CH142
Sample Exam 3 Questions

Multiple Choice

1) The first law of thermodynamics can be stated as ________.
   A) $\Delta E = q + w$
   B) $\Delta H°_{rxn} = \sum n\Delta H°_f\,(\text{products}) - \sum m\Delta H°_f\,(\text{reactants})$
   C) for any spontaneous process, the entropy of the universe increases
   D) the entropy of a pure crystalline substance at absolute zero is zero
   E) $\Delta S = q_{rev}/T$ at constant temperature

2) Which is always true of a reaction that is spontaneous?
   A) It is very rapid.
   B) It proceeds without outside intervention.
   C) It is also spontaneous in the reverse direction.
   D) It has an equilibrium position that lies far to the left.
   E) It releases heat.

3) For an isothermal process, ΔS = ________.
   A) q
   B) q_{rev}/T
   C) q_{rev}
   D) Tq_{rev}
   E) $q + w$

4) The entropy of the universe is ________.
   A) constant
   B) continually decreasing
   C) continually increasing
   D) zero
   E) the same as the energy, E

5) Which one of the following processes produces a decrease of the entropy of the system?
   A) dissolving sodium chloride in water
   B) sublimation of naphthalene
   C) dissolving oxygen in water
   D) boiling of alcohol
   E) explosion of nitroglycerine

6) Which one of the following statements is true about the equilibrium constant for a reaction if $\Delta G°$ for the reaction is negative?
   A) $K = 0$
   B) $K = 1$
   C) $K > 1$
   D) $K < 1$
   E) More information is needed.

7) For the reaction

$$C_2H_6\ (g) \rightarrow C_2H_4\ (g) + H_2\ (g)$$

$\Delta H°$ is +137 kJ/mol and $\Delta S°$ is +120 J/K · mol. This reaction is ________.

A) spontaneous at all temperatures
B) spontaneous only at high temperature
C) spontaneous only at low temperature
D) nonspontaneous at all temperatures
E) spontaneous only at equilibrium

8) Given the following table of thermodynamic data, what is true about the vaporization of $TiCl_4$?

Substance	$\Delta H_f°$ (kJ/mol)	S° (J/mol • K)
$TiCl_4$ (g)	−763.2	354.9
$TiCl_4$ (l)	−804.2	221.9

A) spontaneous at all temperatures
B) spontaneous at low temperature and nonspontaneous at high temperature
C) nonspontaneous at low temperature and spontaneous at high temperature
D) nonspontaneous at all temperatures
E) not enough information given to draw a conclusion

9) Which has the greatest entropy?

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

10) For which reaction is ΔS positive?

A) $2H_2\ (g) + O_2\ (g) \rightarrow 2H_2O\ (g)$
B) $2NO_2\ (g) \rightarrow N_2O_4\ (g)$
C) $CO_2\ (g) \rightarrow CO_2\ (s)$
D) $BaF_2\ (s) \rightarrow Ba^{2+}\ (aq) + 2F^-\ (aq)$
E) $2Hg\ (l) + O_2\ (g) \rightarrow 2HgO\ (s)$

11) Which of the following reactions is a redox reaction?

(a) $K_2CrO_4 + BaCl_2 \rightarrow BaCrO_4 + 2KCl$
(b) $Pb^{2+} + 2Br^- \rightarrow PbBr_2$
(c) $Cu + S \rightarrow CuS$

A) (a) only
B) (b) only
C) (c) only
D) (a) and (c)
E) (b) and (c)

12) Which substance is the oxidizing agent in the following reaction?

$$Fe_2S_3 + 12HNO_3 \rightarrow 2Fe(NO_3)_3 + 3S + 6NO_2 + 6H_2O$$

A) HNO_3
B) S
C) NO_2
D) Fe_2S_3
E) H_2O

13) Which transformation could take place at the anode of an electrochemical cell?
A) $Cr_2O_7^{2-} \rightarrow Cr^{2+}$
B) F_2 to F^-
C) O_2 to H_2O
D) $HAsO_2$ to As
E) None of the above could take place at the anode.

14) What is purpose of the salt bridge in an electrochemical cell?
A) To maintain electrical neutrality in the half-cells via migration of ions
B) To provide a source of ions to react at the anode and cathode
C) To provide oxygen to facilitate oxidation at the anode
D) To provide a means for electrons to travel from the anode to the cathode
E) To provide a means for electrons to travel from the cathode to the anode

15) Consider an electrochemical cell based on the reaction:

$$2H^+ (aq) + Sn (s) \rightarrow Sn^{2+} (aq) + H_2 (g)$$

Which of the following actions would change the measured cell potential?
A) increasing the pH in the cathode compartment
B) lowering the pH in the cathode compartment
C) increasing the $[Sn^{2+}]$ in the anode compartment
D) increasing the pressure of hydrogen gas in the cathode compartment
E) Any of the above will change the measured cell potential.

16) Cathodic protection of a metal pipe against corrosion usually entails ________.
A) attaching an active metal to make the pipe the anode in an electrochemical cell
B) coating the pipe with another metal whose standard reduction potential is less negative than that of the pipe
C) attaching an active metal to make the pipe the cathode in an electrochemical cell
D) attaching a dry cell to reduce any metal ions which might be formed
E) coating the pipe with a fluoropolymer to act as a source of fluoride ion (since the latter is so hard to oxidize)

Half Reaction	E°(V)
F_2 (g) + $2e^-$ → $2F^-$ (aq)	+2.87
Cl_2 (g) + $2e^-$ → $2Cl^-$ (aq)	+1.359
Br_2 (l) + $2e^-$ → $2Br^-$ (aq)	+1.065
Ag^+ + e^- → Ag (s)	+0.799
I_2 (s) + $2e^-$ → $2I^-$ (aq)	+0.536
$2H^+$ + $2e^-$ → H_2 (g)	0
Pb^{2+} + $2e^-$ → Pb (s)	-0.126
Li^+ + e^- → Li (s)	-3.05

17) Which of the halogens in the table above is the strongest oxidizing agent?
A) Cl_2
B) Br_2
C) F_2
D) I_2
E) All of the halogens have equal strength as oxidizing agents.

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

18) Which of the following reactions will occur spontaneously as written? (See table above.)
A) Sn^{4+} (aq) + Fe^{3+} (aq) → Sn^{2+} (aq) + Fe^{2+} (aq)
B) 3Fe (s) + $2Cr^{3+}$ (aq) → 2Cr (s) + $3Fe^{2+}$ (aq)
C) Sn^{4+} (aq) + Fe^{2+} (aq) → Sn^{2+} (aq) + Fe (s)
D) $3Sn^{4+}$ (aq) + 2Cr (s) → $2Cr^{3+}$ (aq) + $3Sn^{2+}$ (aq)
E) $3Fe^{2+}$ (aq) → Fe (s) + $2Fe^{3+}$ (aq)

19) What is the oxidation number of chromium in $Cr_2O_7^{2-}$ ion?
A) +3 B) +12 C) +7 D) +6 E) +14

20) What is a difference between a voltaic cell and an electrolytic cell? In an electrolytic cell, __
A) an electric current is produced by a chemical reaction
B) electrons flow toward the anode
C) a nonspontaneous reaction is forced to occur
D) O_2 gas is produced at the cathode
E) oxidation occurs at the cathode

Short Answer

21) Circle the reactions that produce a decrease in the entropy of the system.

$CaCO_3$ (s) $\rightarrow$ CaO (s) + CO_2 (g)

2C (s) + O_2 (g) $\rightarrow$ 2CO (g)

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

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

4 NH_3 (g) + 5 O_2 (g) $\rightarrow$ 4 NO (g) + 6 H_2O (g)

Na (s) + 1/2 Cl_2 (g) $\rightarrow$ NaCl (s)

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

22) Consider the reaction:

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

Given the following table of thermodynamic data,

Substance	$\Delta H_f°$ (kJ/mol)	S° (J/mol • K)
Ag^+ (aq)	105.90	73.93
Cl^- (aq)	−167.2	56.5
AgCl (s)	−127.0	96.11

What is the temperature above which the reaction is nonspontaneous under standard conditions?

23) In the Haber process, ammonia is synthesized from nitrogen and hydrogen:

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

$\Delta G°$ at 298 K for this reaction is -33.3 kJ/mol. What is the value of ΔG at 298 K for a reaction mixture that consists of 1.9 atm N_2, 2.3 atm H_2, and 0.85 atm NH_3?

Thermodynamic Quantities for Selected Substances at 298.15 K (25 °C)

Substance	$\Delta H°_f$ (kJ/mol)	$\Delta G°_f$ (kJ/mol)	S (J/K-mol)
Oxygen			
O_2 (g)	0	0	205.0
H_2O (l)	-285.83	-237.13	69.91
Sulfur			
S (s, rhombic)	0	0	31.88
SO_2(g)	-269.9	-300.4	248.5
SO_3(g)	-395.2	-370.4	256.2

24) Given the following reaction at 25 °C:

$$2S\text{ (s, rhombic)} + 3O_2(g) \rightarrow 2SO_3\text{ (g)}$$

a) What is the value of $\Delta S°$? (See table above.)

b) What is the value of $\Delta H°$? (See table above.)

c) What is the value of $\Delta G°$? (See table above.)

25) A voltaic cell is constructed with two silver-silver chloride electrodes, where the half-reaction is

$$AgCl\text{ (s)} + e^- \rightarrow Ag\text{ (s)} + Cl^-\text{ (aq)} \qquad E_{red}° = +0.222\text{ V}$$

The concentrations of chloride ion in the two compartments are 0.0100 M and 1.55 M. What is the cell emf?

26) How many grams of aluminum metal are produced through electrolysis of molten $AlCl_3$ for 2.50 hr with an electrical current of 12.0 A?

27) Given the thermodynamic data in the table below, calculate the equilibrium constant at 25 °C for the reaction:

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

Substance	$\Delta H_f°$ (kJ/mol)	S° (J/mol • K)
SO_2 (g)	−297	249
O_2 (g)	0	205
SO_3 (g)	−395	256

28) 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 when 24.7 grams of steam at 1 atm condenses to a liquid at the normal boiling point?

29 a) Calculate the mass of Li formed by electrolysis of molten LiCl by a current of 7.5×10^4 A flowing for a period of 24 h. Assume the electrolytic cell is 85% efficient.

b) The standard reduction potentials for the two half reactions are:

$Li\ (s) \rightarrow Li^+\ (aq) + e^-$ $\quad E°_{red} = -3.05$ V

$Cl_2\ (g) + 2\ e^- \rightarrow 2\ Cl^-$ $\quad E°_{red} = +1.36$ V

What is the minimum voltage required to drive the reaction?

Half-reaction	E° (V)

Fe^{3+} (aq) + e^- → Fe^{2+}(aq)	0.771
Sn^{4+}(aq) + 2 e^- → Sn^{2+}(aq)	0.154

30) a) Given the reduction potentials above, write the balanced reaction equation for the voltaic cell based on the reactions of Sn and Fe in the table.

b) What is the standard cell potential ($E°_{cell}$) for this voltaic cell?

c) What is the $\Delta G°$ for this voltaic cell?

d) What is the *K* for this voltaic cell at 25 °C?

31) From the values given for $\Delta H°$ and $\Delta S°$, calculate $\Delta G°$ for each of the following reactions at 298K. if the reaction is not spontaneous under standard conditions at 298 K, at what temperature (if any) would the reaction become spontaneous?

a) 2 PbS (s) + 3 O_2 (g) → 2 PbO (s) + 2 SO_2 (g); $\Delta H°$ = -844 kJ; $\Delta S°$ = -165 J/K

b) 2 $POCl_3$ (g) → 2 PCl_3 (g) + O_2 (g); $\Delta H°$ = 572 kJ; $\Delta S°$ = 179 J/K

32. Balance in acidic solution: MnO_4^- + CH_3OH --> Mn^{2+} + HCO_2H

33) Consider the equilibria in which the simple salts NaCl (s) and AgCl (s) dissolve in water to form aqueous solutions of ions:

$NaCl (s) \rightleftharpoons Na^+ (aq) + Cl^- (aq)$

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

Thermodynamic data for these reactions are as follows:

Salt	ΔH°_{soln}	ΔS°_{soln}
NaCl	+3.6 kJ/mol	+43.2 J/mol-K
AgCl	+65.7 kJ/mol	+34.3 J/mol-K

a) Calculate the value of ΔG° at 298 K for each of these reactions.

b) The two values from part (a) are very different. Is this difference primarily due to the enthalpy term or the entropy term of ΔG°?

c) Use the values of ΔG° to calculate the K_{sp} values for the two salts at 298K.

d) Sodium chloride is considered a soluble salt, whereas silver chloride is considered insoluble. Are these descriptions consistent with the answers to part (c)?

e) How will ΔG° for the solution process of these salts change with increasing T? What effect should this change have on the solubility of the salts?

34) A voltaic cell is constructed from an Ni^{2+} (aq) – Ni (s) half-cell (E°_{red} = -0.28 V) and an Ag^+ (aq) – Ag (s) half-cell (E°_{red} = +0.80 V). The initial concentration of Ni^{2+} is 0.0100 M. The initial cell voltage (E) is +1.12 V at standard temperature.

a) Calculate the standard emf of the cell.

b) What is the initial concentration of Ag^+ in the Ag^+ - Ag(s) half-cell?

c) Will the concentration of Ni^{2+} (aq) increase or decrease as the cell operates?