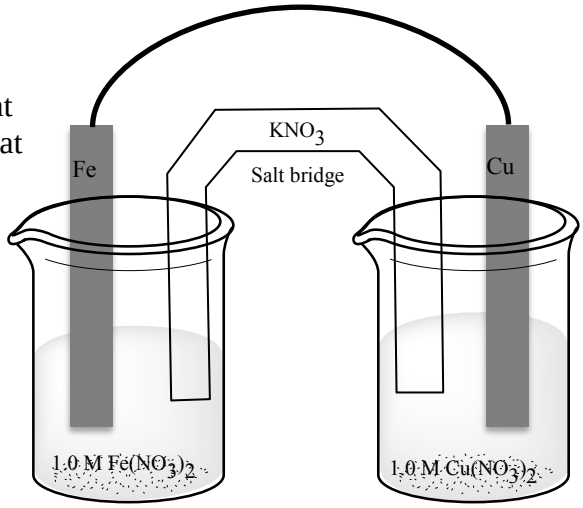
December 2021 Problem Set

Questions 41 – 46 are based on a galvanic cell that is made up of the following two 1.00 L half-cells at 298 K:

i) Fe electrode in a 1.00 M $Fe(NO_3)_2$ solution
ii) Cu electrode in a 1.00 M $Cu(NO_3)_2$ solution



The standard reduction potentials are as follows:

$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$ $\quad E° = -0.45$ V
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ $\quad E° = 0.34$ V

41. Which of the following statements is TRUE?
a) Fe^{2+} is oxidized to Fe when the galvanic cell operates spontaneously.
b) The anode is the copper electrode.
c) The K^+ ions from the salt bridge move in the direction of the copper half-cell.
d) Electrons move from the copper electrode to the iron electrode.
e) As the cell operates, the cell potential gradually increases.

42. The standard cell notation for the galvanic cell is
a) $Fe(s) \mid Fe^{2+}(aq) \parallel Cu^{2+}(aq) \mid Cu(s)$
b) $Cu(s) \mid Cu^{2+}(aq) \parallel Fe^{2+}(aq) \mid Fe(s)$
c) $Fe(s) \mid Fe^{2+}(aq) \parallel Cu(s) \mid Cu^{2+}(aq)$
d) $Fe^{2+}(aq) \mid Fe(s) \parallel Cu(s) \mid Cu^{2+}(aq)$
e) $Cu^{2+}(aq) \mid Cu(s) \parallel Fe(s) \mid Fe^{2+}(aq)$

43. Which of the following statements is FALSE?
a) Increasing the $[Cu^{2+}]$ would increase the cell potential.
b) Decreasing the $[Fe^{2+}]$ would increase the cell potential.
c) As the cell operates, the mass of the copper electrode increases.
d) Increasing the mass of iron electrode would increase the cell potential.
e) Increasing the mass of the copper electrode would not affect the cell potential.

44. What is the standard cell potential for the galvanic cell?
a) 0.34 V b) 0.45 V c) 0.11 V d) 0.79 V e) -0.11 V

45. Which of the following statements is FALSE?
a) When the battery dies the cell potential is zero.
b) The [Cu^{2+}] has essentially all reacted when equilibrium is reached.
c) The standard free energy change is negative for the reaction that occurs in the cell.
d) The reaction that occurs in this galvanic cell essentially goes to completion.
e) At equilibrium, there is a relatively low concentration of Fe^{2+} ions.

46. If the initial [Fe^{2+}] is 1.8 M and the initial [Cu^{2+}] is 0.50 M, what is the cell potential of the galvanic cell?
a) 0.0 V b) 0.65 V c) 0.77 V d) 0.79 V e) 0.81 V

Use the following table of standard reduction potentials to answer questions 47-49.

$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	0.77 V
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	0.34 V
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	0.00 V
$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$	-0.26 V
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	-0.45 V

47. Which of the following substance is the strongest reducing agent?
a) Fe^{3+} b) Fe^{2+} c) Fe d) H_2 e) Cu

48. Which of the following substances is the strongest oxidizing agent?
a) Fe^{3+} b) Fe^{2+} c) Fe d) Ni e) Ni^{2+}

49. To make a galvanic cell with the highest standard cell potential, we should use
a) a Pt cathode in a Fe^{2+}/Fe^{3+} solution and a Fe anode in a Fe^{2+}solution.
b) a Pt anode in a Fe^{2+}/Fe^{3+} solution and a Fe cathode in a Fe^{2+}solution.
c) a Pt cathode in a Fe^{2+}/Fe^{3+} solution and a Cu anode in a Cu^{2+}solution.
d) a Pt anode in a Fe^{2+}/Fe^{3+} solution and a Cu cathode in a Cu^{2+}solution.
e) a Ni anode in Ni^{2+} solution and a Cu cathode in a Cu^{2+}solution

50. Determine the number of water molecules necessary to balance the following chemical reaction:

$$MnO_4^-(aq) + Fe^{2+}(aq) + H^+(aq) \rightarrow Mn^{2+}(aq) + Fe^{3+}(aq) + H_2O(l)$$

a) 0 b) 2 c) 4 d) 5 e) 14

51. Lactic acid ($C_3H_6O_3$) is an intermediate in the metabolism of glucose. When 0.149 g of lactic acid is combusted in a constant volume calorimeter in an excess of oxygen, only CO_2 and H_2O are formed and 2.24 kJ of energy is released. If the heat capacity of the calorimeter is 0.827 kJ K^{-1} and the initial temperature was 23.44°C, calculate the final temperature after combustion.

a) 2.71°C b) 26.15°C c) 28.34°C d) 25.11°C e) 27.23°C

52. When proteins are heated, *denaturation* takes place and the hydrogen bonding in the secondary structure breaks apart. What are the algebraic signs of ΔH and ΔS for this process?

a) Both ΔH and ΔS are negative
b) Both ΔH and ΔS are positive
c) ΔH is positive and ΔS is negative
d) ΔH is negative and ΔS is positive
e) ΔH is positive and ΔS is zero

53. Consider the reaction at 298 K:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

	$2SO_2(g)$	$O_2(g)$	$2SO_3(g)$
$\Delta H_f°$ (kJ/mol)	-297		-396
S° (J/(molK))	248	205	257

Under standard state conditions, which of the following statements is TRUE?
a) The reaction does not occur to a significant extent.
b) At equilibrium, there will be roughly equal amounts of reactants and products.
c) The equilibrium constant for this reaction is large and negative.
d) The reaction essentially goes to completion.
e) The reverse reaction is thermodynamically favoured.

54. For the reaction in Question 53, determine the equilibrium partial pressure of O_2 if the equilibrium mixture has a partial pressure of SO_2 of 1.2 atm and a partial pressure of SO_3 of 0.010 atm?
a) 1.3×10^{29} atm b) 3.1×10^{-14} atm c) 2.8×10^{-15} atm d) 9.6×10^{-28} atm
e) 8.0×10^{-30} atm

55. For the reaction in Question 53, at what temperature is the reaction already at equilibrium under standard state conditions? (Assume $\Delta H_f°$ and S° are independent of temperature.)

a) -273 K b) 1.06 K c) 273 K d) 1059 K e) 2100 K

56. Under what conditions is the following reaction spontaneous?

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

a) The reaction is spontaneous at all temperatures.
b) The reaction is not spontaneous at any temperature.
c) The reaction is spontaneous at lower temperatures.
d) The reaction is spontaneous at higher temperatures.

57. Calculate the $\Delta H°$ for the following reaction:

$$A(g) + 2D(g) \rightarrow F(g) + G(g)$$

given:	$\Delta H°$(kJ/mol)
$E(g) \rightarrow C(g) + D(g)$	-250
$A(g) \rightarrow 2C(g) + G(g)$	-34
$F(g) \rightarrow 2E(g)$	320

a) 146 kJ/mol b) -104 kJ/mol c) 36 kJ/mol d) -36 kJ/mol e) 104 kJ/mol

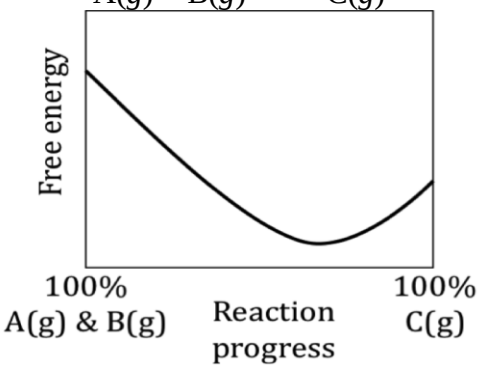
58. Consider the reaction at 298 K:

	$CaCO_3(s) \rightarrow$	$CaO(s) +$	$CO_2(g)$
$\Delta H_f°$ (kJ/mol)	-1207.6	-634.9	-393.5

How much heat is absorbed/released if 10.0 g of $CaCO_3$ decompose?
a) 17.9 kJ absorbed b) 17.9 kJ released c) 22.3 kJ absorbed
d) 22.3 kJ released e) 10.3 kJ absorbed

59. A plot of free energy vs. reaction progress is shown below for the reaction

$A(g) + B(g) \rightleftharpoons C(g)$



How many of the statements (i-v) are **true**?

i. The minimum energy corresponds to the mixture of reactants and products present at equilibrium.
ii. At equilibrium, all of A and B have reacted to give C.
iii. For the reaction, the change in entropy is positive.
iv. The value of K is greater than 1.
v. The standard enthalpy change for the reaction must be negative.

a) 1 b) 2 c) 3 d) 4 e) 5

60. A 10.0 g sample of metal at 52.0 °C is placed in 100.0 g of water at 25.1 °C in an insulated container. The temperature of the water rises to 25.5 °C. What is the specific heat capacity of the metal? Assume that all heat lost by the metal is gained by the water. The specific heat capacity of water is 4.184 J/(gK).
a) 0.24 J/(gK) b) 0.45 J/(gK) c) 0.58 J/(gK) d) 0.63 J/(gK) e) 1.28 J/(gK)