CHEM 3530 - Exam 2 - March 3, 2017

Constants and Conversion Factors

$N_A = 6.02 \times 10^{23}$ mol^{-1}

R = 8.31 J/mol-K = 8.31 kPa-L/mol-K

1 bar = 100 kPa = 750 torr

1 kPa = 7.50 torr

1 J = 1 kPa-L

1 kcal = 4.18 kJ

Molar Masses CH_3OH - 32

CHEM 3530 - Exam 2 – March 3, 2017

Name Solutions

(76) **PART I. MULTIPLE CHOICE (Circle the ONE correct answer)**

1. From the following thermochemical equations,

$2\ H_2O(g) \rightarrow 2\ H_2(g) + O_2(g)$ $\Delta H = +484$ kJ

$2\ O_3(g) \rightarrow 3\ O_2(g)$ $\Delta H = +286$ kJ

ΔH for the reaction, $3\ H_2O(g) \rightarrow 3\ H_2(g) + O_3(g)$, is

(A) -583 kJ (B) +341 kJ (C) +583 kJ (D) -869 kJ

2. The Enthalpy of Formation of trichloromethane ($CHCl_3$) is -103. kJ/mol. Which of the following equations is/are **correct**:

(i) $2\ Cl_2(g) + 2\ C(gr) + 2\ HCl(g) \rightarrow 2\ CHCl_3(g)$ $\Delta H = -206$ kJ

(ii) $2\ CHCl_3(g) \rightarrow H_2(g) + 3\ Cl_2(g) + 2\ C(gr)$ $\Delta H = +206$ kJ

(iii) $(1/2)\ H_2(g) + C(gr) + 3\ Cl(g) \rightarrow CHCl_3(g)$ $\Delta H = -103$ kJ

(A) i only (B) i & ii only (C) ii only (D) ii & iii

3. The Entropy change (at 25 °C) for the reaction $2\ NO(g) + O_2(g) \rightarrow 2\ NO_2(g)$, is $\Delta S = -148.$ J/K. The Molar Entropy of $NO_2(g)$ is $S°(NO_2) = +240.$ J/mol-K. Therefore, the Molar Entropy of NO(g) is:

(A) +314 J/mol-K (B) +628 J/mol-K (C) -314 J/mol-K

(D) Insufficient information is given to determine the answer

4. The enthalpy change for the combustion of **two (2)** moles of methanol (CH_3OH), is $2\ CH_3OH(l) + 3\ O_2(g) \rightarrow 2\ CO_2(g) + 4\ H_2O(l)$ $\Delta H = -1450$ kJ. Therefore, the Fuel Value (FV) of methanol is approximately:

(A) -45 kJ/g (B) +23 kJ/g (C) +45 kJ/g (D) +725 kJ/g

5. Which of the following processes/reactions are **exothermic**? (i) combustion, (ii) deposition, (iii) condensation, (iv) fusion

(A) i & ii & iii (B) i & iii & iv (C) ii & iii (D) ii & iii

6. The constant pressure molar heat capacity of $CO_2(g)$ is 37.1 J/mol-K. What is the approximate value of ΔS when 3 moles of $CO_2(g)$ is heated at constant pressure from 50 °C to 200 °C?

(A) -51.4 J/K (B) +154.3 J/K (C) +42.5 J/K (D) +51.4 J/K

7. A sample of 3. moles of $N_2(g)$ originally at 500 kPa and 25 L is expanded reversibly and isothermally to a final pressure of 100 kPa. ΔS for this process is approximately:

(A) +6.7 J/K (B) 40. J/K (C) -6.7 J/K

(D) Cannot be determined without the Molar Heat Capacity of $N_2(g)$

8. When a gas is compressed adiabatically and reversibly, then:

(A) $q<0$ & $\Delta S<0$ (B) $q=0$ & $\Delta S=0$ (C) $q<0$ & $\Delta S>0$ (D) $q>0$ & $\Delta S=0$

9. The normal boiling point of methanol is 64 °C. The Enthalpy of Vaporization of methanol is 35.3 kJ/jmol. What is the entropy change of the **system** when 1 mole of methanol gas is condensed reversibly to the liquid at 64 °C?

(A) -550 J/K (B) +550 J/K (C) +105 J/K (D) -105 J/K

10. The enthalpy of fusion of mercury is 2.3 kJ/mol. What is the entropy change of the **surroundings** when **4 (four) moles** of mercury liquid are frozen (i.e. crystallized) to the solid at -39 °C?

(A) +9.8 J/K (B) +39.3 J/K (C) -9.8 J/K (D) -39.3 J/K

11. The reaction A → B is **exergonic** at 25 °C and the enthalpy change is +20 kJ. What can be concluded about the entropy change for this reaction?

(A) $\Delta S > 67$ J/K (B) $\Delta S > 800$ J/K (C) $\Delta S < -67$ J/K

(D) No conclusion can be made about ΔS

12. For the **endergonic** reaction C → D, $\Delta S = +20$ J/K. For this reaction,

(A) $\Delta G<0$ & $\Delta H<0$ (B) $\Delta G>0$ & $\Delta H<0$ (C) $\Delta G<0$ & $\Delta H>0$ (D) $\Delta G>0$ & $\Delta H>0$

13. The Enthalpy of Vaporization of methanol is 35.3 kJ/mol. The Entropy of Vaporization of methanol is 105 J/mol-K. What is the Gibbs Energy change for the condensation of one mole of methanol gas at 30 °C?

(A) +3.5 kJ/mol (B) 0 kJ/mol (C) -3.5 kJ/mol (D) -32.2 kJ/mol

14. A hypothetical polypeptide, PP, has two structural forms, PP(α) and PP(β). For the transition PP(α) → PP(β), the entropy change is -150 J/mol-K and the enthalpy change is -50 kJ/mol. Over what temperature range is this transition spontaneous?

(A) Below 60 °C (B) Above 333 °C (C) Below 333 °C (D) Above 60 °C

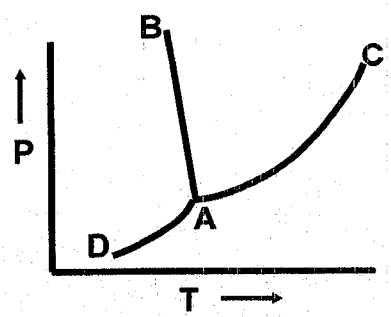
15. As discussed in class, hydrophobic (non-polar) amino acid sidechains tend to reside in the interior of proteins' tertiary structure. The reason they do **not** reside on the exterior of the protein is that they would

(A) raise the entropy of the surrounding water molecules
(B) lower the entropy of the surrounding water molecules
(C) raise the enthalpy of the surrounding water molecules
(D) hydrogen bond with the surrounding water moleciules

16. ΔG^o= -1330 kJ/mol for the aerobic metabolism of one mole of pyruvic acid to CO_2 and H_2O. If ΔG^o= -40 kJ/mol for the hydrolysis of one mole of ATP to ADP, and the metabolism results in the conversion of 18 moles of ADP to ATP, then the efficiency of energy storage in aerobic metabolism

(A) 54% (B) 41% (C) 28% (D) 83%

For #17 - #19 consider the phase diagram to the right



17. The slope of curve A-B is negative because

(A) $S_m(liq)>S_m(sol)$ (B) $S_m(liq)<S_m(sol)$
(C) $V_m(liq)<V_m(sol)$ (D) $V_m(liq)>V_m(sol)$

18. If the pressure on this substance is **decreased** from 500 bar to 1 bar, the melting point will _____ and the boiling point will _____.

(A) decrease, increase (B) increase, decrease (C) increase, increase
(D) increase/decrease depends on relative solid and liquid entropies, increase

19. At pressures below the triple point pressure, this substance can exist as:

(A) vapor only (B) solid or liquid or vapor
(C) liquid or vapor only (D) solid or vapor only

PART II. TWO (2) PROBLEMS ON FOLLOWING PAGES (Show work for partial credit)

(12) 1. The normal boiling point of Bromobenzene (C_6H_5Br) is 156 C.*
*This is the tempeature at which the vapor pressure is 1. bar (=100 kPa

The vapor pressure of Bromobenzene at 40 °C is 16.7 torr

Calculate the Enthalpy of Vaporization of Bromobenzene, **in kJ/mol.**

$P_1 = 1 bar \times \frac{750 torr}{1 bar}$

$= 750 torr$

$T_1 = 156°C + 273$

$= 429 K$

$P_2 = 16.7 torr$

$T_2 = 40°C = 313 K$

$\Delta_{vap}H = ?$

$$\ln\left(\frac{P_2}{P_1}\right) = -\frac{\Delta_{vap}H}{R}\left[\frac{1}{T_2} - \frac{1}{T_1}\right]$$

$$\Delta H_{vap} = \frac{-R\ln(P_2/P_1)}{\frac{1}{T_2} - \frac{1}{T_1}}$$

$$= \frac{-8.31 J/mol\cdot K \ln(16.7/750)}{\frac{1}{313 K} - \frac{1}{429 K}}$$

$= 3.66 \times 10^4 J/mol \times \frac{1 kJ}{1000 J}$

$= \boxed{36.6 kJ/mol}$

(12) 2. The constant pressure molar heat capacity of ethanol gas [$C_2H_5OH(g)$] is is 87.2 J/mol-K. The molar enthalpy of vaporization of water is 38.6 kJ/mol at its normal boiling point, 78 °C (and 1 bar pressure). Calculate the entropy and enthalpy changes, ΔS (in J/K) and ΔH (in kJ), when **two (2)** moles of ethanol gas is cooled at constant pressure (1 bar) from 200 °C to 78 °C and then condensed to the liquid; i.e. for the process $C_2H_5OH(gas, 200\ ^\circ C) \rightarrow C_2H_5OH(liq, 78\ ^\circ C)$.

$n = 2\,mol$

$C_{p,m}(g) = 87.2\ J/mol\cdot K$

$C_2H_5OH(gas, 200^\circ C = 473K) \xrightarrow{(1)} C_2H_5OH(gas, 78^\circ C = 351K) \xrightarrow{(2)} C_2H_5OH(liq, 78^\circ C = 351K)$

$\Delta_{cond}H = -\Delta_{vap}H = -38.6\ kJ/mol$

ΔS

$\Delta S_1 = n C_{p,m} \ln\left(\frac{T_f}{T_i}\right)$

$= 2\,mol(87.2\ J/mol\cdot K)\left(\ln\frac{351}{473}\right) = -52.03\ J/K$

$\Delta S_2 = \frac{q}{T_2} = \frac{n\Delta_{cond}H}{351K} = \frac{2\,mol(-38.6\times10^3\ J/mol)}{351K}$

$= -219.94\ J/K$

$\Delta S = -52.03 + (-219.94)$

$= -272.0\ J/K$

ΔH (eq)

$\Delta H_1 = n C_{p,m}[T_2 - T_1] = 2\,mol(87.2\ J/mol\cdot K)(351K - 473K)$

$= -21,280\ J = -21.3\ kJ$

$\Delta H_2 = n\Delta_{cond}H = 2\,mol(-38.6\ kJ/mol) = -77.2\ kJ$

$\Delta H = -21.3\ kJ + (-77.2\ kJ)$

$= \boxed{-98.5\ kJ}$