CHEM 103 Exam #2

Multiple Choice

Identify the letter of the choice that best completes the statement or answers the question.

____ 1. Two substances, A and B, have identical enthalpies of vaporization. They boil at 164 C and 236 C, respectively. If the entropy of vaporization of A is 87.2 J/K, what is the entropy of vaporization of B, in J/K?
a. 102
b. 60.6
c. 126
d. 38.3
e. 74.9

____ 2. Which process involves a decrease of entropy for the system?
a. baking a cake from scratch
b. making tossed salad
c. alphabetizing your chemistry books by author
d. mixing fruit punch
e. preparing instant mashed potatoes

____ 3. Calculate the value of S for the reaction shown:

$2\ NH_3(g) \rightleftharpoons N_2(g) + 3\ H_2(g)$

At 25 C the values of entropy in J K^{-1} mol^{-1} are ammonia, 192.77; nitrogen, 191.61; and hydrogen, 130.68.
a. +969.19 J/K
b. +393.20 J/K
c. +390.88 J/K
d. +259.03 J/K
e. +198.11 J/K

____ 4. A reaction is exothermic and has a negative value of S . The value of G for this reaction is therefore:
a. negative at all temperatures.
b. positive at all temperatures.
c. positive above 0 C and negative below 0 C.
d. positive above a certain temperature and negative below it.
e. negative above a certain temperature and positive below it.

____ 5. Use the data given to calculate the value of G_{rxn} for the reaction at 25 C.

$2\ C(graphite) + H_2(g) \rightarrow C_2H_2(g)$

	C(graphite)	$H_2(g)$	$C_2H_2(g)$
S (J K^{-1} mol^{-1})	5.74	130.68	201.0
H_f (kJ/mol)	0	0	-226.8

a. -291.4 kJ
b. -244.3 kJ
c. -226.8 kJ
d. -207.6 kJ
e. -64.6 kJ

____ 6. Use the data at 25 C given below to calculate the value of G_{rxn} for the reaction shown when it takes place at 120 C.

$C_3H_8(g) + 5\ O_2(g) \rightarrow 4\ H_2O(g) + 3\ CO_2(g)$

	$C_3H_8(g)$	$O_2(g)$	$H_2O(g)$	$CO_2(g)$
H_f (kJ/mol)	-104.8	0	-241.84	-393.52
S (J K^{-1} mol^{-1})	270.2	205.15	188.74	213.80
G_f (kJ/mol)	-23.6	0	-228.61	-394.39

a. -2004 kJ
b. -2046 kJ
c. -2055 kJ
d. -2073 kJ
e. -2083 kJ

____ 7. If a chemical reaction is at equilibrium, it must be true that
a. G = 1.
b. G > 1.
c. G < 1.
d. G = 1.
e. G = 0.

____ 8. The value of the equilibrium constant for a reaction is 2.65×10^{-6} at 45 C. Calculate the value of G_{rxn} at this temperature.
a. +47.4 kJ
b. +34.0 kJ
c. +14.8 kJ
d. +335 kJ
e. -14.8 kJ

____ 9. Use the data given to calculate the value of K for the reaction at 25 C

$AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$

	AgCl(s)	$Ag^+(aq)$	$Cl^-(aq)$
S (J K^{-1} mol^{-1})	+96.2	+72.68	+56.4
H_f (kJ/mol)	-127.07	+105.58	-167.2

a. 6.61×10^{-14}
b. 3.41×10^{-12}
c. 4.75×10^{-12}
d. 1.76×10^{-10}
e. 5.69×10^{9}

____ 10. Which statement correctly describes the meaning of the value of G_{rxn} for a reactant-favored reaction?
a. It is the amount of energy that is required to overcome the disorder of the system.
b. It is the amount of additional energy that must be supplied in order to initiate reaction.
c. It is the minimum amount of heat released from the system when reaction occurs.
d. It is the maximum amount of useful work obtainable from the reaction when it occurs.
e. It is the minimum amount of work which must be done on the system to make reaction occur.

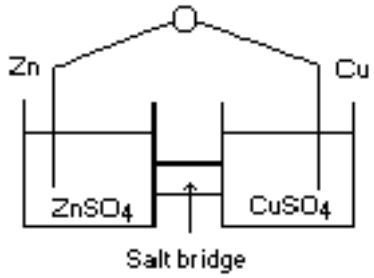
____ 11. Which of these ***must*** be present in a redox reaction?
a. a substance present as an element which becomes incorporated into a molecule, or *vice versa*
b. an atom whose oxidation number increases
c. an atom whose oxidation number decreases
d. either b or c
e. both b and c

____ 12. When the reaction shown below is balanced, the coefficients are _____,and _____ electrons are transferred.

$Al(s) + Hg^{2+}(aq) \rightarrow Al^{3+}(aq) + Hg(l)$

a. 1, 3, 1, and 3; 6
b. 2, 3, 2, and 3; 6
c. 3, 2, 3, and 2; 6
d. 2, 3, 2, and 3; 12
e. 3, 2, 3, and 2; 12

____ 13. Consider an electrochemical cell as shown, with Zn in $ZnCl_2(aq)$ and Cu in $Cu(NO_3)_2(aq)$, and a salt bridge containing $KNO_3(aq)$. The overall chemical reaction is $Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$. Which statement is correct?



a. One mole of electrons is transferred in this reaction.
b. Copper is oxidized at the anode.
c. Electrons travel from the Zn to the Cu.
d. This is an example of a concentration cell.
e. Zinc is reduced at the cathode.

____ 14. Which cell notation represents a battery constructed using zinc and iron, with electrons flowing from zinc to iron?
a. $Fe^{3+}(aq) \mid Fe^{2+}(aq) \parallel Zn(s) \mid Zn^{2+}(aq)$
b. $Fe^{3+}(aq) \mid Fe(s) \parallel Zn(s) \mid Zn^{2+}(aq)$
c. $Zn(s) \mid Zn^{2+}(aq) \parallel Fe^{3+}(aq) \mid Fe^{2+}(aq)$
d. $Zn(s) \mid Zn^{2+}(aq) \parallel Fe^{3+}(aq) \mid Fe(s)$
e. $Zn(s) \mid Zn^{2+}(aq) \parallel Fe(s) \mid Fe^{3+}(aq)$

Exhibit 19-1
Use this list of half-reactions to answer the following question(s).

$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$	+1.51 V
$Cr_2O_7^{2-}(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$	+1.33 V
$Pt^{2+}(aq) + 2e^- \rightarrow Pt(s)$	+1.20 V
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	+0.34 V
$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$	-0.13 V
$Al^{3+}(aq) + 3e^- \rightarrow Al(s)$	-1.66 V

____ 15. Refer to Exhibit 19-1. The potential for the product-favored reaction involving aluminum and copper metals, $Al^{3+}(aq)$, and $Cu^{2+}(aq)$ is
a. 2.17 V.
b. 2.00 V.
c. 1.79 V.
d. 1.32 V.
e. 1.15 V.

____ 16. Refer to Exhibit 19-1. An electrochemical cell is designed using copper as one electrode and another metal higher than copper on the table above as the other electrode. The cell potential is +0.515 V. The potential for the unknown half-reaction is _____,and that electrode is the _____.
a. 0.175 V; anode
b. 0.175 V; cathode
c. 0.340 V; cathode
d. 0.855 V; anode
e. 0.855 V; cathode

____ 17. Consider the cell reaction
$Sn(s) + Cu^{2+}(aq) \rightarrow Sn^{2+}(aq) + Cu(s)$.
The value of E_{cell} is 0.447 V at 25 C. Calculate the value of G and K for this cell.
a. -86.3 kJ; 1.34×10^{15}
b. -43.1 kJ; 1.37×10^{43}
c. 43.1 kJ; 3.55×10^{7}
d. 86.3 kJ; 7.92×10^{-16}
e. 86.3 kJ; 2.00×10^{86}

____ 18. The value of E_{cell} for the cell shown below is + 1.41 V.
$Al(s) \mid Al^{3+}(aq) \parallel Ni^{2+}(aq) \mid Ni(s)$
What is the value of E_{cell} at 25 C if the concentration of $Al^{3+}(aq)$ is 0.050 M, and of $Ni^{2+}(aq)$, 2.0 M?
a. +1.34 V
b. +1.38 V
c. +1.41 V
d. +1.44 V
e. +1.48 V

____ 19. Which statement concerning concentration cells is not correct?
a. The electrons flow from the anode to the cathode.
b. The cell becomes useless when the concentrations of the metal ions in both compartments becomes equal.
c. The concentration of metal ions in the cathode compartment must be greater than the concentration of metal ions in the anode compartment.
d. The value of Q for the system is 1.
e. Both cell compartments use the same half-reaction.

____ 20. A mass of 0.839 g of a divalent metal is plated out of a solution of the divalent metal ion. This takes 67.2 min at a current of 0.63 A. What is the metal? (Hint: find its atomic mass.)
a. Cd
b. Cu
c. Hg
d. Fe
e. Mg

Short Answer

21. For the reaction shown, G = -32.8 kJ at 25 C.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

a. Calculate the equilibrium constant for this reaction at 25 C.
b. Is a mixture of the three gases where p_{N2} = 3.5 bar, pH_2 = 1.2 bar, and pNH_3 = 0.22 bar at equilibrium? Justify your answer.
c. What is the value of G under the conditions of part b?
d. Compare the answer from part c. with G . Explain the difference observed.

22. Refer to the following values of standard reduction potentials.

$Au^{3+}(aq) + 3e^- \rightarrow Au(s)$	+1.00 V
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	-0.763 V

a. Write the balanced overall reaction for gold reacting with zinc(II) ion.
b. Calculate the value of E_{cell} for the reaction.
c. How many electrons are transferred in this reaction? Explain.
d. Calculate the value of G for this cell at 25 C.
e. Calculate the value of the equilibrium constant for this reaction at 25 C.
f. Is this reaction product-favored or reactant-favored? Explain how your answers in parts b, d, and e support this conclusion.

CHEM 103 Exam #2
Answer Section

MULTIPLE CHOICE

1. ANS: E OBJ: 18.3 Measuring Dispersal of Energy: Entropy
2. ANS: C OBJ: 18.3 Measuring Dispersal of Energy: Entropy
3. ANS: E OBJ: 18.4 Calculating Entropy Changes
4. ANS: D OBJ: 18.6 Gibbs Free Energy
5. ANS: B OBJ: 18.6 Gibbs Free Energy
6. ANS: E OBJ: 18.6 Gibbs Free Energy
7. ANS: E OBJ: 18.7 Gibbs Free Energy Changes and Equilibrium Constants
8. ANS: B OBJ: 18.7 Gibbs Free Energy Changes and Equilibrium Constants
9. ANS: D OBJ: 18.7 Gibbs Free Energy Changes and Equilibrium Constants
10. ANS: E OBJ: 18.8 Gibbs Free Energy, Maximum Work, and Energy Resources
11. ANS: E OBJ: 19.1 Redox Reactions
12. ANS: B OBJ: 19.2 Using Half-reactions to Understand Redox Reactions
13. ANS: C OBJ: 19.3 Electrochemical Cells
14. ANS: D OBJ: 19.3 Electrochemical Cells
15. ANS: B OBJ: 19.5 Using Standard Cell Potentials
16. ANS: E OBJ: 19.5 Using Standard Cell Potentials
17. ANS: A OBJ: 19.6 E° and Gibbs Free Energy
18. ANS: D OBJ: 19.7 Effect of Concentration on Cell Potential
19. ANS: D OBJ: 19.7 Effect of Concentration on Cell Potential
20. ANS: B OBJ: 19.12 Counting Electrons

SHORT ANSWER

21. ANS:

a. $G = -RT \ln K$
$\Rightarrow K = e(-G/RT) = e(3.28 \times 10^4 \text{ J mol}^{-1}/(8.3145 \text{ J K}^{-1} \text{ mol}^{-1} \times 298.2 \text{ K}) = 5.56 \times 10^5$.

b. $Q = \dfrac{\rho^2_{NH_3}}{\rho_{N_2} \cdot \rho^3_{H_2}} = (0.22)^2/(3.5 \times (1.2)^3) = 8.0 \times 10^{-3}$.

Since this is much less than K, the system is not at equilibrium; it will react left to right.

c. $G = G + RT \ln Q$
$= -3.28 \times 10^4 \text{ J mol}^{-1} + (8.314 \text{ J K}^{-1} \text{ mol}^{-1} \times 298.2 \text{ K} \times \ln (8.0 \times 10^{-3})$
$= (-32.8 - 12.0) \text{ kJ mol}^{-1}$
$= -44.8 \text{ kJ mol}^{-1}$.

d. The value of G is negative, and even larger than the value of G . This is reasonable; in contrast to the conditions of G , where all pressures are 1 bar, the conditions of part b. have less products and more reactants. We therefore expect a greater tendency towards product-favored behavior.

22. ANS:

a. $3\ Zn^{2+}(aq) + 2\ Au(s) \rightarrow 3\ Zn(s) + 2\ Au^{3+}(aq)$

b. $E_{cell} = E_{cathode} - E_{anode} = -0.763\ V - (+1.00\ V) = -1.76\ V$

c. Six electrons are transferred because six is the least common multiple of 2 and 3. Zinc ions gain electrons in multiples of two and gold atoms lose electrons in multiples of three.

d. $G = -nF\ E_{cell}$
$= -(6\ mol\ electrons \times 96{,}485\ C/mol\ electrons \times (-1.76\ V) \times 1\ J\ V^{-1}\ C^{-1}$
$= +1.02 \times 10^{6}\ J$

e. $G = -RT \ln K \Rightarrow \ln K = -G/RT$.

Thus, $\ln K = -(+1.02 \times 10^{6}\ J/(8.314\ J/K \times 298.2\ K)) = -411$

$\Rightarrow K = \sim 3 \times 10^{-179}$.

f. This reaction is extremely reactant-favored; the value of G is a large positive number, the value of E_{cell} is large and negative, and the value of K is very small. This is scarcely surprising; Zn is a moderately reactive metal and the reduction of Zn^{2+} to the metal is therefore reactant-favored. On the other hand, gold, a coinage metal, is resistant to oxidation. Thus, the process is heavily reactant-favored overall.