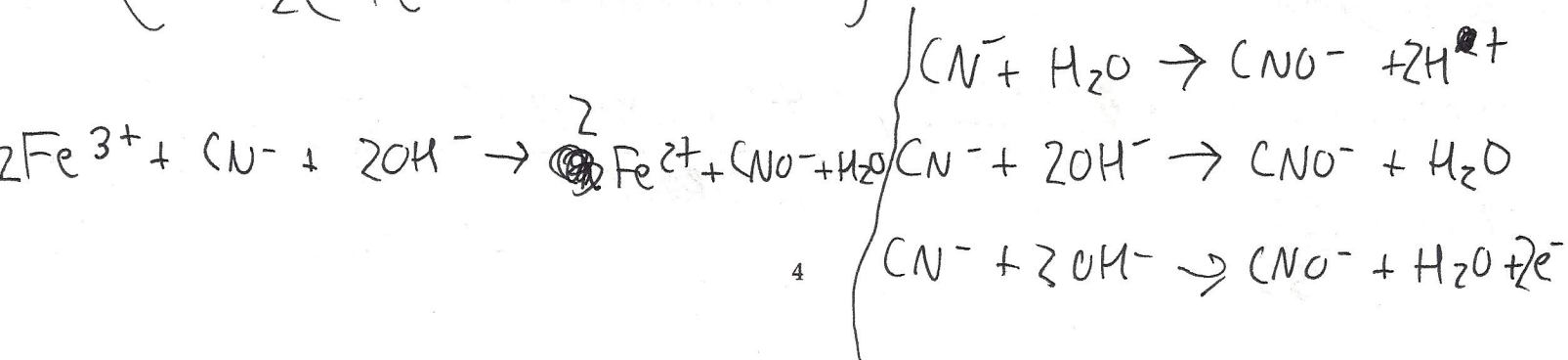
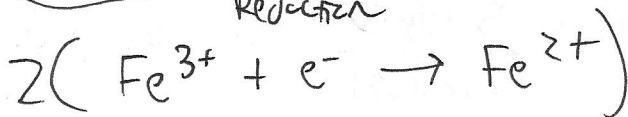


Table 20.2

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

~~anode~~ ~~anode~~ ~~anode~~ ~~anode~~
made
cathode

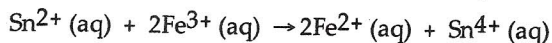
13) Which of the following reactions will occur spontaneously as written?

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

13) B

14) The standard cell potential (E°_{cell}) for the voltaic cell based on the reaction below is _____ V.

$$+0.771 - (+0.154)$$



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

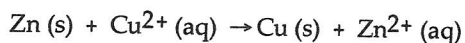
14) B

15) The reduction half reaction occurring in the standard hydrogen electrode is _____.

- 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) D

16) The standard cell potential (E°_{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 $[\text{Zn}^{2+}] = 1.0 \text{ M}$.



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

16) A

17) The thermodynamic quantity that expresses the degree of disorder in a system is _____.

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

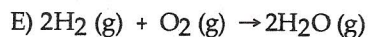
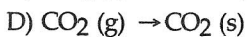
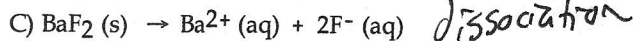
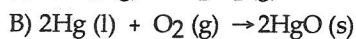
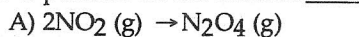
17) B

18) The normal boiling point of water is 100.0°C and its molar enthalpy of vaporization is 40.67 kJ/mol . What is the change in entropy in the system in J/K when 39.3 grams of steam at 1 atm condenses to a liquid at the normal boiling point?

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

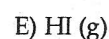
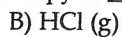
18) E

19) ΔS is positive for the reaction _____.



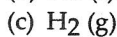
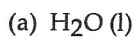
19) C

20) Of the following, the entropy of _____ is the largest.



20) E

21) The standard Gibbs free energy of formation of _____ is zero.



A) (a) only

B) (b) only

C) (c) only

D) (b) and (c)

E) (a), (b), and (c)

21) D

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

22) The solubility product of a compound is numerically equal to the product of the concentration of the ions involved in the equilibrium, each multiplied by its coefficient in the equilibrium reaction.

T or F F

23) The vaporization of a substance at its boiling point is an isothermal process

raised to power
T or F T

24) The more negative ΔG° is for a given reaction, the larger the value of the corresponding equilibrium constant, K .

T or F T

25) The standard reduction potential, E°_{red} , is proportional to the stoichiometric coefficient.

T or F F

26) 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 F