Chem 1310 A/B 2005, Professor Williams
Practice Exam 3 (chapters 10, 11 and 12)

Chapter 10 Thermochemistry

1. The heat capacity (C_P) is related to the heat absorbed at constant pressure (q_P) and the temperature change (ΔT) by C_P =
a. $q_P/\Delta T$
b. $\Delta T/q_P$
c. $q_P*\Delta T$
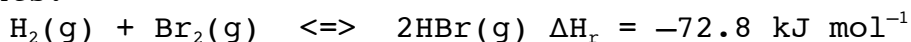d. $[q_P(\Delta T)]^{-1}$
e.   none of these
Answer: a

2.   Which one of the following processes has $\Delta H < 0$?
a.   freezing of liquid Hg
b.   combustion of cellulose
c.   cooling water
d.   all of the above (a-c)
e.   none of the above (a-c)
Answer: d

3. What is ΔH for the decomposition of 9.74 g of HBr(g) (M = 80.91 g mol^{-1}) into its elements?
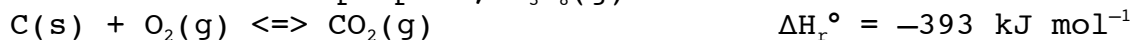 $H_2(g) + Br_2(g)$ <=> $2HBr(g)$ ΔH_r = −72.8 kJ mol^{-1}
a.   36.4 kJ
b.   4.38 kJ
c.   8.76 kJ
d.   This cannot be determined from the available information.
e.   none of these
(−)(9.7g)(81g/mol)$^{-1}$ [(1/2)(−72.8 kJ mol^{-1})] = 4.35 KJ.
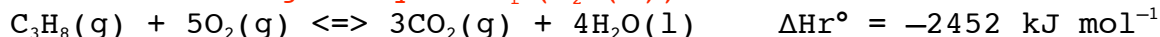This is for the decomposition of one mole of HBR to 1/2($H_2(g) + Br_2(g)$)
Answer: b

4. Given the following thermochemical equations, calculate the standard enthalpy of formation for propane, $C_3H_8(g)$.
C(s) + O_2(g) <=> CO_2(g) $\Delta H_r°$ = −393 kJ mol^{-1}
This reaction gives you $\Delta H_f°(CO_2)$
H_2(g) + 1/2 O_2(g) <=> H_2O(l) $\Delta Hr°$ = −286 kJ mol^{-1}
This reaction gives you $\Delta H_f°(H_2O(l))$
C_3H_8(g) + $5O_2$(g) <=> $3CO_2$(g) + $4H_2O$(l) $\Delta Hr°$ = −2452 kJ mol^{-1}
Use $\Delta Hr°$ = Σ $\Delta Hf°$(**products**) − Σ $\Delta Hf°$(**reactants**)
a.   −3131 kJ mol^{-1}
b.   129 kJ mol^{-1}
c.   4775 kJ mol^{-1}
d.   −1773 kJ mol^{-1}
e.   none of these
Answer: b

Given the following enthalpies of formation:

Species	ΔHf° (kJ mol^{-1})
glucose [C6H12O6(s)]	−1274
CO_2(g)	−393
H_2O(l)	−286

5. How much heat can be obtained from the complete combustion of 1.8 g of glucose to carbon dioxide and liquid water at constant pressure?
a.   2800 kJ
b.   595 kJ
c.   29 kJ
d.   6.1 kJ
e.   none of these
Answer: c
1.8g (180g/mol)$^{-1}$ [(−1274) + 0 − 6*(−393) − 6*(−286) kJ/mol] = 28

6. For the reaction, 2NO(g) + O_2(g) <=> $2NO_2$(g), ΔH_r° is −114 kJ mol^{-1}. Calculate ΔHf° of gaseous nitrogen monoxide, given that ΔHf° of NO_2(g) is 33.9 kJ mol^{-1}.
a.   −148.0 kJ mol^{-1}
b.   −114.14 kJ mol^{-1}
c.   91.0 kJ mol^{-1}
d.   181.9 kJ mol^{-1}
e.   this cannot be determined from the available information.
Answer: c

7. The tabulated molar heat of formation (ΔH_f°) for tribromobenzene gas [$C_6H_3Br_3$(g)] is the enthalpy for the reaction,
a.   6C(graphite) + 3H(g) + 3Br(g) <=> $C_6H_3Br_3$(g)
b.   6C(graphite) + H_2(g) + Br_2(g) <=> $C_6H_3Br_3$(g)
c.   12C(graphite) + $3H_2$(g) + $3Br_2$(g) <=> $2C_6H_3Br_3$(g)
d. $C_6H_3Br_3$(g) <=> 6C(graphite) +   3/2 H_2(g) +   3/2 Br_2(l)
e.   none of these
Answer: e

8. Bond enthalpy is
a.   the enthalpy required to break a bond in the gas phase
b.   the enthalpy released when one mole of a substance forms in the gas phase
c.   the enthalpy required to break a molecule apart into its elements in their
        standard states.
d.   the enthalpy required to break a gaseous molecule into gaseous atoms.
e.   none of these
Answer: a

9. The enthalpy required to convert $CHCl_3$(g) to gaseous C, H, and Cl atoms is 1397 kJ mol−1, and the C—H bond enthalpy is 413 kJ mol^{-1}. Calculate the C—Cl bond enthalpy.
a.   741 kJ mol^{-1}

b.   328 kJ mol^{-1}
c.   984 kJ mol^{-1}
d.   1397 kJ mol^{-1}
e.   none of these
Answer: b

10. The enthalpy of vaporization of a substance is 23.35 kJ mol^{-1}. Hence the enthalpy of freezing of this substance is
a.   −46.70 kJ mol^{-1}
b.   −23.35 kJ mol^{-1}
c.   23.35 kJ mol^{-1}
e.   46.70 kJ mol^{-1}
d.   This cannot be determined from the available information.
Answer: d

11. In SI units the universal gas constant R is 8.31451 J mol^{-1}K—1. R is also 0.082058 L atm mol^{-1}K—1. Therefore, 1.00 L atm is equivalent to how many J?
a.   9.8693
b.   9.8693x10^{-3}
c.   101.325
d.   1.01325x10^{5}
e.   this cannot be answered without additional information.
Answer: c

12. For a balloon expanding against atmospheric pressure, the work w done on the balloon is
a.   positive
b.   negative
c.   of indeterminate sign
d.   zero
e.   this cannot be answered without additional information.
Answer: b

13. In any process, ΔE_{univ} =
a. ΔE_{sys}
b. ΔE_{surr}
c. $-\Delta E_{sys}$
d. $-\Delta E_{surr}$
e.   0
Answer: e

14. In processes that involve exchange of heat with the surroundings, ΔH = ____ and ΔE = ____.
a. q_V, q_P
b. q_P, q_V
c. q_P, q_P
d. q_V, q_V
e.   this must be answered on a case-by-case basis.

Answer: b

15. For a certain liquid hydrocarbon ΔHvap = 25.45 kJ mol—1.   The density of the hydrocarbon is 1.13 g/mL. Calculate the change in enthalpy for the vaporization of 1.930 mol of the hydrocarbon.
a.   25.45 kJ
b.   28.76 kJ
c.   49.12 kJ
d.   55.50 kJ
e.   none of these
Answer: c

A gas is compressed from 40 L to 13 L at a constant pressure of 5.0 atm.   In the course of this compression 9.8 kJ of energy is released as heat.

16. ΔH for this process is
a.   —9.82 kJ
b.   —7.09 kJ
c.   3.83 kJ
d.   9.82 kJ
e.   none of these
Answer: a

17. Given the following $\Delta H_f°$ values:
$SiH_4(g)$ 34.3 kJ mol^{-1}
$SiO_2(s)$ —910.9 kJ mol^{-1}
$H_2O(l)$ —285.8 kJ mol^{-1}

Also,
H_2O ΔH_{vap} = 44.0 kJ mol—1.

What is $\Delta Hr°$ for $SiH_4(g) + 2O_2(g) <=> SiO_2(s) + 2H_2O(g)$?
This problem uses the path—independence of a state function. First calculate the enthalpy of the reaction to give $H_2O(l)$, then add the enthalpy of vaporization of water. Don't forget that you are vaporizing 2 moles.
a.   —1517 kJ mol^{-1}
b.   —1429 kJ mol^{-1}
c.   —1187 kJ mol^{-1}
d.   this cannot be determined without additional information.
e.   none of these

1. The Entropy of a system is the thermodynamic property that constitutes a quantitative measure of the
a. heat content of the system.
b. degree of disorder of the system.
c. internal energy of the system.
d. all of these
e. none of these
Answer: b

2. When a process results in an increase in the number of microstates available to a system, the change in entropy of the system is
a. positive
b. negative
c. zero
d. all of these are possible, depending upon specific circumstances.
e. cannot be determined from the information given.
Answer: a

3. When a process results in an increase in the number of microstates available to a system, the change in entropy of the surroundings is
a. positive
b. negative
c. zero
d. all of these are possible, depending upon specific circumstances
e. cannot be determined from the information given.
Answer: a (this answer is not correct. It is possible to increase the entropy of a system without exchanging heat with the surroundings, so $\Delta S_{sur}=0$).
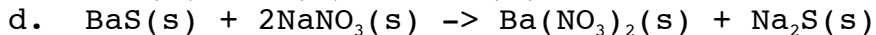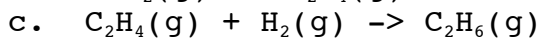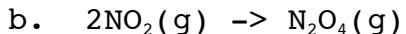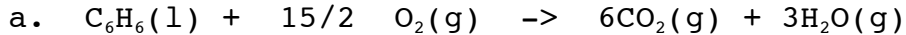
4. The third law of thermodynamics states that
a. energy is conserved in spontaneous processes.
b. the entropy of the universe increases during a spontaneous process.
c. matter and energy are interconvertible, but matter and energy together are
      conserved.
d. the entropy of a perfect crystal is zero at absolute zero.
e. work and heat are interconvertable.
Answer: d

5. Which of the following is not a possible value of S° for a pure substance?
a. −31.9 J K^{-1} mol^{-1}
b.   85.0 J K^{-1} mol^{-1}
c.   1.856 J K^{-1} mol^{-1}
d.   all of these are possible.
e.   none of these is possible.
Answer: a

6. If you ignore the effects of heat dissipation, which of the following processes should show the greatest increase in entropy?
a. $C_6H_6(l)$ + 15/2 $O_2(g)$ -> $6CO_2(g)$ + $3H_2O(g)$
b. $2NO_2(g)$ -> $N_2O_4(g)$
c. $C_2H_4(g)$ + $H_2(g)$ -> $C_2H_6(g)$
d. $BaS(s)$ + $2NaNO_3(s)$ -> $Ba(NO_3)_2(s)$ + $Na_2S(s)$
e. this cannot be predicted without additional information.
Answer: a Count the number of molecules, does it increase or decrease. Breaking one molecule into two increases configurational entropy. Also note the phases, for configurational entropy, S(gas)>S(liq)>S(solid).

7. The second law of thermodynamics states that
a. energy is conserved in a spontaneous process.
b. the entropy of the universe increases during a spontaneous process.
c. the heat content of the universe increases during a spontaneous process.
d. All of these are valid components of the second law.
e. None of these is correct.
Answer: b

8. Which of the following statements about spontaneous processes at constant temperature and pressure is not true?
a. A spontaneous process having negative ΔH and negative ΔS is enthalpy driven.
b. A spontaneous process having positive ΔH and positive ΔS is entropy driven.
c. A process having positive ΔH and negative ΔS cannot occur spontaneously at anytemperature.
d. A process having negative ΔH and positive ΔS can occur spontaneously at any temperature.
e. All of these statements are true.
Answer: e (Think $\Delta G=\Delta H-T\Delta S$ and DG<0 is spontaneous)

9. Which of the following is true for system at equilibrium?
a. $\Delta S univ = 0$
b. $\Delta S univ > 0$
c. $\Delta S univ < 0$
d. $\Delta S sys = \Delta S surr$
e. none of these
Answer: a

The next two problems concern the conversion of 2.00 moles of liquid benzene (C_6H_6) to vapor at a pressure of 1.00 atm and a temperature of 80.1°C, its normal boiling point. ΔH_{vap} for benzene at this temperature is 3.08×10^4 J mol^{-1}.
$\Delta G_{vap}=0$ at the boiling point.
10. Calculate ΔS_{vap} for benzene in this process.
a. -769 J K^{-1}
b. 769 J K^{-1}
c. -174 J K^{-1}
d. 174 J K^{-1}

e. none of these
Answer: d

11. Calculate the change in entropy of the universe for this process.
a. −769 J K^{-1}
b. 769 J K^{-1}
c. −174 J K^{-1}
d. 174 J K^{-1}
e. none of these
Answer: e

12. If ΔSuniv is positive for a process, the process is _____, if ΔSuniv for a process is negative, the process is _____, and if the ΔSuniv accompanying a process is zero, the process is _____.
a. at equilibrium, spontaneous, nonspontaneous
b. nonspontaneous, spontaneous, at equilibrium
c. spontaneous, at equilibrium, nonspontaneous
d. spontaneous, nonspontaneous, at equilibrium
e. none of these
Answer: d

13. Consider the process whereby 1.00 mol of $H_2O(s)$ is melted to $H_2O(l)$ at the normal melting point of ice, 273.15 K. Which of the following is true for this process?
a. $\Delta H > 0$
b. $\Delta G = 0$
c. $\Delta H = T\Delta S$
d. all of these are true.
e. none of these is true.
Answer: d

14. With care, water can be cooled below its normal freezing point (undercooling). Suppose 10 g of water is undercooled to −10°C in an insulated container. If this undercooled water then undergoes a spontaneous process, the result will be
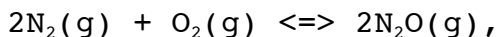a. 10 g of ice at −10° C.
b. an ice/water mix at −10° C.
c. an ice/water mix at 0° C.
d. 10 g of water at 0° C.
e. an ice/water mix at T > 0° C.
Answer: c

15. Under what conditions will the reaction,
        $2N_2(g) + O_2(g) \iff 2N_2O(g)$,
be spontaneous? At 25°C $\Delta G_f°$ and $\Delta H_f°$ for dinitrogen oxide are 104.2 kJ mol^{-1} and 82.0 kJ mol−1, respectively.
a. under all conditions
b. under no conditions

c. at high temperature
d. at low temperature
e. This cannot be answered without additional information.
Answer: b

16. Under what conditions will the reaction,
         $H_2(g) + F_2(g) \iff 2HF(g)$,
be spontaneous? At 25°C $\Delta H_f°$ and $S_f°$ for HF(g) are -271.1 kJ mol^{-1}and 173.67 J K^{-1} mol^{-1}, respectively.
a. under all conditions
b. under no conditions
c. at high temperature
d. at low temperature
e. This cannot be answered without additional information.
Answer: The legally correct answer is e, because you need $\Delta S_f°(H_2)$, $\Delta S_f°(F_2)$, $\Delta H_f°(H_2)$ and $\Delta H_f°(F_2)$ to calc $\Delta H_r°$ and $\Delta S_r°$. But if you look them up in Appendix D you show that:
$\Delta H_r°$ = 2(-271)-0-0   = -542 kJ/mol (NEGATIVE)
$\Delta S_r°$ = 2(174)-131- 203 = 14 J/mol (POSITIVE).
So if you cheat and use the information from appendix D, the reaction is seen to be spontaneous under all conditions. The answer is a because you are not supposed to know what appendix d says.
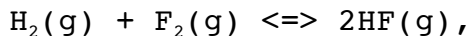
17. For the reaction, X + Y $\iff$ A + B, $\Delta G_r°$ is -1324 kJ mol^{-1}. Which one of the following statements is **not** valid concerning this reaction?
a. The reaction is thermodynamically favorable.
b. The reaction is spontaneous as written.
c. The products are more stable than the reactants.
d. The reaction will proceed rapidly from left to right.
e. All of these are valid.
Answer: d

18. As a warm brick cools, the entropy of the brick
a. increases
b. decreases
c. does not change
d. change cannot be predicted
e. all of the above
Answer: b

19. As a warm brick cools, the entropy of the surroundings
a. increases
b. decreases
c. does not change
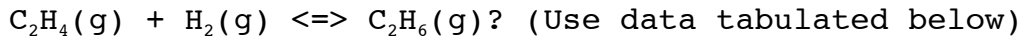d. change cannot be predicted
e. all of the above
Answer: a

20. Element A is found in two allotropic forms, with $\Delta G° > 0$ for the conversion of allotrope A1 to allotrope A2. Which of the following statements is valid concerning these allotropes?
a. A1 should rapidly convert to A2.
b. A2 should rapidly convert to A1.
c. The conversion from one form to another maybe favorable but may or may not occur at an appreciable rate.
d. All of these statements are valid.
e. None of these statements is valid.
Answer: c

21. Assuming that $\Delta H_r°$ and $\Delta S_r°$ are independent of T, at what temperature will the equilibrium constant K be equal to 1.00 for the reaction:
$$C_2H_4(g) + H_2(g) <=> C_2H_6(g)?$$ (Use data tabulated below)
a. 1.14°C
b. 838 K
c. 1136 K
d. 1136°C
e. K will not equal 1.00 at any T, because $\Delta H°$ is negative and $\Delta S°$ is positive.
Answer: c
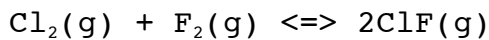(1) Find $\Delta H°_r$ from $\Delta H°_f$.
(2) Find $\Delta G°_r$ from $\Delta G°_f$.
(3) Use $\Delta H°_r$ and $\Delta G°_r$ to determine $\Delta S°_r$ at 298 [use $\Delta G°_r = \Delta H°_r - 298\Delta S°_r$, you cannot calc $\Delta S°_r$ directly from $\Delta S°_f$ because you do not know $\Delta S°_f(H_2)$].
(4) Use $-RTln(K)=\Delta H°_r-T\Delta S°_r$ and $ln(K)=0$

22. For the following reaction, $K = 8.6 \times 10^{19}$ at T = 298 K and $K = 1.09 \times 10^{15}$ at 398 K:
$$Cl_2(g) + F_2(g) <=> 2ClF(g)$$
Assuming that $\Delta H_r°$ and $\Delta S_r°$ are independent of T over this range, calculate $\Delta S_r°$.
a. 3.7 J K—1 mol^{-1}
b. 8.5 J K—1 mol—1
c. 11.3 J K—1 mol^{-1}
d. −111.2 J K—1 mol^{-1}
e. −113.7 J K—1 mol^{-1}
Answer: b

23. Using data tabulated below,calculate the equilibrium constant at 25°C for the reaction, $2NH_3(g) <=> N_2(g) + 3H_2(g)$.
a. 1.7×10^{-6}
b. 1.3×10^{-3}
c. 7.7×10^{2}
d. 5.9×10^{5}
e. This cannot be determined without additional information.
Answer: a

The following thermodynamic data (valid at 25°C) are needed in some problems.

Species	ΔH_f° (kJ mol^{-1})	S° (J K^{-1} mol^{-1})	ΔG_f° (kJ mol^{-1})
$C_2H_4(g)$	52.26	219.45	68.12
$C_2H_6(g)$	-84.68	229.49	-32.89
$C_2H_5OH(\ell)$	-277.69	160.7	-174.89
$CO_2(g)$	-393.51	213.63	-394.36
$Cl^-(aq)$	-167.16	56.5	-131.23
$H_2O(\ell)$	-285.83	69.91	-237.18
$H_2O(g)$	-241.82	188.72	-228.59
$Mg^{2+}(aq)$	-466.85	-138.1	-454.8
$MgCl_2(s)$	-641.32	89.62	-591.82
$NH_3(g)$	-46.11	192.34	-16.48
$NO(g)$	90.25	210.65	86.55
$O_2(g)$	0	205.03	0
$O_3(g)$	142.7	238.82	163.2
$PbS(s)$	-100.4	91.2	-98.7
$SO_2(g)$	-296.83	248.11	-300.19
$SO_3(g)$	-395.72	256.65	-371.08

Chapter 12 Electrochemistry

1. An oxidizing agent is a substance that
a.   is oxidized
b.   causes oxidation
c.   causes reduction
d.   provides oxygen
e.   none of these
Answer: b

2. Which species is the oxidizing agent in the reaction (unbalanced),
     MnO_4^- + $SO4^{2-}$ <=> Mn^{2+} + $S_2O_8^{2-}$ (this is not the correct type of arrow, sorry)
a. MnO_4^{4-}
b. SO_4^{2-}
c. Mn^{2+}
d. $S_2O_8^{2-}$
e.   None; this is not a redox reaction.
Answer: a

3. Identify the correctly balanced reduction half reaction for the reaction,
$PbO_2(s)$ + $SO_4^{2-}(aq)$ + $4H^+(aq)$ + $2Hg(l)$ + $2Cl^-(aq)$ <=> $Hg_2Cl_2(s)$ + $PbSO_4(s)$ + $2H_2O(l)$
a. PbO_2 + SO_4^{2-} + $4H^+$ + $2e^-$ <=> $PbSO_4$ + $2H_2O$
b. $2Hg$ + $2Cl^-$ <=> Hg_2Cl_2 + $2e^-$

c. $PbSO_4 + 2H_2O$ <=> $PbO_2 + SO_4^{2-} + 4H^+ + 2e^-$
d. $Hg_2Cl_2 + 2e^-$ <=> $2Hg + 2Cl^-$
e.   none of these
Answer: a

4. The correctly balanced half reaction for the conversion of dichromate ion to chromium(III) in acid is
a. $CrO_4^- + 8H^+ + 4e^-$ <=> $Cr^{3+} + 4H_2O$
b. $CrO_4^{2-} + 8H^+ + 3e^-$ <=> $Cr^{3+} + 4H_2O$
c. $Cr_2O_7^- + 14H^+ + 7e^-$ <=> $2Cr^{3+} + 7H_2O$
d. $Cr_2O_7^{2-} + 14H^+ + 6e^-$ <=> $2Cr^{3+} + 7H_2O$
e. none of these
Answer: d