Problem Set 3 – December 2020

41. A student wishes to nickel plate the cathode of an electrolytic cell. What current should the student use to plate out 1.50 g of nickel after 20.0 minutes?

a) 2.05 A
b) 4.11 A
c) 9.00 A
d) 13.52 A
e) 15.25 A

42. Consider a galvanic cell based on the following half-reactions:

$Ag^+ + e^- \rightarrow Ag$ standard reduction potential = 0.80 V
$Cu^{2+} + 2e^- \rightarrow Cu$ standard reduction potential = 0.34 V

What is the cell potential (E_{cell}) at 25 °C if $[Ag^+] = 1.0 \times 10^{-2}$ M and $[Cu^{2+}] = 2.0 \times 10^{-3}$ M?

a) 0.46 V
b) 0.42 V
c) 0.38 V
d) -0.46 V
e) -0.38 V

43. For the galvanic cell in Question 42, which of the following statements is true if the cell operates spontaneously under standard conditions:

i. the mass of the silver electrode increases
ii. the mass of the copper electrode increases
iii. the copper electrode is the anode
iv. the silver electrode is the anode

a) i and iv
b) ii and iii
c) i and iii
d) ii and iv

44. Calculate E_{cell} and ΔG^0 at 25 °C for the following electrochemical cell:

$Cr(s) \mid Cr^{3+}(aq, 1.0 \times 10^{-2}\ M) \parallel Tl^{+}(aq, 1.0 \times 10^{-4}\ M) \mid Tl(s)$

$Tl^{+} + e^{-} \rightarrow Tl$ standard reduction potential = -0.34 V
$Cr^{3+} + 3e^{-} \rightarrow Cr$ standard reduction potential = -0.74 V

a) $E_{cell} = 0.88$ V, $\Delta G^0 = -313$ kJ
b) $E_{cell} = -0.88$ V, $\Delta G^0 = 313$ kJ
c) $E_{cell} = -0.20$ V, $\Delta G^0 = 116$ kJ
d) $E_{cell} = 0.20$ V, $\Delta G^0 = -116$ kJ
e) $E_{cell} = 0.20$ V, $\Delta G^0 = -313$ kJ

45. You would like to design a galvanic cell, and have the following half-cells at your disposal. Which combination would you choose to generate the highest voltage?

$Cu^{2+} + 2e^{-} \rightarrow Cu$ standard reduction potential = 0.34 V
$Ag^{+} + e^{-} \rightarrow Ag$ standard reduction potential = 0.80 V
$Fe^{2+} + 2e^{-} \rightarrow Fe$ standard reduction potential = -0.44 V

a) Anode: copper, cathode: silver
b) Anode: silver, cathode: copper
c) Anode: copper, cathode: iron
d) Anode: iron, cathode: copper
e) Anode: iron, cathode: silver

46. A concentration cell with Ni electrodes has concentrations of Ni^{2+} of 0.050 M and 0.18 M in each half-cell. What is E_{cell} for the spontaneous process at 298 K, and which solution contains the cathode?

a) $E_{cell} = 0.016$ V, cathode has $[Ni^{2+}] = 0.18$ M
b) $E_{cell} = -0.016$ V, cathode has $[Ni^{2+}] = 0.050$ M
c) $E_{cell} = 0.033$ V, cathode has $[Ni^{2+}] = 0.18$ M
d) $E_{cell} = -0.033$ V, cathode has $[Ni^{2+}] = 0.050$ M
e) $E_{cell} = 0.078$ V, cathode has $[Ni^{2+}] = 0.18$ M

47. Consider the following reaction at 25 °C:

$$Fe(OH)_2\ (s) \rightleftharpoons Fe^{2+}\ (aq) + 2OH^-\ (aq)$$

K_{sp} for $Fe(OH)_2$ is 1.6×10^{-14}.

What is ΔG^0 for the reaction, and based on this value, indicate whether reactants or products are favoured at equilibrium.

a) 79 kJ; reactants are favoured over products at equilibrium
b) -79 kJ; reactants are favoured over products at equilibrium
c) 79 kJ; products are favoured over reactants at equilibrium
d) -79 kJ; products are favoured over reactants at equilibrium
e) not enough information provided

48. Ammonia (NH_3) is a colourless gas at room temperature. Given that its enthalpy of fusion is 5.65 kJ mol^{-1} and its entropy of fusion is 28.9 J mol^{-1} K^{-1}, will NH_3 (s) spontaneously melt at 170 K? What is the approximate melting point of ammonia?

a) Yes; 156 K
b) No; 203 K
c) Yes; 141 K
d) No; 196 K
e) Yes; 164 K

49. Nitrogen, which is used to synthesize ammonia, is heated slowly, maintaining the external pressure close to the internal pressure of 50 atm. If the volume increases from 250 L to 500 L, calculate the amount of work done on the nitrogen as it is heated. (Note: 1 L atm = 101.325 J)

a) -1.27×10^6 J
b) 1.27×10^6 J
c) 1.25×10^4 J
d) -1.25×10^4 J
e) -1.15×10^4 J

50. When considering the spontaneity of a process, which statement is TRUE?

a) For $\Delta S > 0$ and $\Delta H > 0$, the process will be spontaneous at all temperatures.
b) For $\Delta S < 0$ and $\Delta H > 0$, the process is spontaneous at high temperatures.
c) For $\Delta S < 0$ and $\Delta H < 0$, the process will be spontaneous at low temperatures.
d) For $\Delta S > 0$ and $\Delta H < 0$, the process is not spontaneous at any temperature.
e) A process is spontaneous when $\Delta G°$ is positive.

51. Hot packs used in first aid kits and hand warmers usually contain calcium chloride. By breaking an inner pouch, the dissolution of this salt results in heating of the water. Calculate the standard enthalpy change $\Delta H°$ for this reaction, and the temperature reached if 18.0 g of $CaCl_2$ is dissolved in water to give a volume of 100.0 mL of solution at 20.0 °C (Assume the solution is ideal with a heat capacity close to that of pure water = 4.18 J mL^{-1} K^{-1} and that no heat is lost from the solution)

$CaCl_2\ (s) \rightarrow Ca^{2+}\ (aq) + 2Cl^-\ (aq)$

Data:
$\Delta H°_f\ (CaCl_{2\ (s)}) = -795.8$ kJ/mol
$\Delta H°_f\ (Ca^{2+}{}_{(aq)}) = -542.8$ kJ/mol
$\Delta H°_f\ (Cl^-{}_{(aq)}) = -167.2$ kJ/mol

a) $\Delta H° = 81.4$ kJ; T = 51.6 °C
b) $\Delta H° = -81.4$ kJ; T = 51.6 °C
c) $\Delta H° = 85.8$ kJ; T = 53.3 °C
d) $\Delta H° = -85.8$ kJ; T = 53.3 °C
e) $\Delta H° = 78.2$ kJ; T = 50.3 °C

52. Adenosine triphosphate (ATP) hydrolysis to adenosine diphosphate (ADP) is an important source of energy in our cells. Symbolically, this reaction can be written as

$ATP\ (aq) + H_2O\ (l) \rightarrow ADP\ (aq) + H_2PO_4^-\ (aq)$ $\Delta G° = -30.5$ kJ/mol

The body can synthesize ATP from ADP using the energy released from the metabolism of glucose:

$C_6H_{12}O_6\ (s) + 6\ O_2\ (g) \rightarrow 6\ CO_2\ (g) + 6\ H_2O\ (l)$

Calculate K for ATP hydrolysis at 25 °C. If all the free energy from the metabolism of glucose goes into forming ATP from ADP, how many molecules of ATP can be produced for every molecule of glucose metabolized?

Data:
$\Delta G_f°\ (C_6H_{12}O_{6\ (s)}) = -911$ kJ/mol
$\Delta G_f°\ (CO_{2\ (g)}) = -394$ kJ/mol
$\Delta G_f°\ (H_2O_{\ (l)}) = -237$ kJ/mol

a) K = 1.01; 9 molecules
b) $K = 2.22 \times 10^5$; 94 molecules
c) $K = 2.22 \times 10^5$; 17 molecules
d) K = 1.01; 17 molecules
e) $K = 1.23 \times 10^3$; 94 molecules

53. Balance the following reaction in basic solution:
$ClO^-(aq) + Cr(OH)_4^-(aq) \rightarrow CrO_4^{2-}(aq) + Cl^-(aq)$

What is the coefficient in front of $CrO_4^{2-}(aq)$ in the balanced reaction?

a) 1 b) 2 c) 3 d) 4 e) 6

Use the following potentials to answer Questions 54 to 55.

	E° (V)
$Au^{3+}(aq) + 2e^- \rightleftharpoons Au^+(aq)$	1.40
$Al^{3+}(aq) + 3e^- \rightleftharpoons Al(s)$	-1.66
$Fe^{3+}(aq) + 3e^- \rightleftharpoons Fe(s)$	-0.04
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	0.80
$Br_2(l) + 2e^- \rightleftharpoons 2Br^-(aq)$	1.09

54. Which of the following substances is the strongest oxidizing agent?
a) Al b) Br_2 c) Au^{3+} d) Al^{3+} e) Au^+

55. Which substance could be spontaneously oxidized by Ag^+?
a) Au^{3+} b) Al^{3+} c) Br^- d) Al e) Au^+

56. Lime (CaO) is used in large quantities in construction, in production of chemicals and in wastewater treatment. Lime can be produced from the thermal decomposition of calcium carbonate:

	$CaCO_3(s) \rightleftharpoons$	$CaO(s) +$	$CO_2(g)$
H_f° (kJ mol^{-1})	-1207	-636	-394
S° (J mol^{-1}K^{-1})	93	40	214

Assuming ΔH° and ΔS° are independent of temperature, what is the equilibrium pressure of CO_2 when $CaCO_3$ is added to an evacuated flask at 950 K?

a) 21 atm b) 3.2 atm c) 1.0 atm d) 0.092 atm e) 0.048 atm

57. A given redox reaction has a positive standard cell potential. Which of the following statements must be true for the redox reaction?

i) The equilibrium constant for the reaction is greater than 1.
ii) The standard free energy change for the reaction is negative.
iii) The reaction occurs spontaneously with any concentrations of reactants and products.

a) i only b) ii only c) iii only d) i and ii only e) i, ii and iii

58. A galvanic cell is set up under standard state conditions based on the following half-reactions at 298 K:

$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$ standard reduction potential = -0.26 V

$Co^{2+}(aq) + 2e^- \rightarrow Co(s)$ standard reduction potential = -0.28 V

What is the $[Co^{2+}]$ when the battery is dead?

a) 0.35 M b) 0.65 M c) 1.35 M d) 1.55 M e) 1.65 M

59. Which of the following statements about galvanic and electrolytic cells is TRUE?

a) The anode will increase in weight in a galvanic cell.
b) Oxidation occurs at the cathode of both cells.
c) The free energy change, ΔG, is negative for the galvanic cell.
d) The electrons in the external wire flow from cathode to anode in an electrolytic cell.
e) None of a)-d) are correct.

60. The solubility product of $PbCl_2$ is 1.7×10^{-5} at 298 K. Calculate the standard free energy change for the dissolution of $PbCl_2$. Is it possible to prepare a solution that contains 1 M Pb^{2+} ions and 1 M Cl^- ions?

a) 27.2 kJ, No.
b) -27.2 kJ, No.
c) 27.2 kJ, Yes.
d) -27.2 kJ, Yes.
e) 0 kJ, Yes.