MC, Chem1B, Sp17, Test3

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 NH_4Cl must be added to 2.0 L of 0.10 M ammonia (NH_3) to form a buffer, whose pH=9.0? Assume that no volume change happens when NH_4Cl is added into the solution). Kb of NH_3 is 1.8×10^{-5} (8 pts). 1) _____

conj acid weak base

$K_a = \frac{K_w}{K_b} = \frac{10^{-14}}{1.8\times10^{-5}} = 5.555\times10^{-10}$

$pH = pK_a + \log\frac{[Base]}{[Acid]}$ $pK_a = -\log K_a = 9.25527$

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

$\frac{[0.10]}{[Acid]} = 0.5555$ $[Acid] = 0.18M$ $0.18M\ NH_4Cl \times 2.0L = 0.36$ moles NH_4Cl

0.36 moles NH_4Cl

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

$MW = 310.174 g/mol$

2) If K_{sp} of calcium phosphate, $Ca_3(PO_4)_2$ in water is 1.0×10^{-33}, then what is its solubility in water in gram/L (10 pts)? 2) _____

Ca 40.078
P 30.974
O 15.999

$Ca_3(PO_4)_2 \rightleftharpoons 3Ca^{2+} + 2PO_4^{3-}$

$K_{sp} = [Ca^{2+}]^3[PO_4^{3-}]^2 = 1.0\times10^{-33}$

	$Ca_3(PO_4)_2 \rightleftharpoons$	$3Ca^{2+}$	$+\ 2PO_4^{3-}$
I	Initial amt	Ø	Ø
C	−S	+3S	+2S
E	Initial amt − S	3S	2S

$1.0\times10^{-33} = (3S)^3 \times (2S)^2 = 108S^5$

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

$S = (1.0\times10^{-33}/108)^{\frac{1}{5}} = 9.85\times10^{-8}\ \frac{mol}{L}$

$S = 1.26703\times10^{-7}\ \frac{mol}{L}$

$\frac{9.85\times10^{-8}\ mol}{L} \times 310.174\ g/mol =$

$3.805\times10^{-5}\ g/L$

$= 3.05\times10^{-5}\ g/L$

Products Reactants

$\Delta G^\circ_{rxn} = \sum n\Delta G^\circ_f - \sum n\Delta G^\circ_f$ $\quad \Delta S^\circ_{rxn} = \sum nS^\circ - \sum nS^\circ$

Products Reactants

$\Delta H^\circ_{rxn} = \sum n\Delta H^\circ_f - \sum n\Delta H^\circ_f$

$+\Delta H = +T\Delta S$

ΔS

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

$CaCO_3$ (s) ----> CaO (s) + CO_2 (g)

$\Delta G_f°$ (kJ/mol)	-1129.16	-603.42	-394.36
$\Delta H_f°$ (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.).

$\Delta G^\circ_{rxn} = (-394.36 - 603.42) - (-1129.16) =$ **131.38 kJ/mol**

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

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

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

$1117.07\text{K} - 273.15°\text{C} =$ **843.92 °C**

This reaction will be favorable above 843.92°C

-393.51

$\Delta H^\circ_{rxn} = (-635.09) - (-1207.6)$

$\Delta H^\circ_{rxn} = 179$ kJ/mol

$\Delta S^\circ_{rxn} = (213.74 + 38.2) - (91.7)$

$\Delta S^\circ_{rxn} = 160.24$ J/mol·K

4) A nonlinear best fit plot of Keq versus Temperature (Kelvin) of tetraborate equlilibrium: 4) _____

$Na_2B_4O_5(OH)_4 \cdot 8H_2O(s) \longleftrightarrow 2\ Na^+(aq) + B_4O_5(OH)_4^{2-}(aq) + 8\ H_2O(l)$

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

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

$R = 8.314$ J/mol·K $\quad \Delta G^\circ_{rxn} = -RT \ln K$

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

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

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

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

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

$K_{eq} =$ **7.105×10^{-2}**

5) Given Cathode O_2 (g) + 4H+ (aq)+ 4e- --> 2 H_2O (l) E_{red}^0 = + 1.23 V 5) _____

Anode Ag+ (aq) + e- --> Ag (s) E_{red}^0 = + 0.80 V

For redox reaction: 4Ag (s) + O_2 (g) + 4H+ (aq) --> 4 Ag+ (aq) + 2 H_2O (l)

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

$O_2(g) + 4H^+(aq) + 4e^- \rightarrow H_2O(l)$

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

$4Ag(s) \rightarrow 4e^- + 4Ag^+(aq) \Rightarrow Ag(s) \rightarrow e^- + Ag^+(aq)$

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

$\Delta G^\circ = -nFE^\circ_{cell}$ $E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode}$

$n = 4$ mol e⁻

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

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

$\Delta G^\circ = -4\ mol\ e^- \times \frac{96,485\ C}{mol\ e^-} \times 0.43\ \frac{J}{C} = -165454.2\ J/mol$

$\Delta G^\circ = -165.4542\ kJ/mol$

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

Used this approach → $\Delta G^\circ_{rxn} = -RT \ln K$ OR $E^\circ_{cell} = \frac{0.0592\ V}{n} \log K$

$-165454.2\ J/mol = -8.314\ J/mol \cdot K \cdot 298.15\ K \cdot \ln K$

$\frac{-165454.2\ J/mol}{-2478.8191\ J/mol} = \ln K = 66.94889514$

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

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.) 6) _____

$Al^{3+} + 3e^- \rightarrow Al(s)$

MW 26.982 g/mol

$\frac{4.00\ g\ Al}{26.982\ g/mol} = 0.148247\ mol\ Al \times \frac{3\ mol\ e^-}{1\ mol\ Al} = 0.444741\ mol\ e^-$

F

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

$12.0\ A = \frac{12\ C}{1\ s}$

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

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 $PbCl_2$ to have the lowest solubility? 8) B

A) 0.015 M NaCl 0.015 Cl
B) 0.020 M $BaCl_2$ 0.040 Cl
C) pure water
D) 0.015 M $PbNO_3$ 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.

+1 +5 -6

10) What is the oxidation number of nitrogen in the HNO_3? 10) C

A) -1 B) +1 C) +5 D) +7 E) +3

11) What is the coefficient of Fe^{3+} when the following equation is balanced? 11) B

$CN^- + Fe^{3+} \rightarrow CNO^- + Fe^{2+}$ (basic solution)

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

reduction

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

A) $Mn^{2+} \rightarrow MnO_4^-$ (+2 → +8)
B) $MnO_2 \rightarrow MnO_4^-$ (+4 → +8)
C) $Br_2 \rightarrow BrO_3^-$ (+4)
D) $HSO_4^- \rightarrow H_2SO_3$ (+7 → +4)
E) $NO \rightarrow HNO_2$

Reduction

$2(Fe^{3+} + e^- \rightarrow Fe^{2+})$

Oxidation

$CN^- \rightarrow CNO^-$

$CN^- + H_2O \rightarrow CNO^- + 2H^+$

$CN^- + 2OH^- \rightarrow CNO^- + H_2O$

$CN^- + 2OH^- \rightarrow CNO^- + H_2O + 2e^-$

$2Fe^{3+} + CN^- + 2OH^- \rightarrow 2Fe^{2+} + CNO^- + H_2O$

Table 20.2

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

anode
cathode

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

A) $Sn^{4+}(aq) + Fe^{2+}(s) \rightarrow Sn^{2+}(aq) + Fe(s)$

B) $2Cr(s) + 3Fe^{2+}(s) \rightarrow 3Fe(s) + 2Cr^{3+}(aq)$

C) $2Cr^{3+}(aq) + 3Sn^{2+}(aq) \rightarrow 3Sn^{4+}(aq) + 2Cr(s)$

D) $Sn^{2+}(aq) + Fe^{2+}(s) \rightarrow Sn^{4+}(aq) + Fe^{3+}(aq)$

E) $3Fe^{2+}(aq) + Cr^{3+}(aq) \rightarrow Cr(s) + 3Fe^{3+}(aq)$

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

$+0.771 - (+0.154)$

$Sn^{2+}(aq) + 2Fe^{3+}(aq) \rightarrow 2Fe^{2+}(aq) + Sn^{4+}(aq)$

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

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

A) $H_2(g, 1\ atm) \rightarrow 2H^+(aq, 1M) + 2e^-$

B) $2H^+(aq) + 2OH^- \rightarrow H_2O(l)$

C) $2H^+(aq, 1M) + Cl_2(aq) \rightarrow 2HCl(aq)$

D) $2H^+(aq, 1M) + 2e^- \rightarrow H_2(g, 1\ atm)$

E) $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$

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 $[Cu^{2+}] = 1.0 \times 10^{-5}$ M and $[Zn^{2+}] = 1.0$ M. 16) A

$Zn(s) + Cu^{2+}(aq) \rightarrow Cu(s) + Zn^{2+}(aq)$

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

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

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

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? 18) E

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

19) ΔS is positive for the reaction _____. 19) C

A) $2NO_2$ (g) $\rightarrow N_2O_4$ (g)

B) 2Hg (l) + O_2 (g) $\rightarrow$ 2HgO (s)

C) BaF_2 (s) $\rightarrow$ Ba^{2+} (aq) + $2F^-$ (aq) dissociation

D) CO_2 (g) $\rightarrow$ CO_2 (s)

E) $2H_2$ (g) + O_2 (g) $\rightarrow$ $2H_2O$ (g)

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

A) HCl (s) B) HCl (g) C) HCl (l) D) HBr (g) E) HI (g)

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

(a) H_2O (l)

(b) Na (s)

(c) H_2 (g)

A) (a) only

B) (b) only

C) (c) only

D) (b) and (c)

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

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

raised to power

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

24) The more negative $\Delta G°$ is for a given reaction, the larger the value of the corresponding equilibrium constant, K. T or F

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