R = 8.31 joule/mol K.

**Assume that all reactions in this exam take place at 298.15K**

**Thermodynamic Quantities. (At 298.15 K )**

|  |  |  |  |
| --- | --- | --- | --- |
| Substance | **ΔHof kJ/mol)** | **ΔGof (kJ/mol)** | **So (J/mol K)** |
| C6H6 (*l*) | 49.0 | 124.5 | 172.8 |
| C6H6(g) | 82.9 | 129.7 | 269.2 |
| C2H4(g) | 52.30 | 68.11 | 219.4 |
| C2H5OH(*l*) | -277.7 | -174.76 | 160.7 |
| H2(g) | 0 | 0 | 130.58 |
| Cl(g) | 121.7 | 105.7 | 165.2 |
| CO2(g) | –393.5 | – 394.4 | 213.6 |
| C2H6(g) | –84.68 | –32.89 | 229.5 |
| HCl(g) |  | – 95.27 |  |
| H2O(*l*) | -285.85 | -236.81 | 69.96 |

Heat of combustion of ethanol C2H5OH(*l)*  + 3 O2(g) ➞ 2 CO2(g)  + 3 H2O(g)

ΔH° = –1234.76 kJ/mol ΔG = ΔG° + RT Ln Q

Some of these are difficult, and /or tricky!

Second Lecture test in chemistry 2. Spring 2011.

Name\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Part I: Multiple Choice and fill -in questions. These must be answered in the spaces provided with the questions. (1 and 3/4 pts each)

\_\_\_\_B\_\_\_1. A certain reaction is spontaneous only at temperatures below 380 K. At 298 K, for this reaction, ΔG° , ΔH°, and ΔS° , respectively are

A) all + B) all − C) − , +, + D) +, − ,− E) −, −, + If it is spontaneous, then DGo must be -. If a reaction is spontaneous only at LOW temperature, then DH and D S must both be -

\_\_C\_\_\_\_\_2. Find the value of ΔG° in kJ/ mol for the conversion of liquid benzene to gaseous benzene at 298 K. ( C6H6(ℓ) → C6H6(g) )

A) 124.5 B) 129.7 C) 5.2 D) −5.2 E) −129.5 (Just product – reactant.)

\_\_B\_\_\_\_3. For the reaction H2(g) + Cl2(g) → 2 HCl(g), Δ H° is − 184.6 kJ

What is the standard heat of formation of HCl(g)?

A) + 92.3 kJ/mol B) −92.3 kJ/mol C) + 184.6 kJ/mol D) −369.2 kJ

E) + 369.2 kJ

\_\_\_D\_\_\_\_4. What is the value of ΔG° for reaction at 298 K if the equilibrium constant for that reaction at 298 K is 1.00? A) 1.00 B) 2.48 kJ C) −2.48 kJ

D) 0 E) −1 Since Ln 1.00 = 0, -RT Ln K has to = 0

\_\_\_\_C\_\_5. Which of the following would have the greatest standard entropy, S°?

A) H2 gas at 300 K, and 1.00 atm B) He gas at 200 K and 2.00 atm

C) SO2 gas at 300 K and 0.80 atm D) NO2 gas at 200 K and 2.00 atm

E) Br2 liquid at 300 K and 1.00 atm Larger molecule, at higher T and lower P.

\_\_D\_\_\_\_6. Which has a ΔGof (standard free energy of formation) of ZERO ?

A) O(g) B) NH3(g) C) S(g) D) N2(g)

For the following questions, 7 to 12, the answers are +, –, or 0. (assume that T=298K)

\_\_\_\_0\_\_\_7. ΔGof , the free energy of formation, of N2(g)

\_\_\_\_\_-\_\_8. ΔH° f, the standard enthalpy of formation, of CO2(s)

\_\_\_\_**-**\_\_\_9 ΔGof of NH3(g), given that the equilibrium constant for the reaction

N2(g) + 3 H2(g) ➞ 2 NH3(g) is 6.7 x 105

\_\_+\_\_\_\_\_10. S° , the standard molar entropy of NaCl(s) at 298 K.

\_\_-\_\_\_\_\_11. ΔS° for the reaction 2 Na(s) + Cl2(g) → 2 NaCl(s)

\_\_-\_\_\_\_\_12. ΔG° for the condensation of benzene, C6H6(g) → C6H6(ℓ)

\_D\_\_\_\_\_\_13. For which of the following processes are ΔG° , ΔH°, and ΔS° all positive in

sign at 25°C ? A) melting of ice B) condensation of water vapor

C) freezing of water D) decomposition of liquid water to hydrogen and oxygen gas.

\_\_B\_\_\_\_14. Reactions for which the signs of ΔH and ΔS are **both** negative will be spontaneous

A) at high temperatures B) at low temperatures C) at all temperatures D) at no temperatures

\_\_\_22 J/molK\_\_15. ΔH° for the melting of ice at 0°C, (the heat of fusion) is 6.0 kJ/mole.

What is ΔS° for the melting of ice at that temperature?

( At the melting or normal boiling point, DGo = 0. So DS = DH/T)

\_A\_\_\_16. For a certain reaction, ΔG̊ at 298 K is negative. This implies that

A) The equilibrium constant is > 1 B) The equilibrium constant is < 1

C) The reaction is spontaneous at all temperatures

D) ΔH̊ is negative at 298 K

I. For the combustion of liquid ethanol, C2H5OH(*l*) + 3O2(g) → 2 CO2(g) + 3 H2O(*l*)

(12)

A. Find ΔG°, ΔH°, and ΔS° at 298.15 K. (note that the combustion given on the accompanying chart forms **gaseous** water, while this question refers to formation of liquid water) The DHo and DGo can be found directly from the chart given, recalling that O2 would be 0. I got -1366.85 kJ for DHo and =1324.97 kJ for DGo.

But you can’t get DS this way, because you don’t have a value of DSo for O2. You must use DGo = DHo - TDSo I got -140.5 J/mol K

( or – 0.1405 kJ/mol K)

B. Find the standard molar entropy, S°, of O2(g) .

Now, since you know DSo for the reaction, ( -140.5 J/molK), and your chart has So for every substance in the reaction EXCEPT O2, you can solve for O2

**(3 x 69.96 + 2 x 213.6) - 160.7 - 3 x = - 140.5 x = 206 J/molK**

C. By comparing your value for ΔG° from part A with the value given on the chart for the combustion of ethanol with the formation of **gaseous** water, find the free energy of vaporization of water in kJ/mol. (ΔG° for H2O(ℓ) → H2O(*g*) )

30 kJ/mol

II. A. Find the equilibrium constant at 298 K for the reaction H2(g)+ Cl2(g) → 2 HCl(g)

-190.54 kJ = - 0.00831 x 298 Ln K. K = 2.6 x 1033

(8) B. Find the value of ΔG for this reaction at 298 K when the partial pressures of the three gases are as follows: H2 = 3.00 atm, Cl2 = 3.00 atm, HCl = 4.00 x 10−5 atm.

DGo for the reaction is -95.27 x 2, or -190.54.

DG = DGo + RT Ln Q. Q = ( 4.00 x 10-5)2 / 9.00 = 1.78 x 10-10

= -190.54 + 0.00831( 298)( Ln(1.78 x 10-10) = -246 kJ

III. For the reaction H2(g) + Cl2(g) → 2 HCl(g), ΔH̊ = –184.6 kJ.

Use the information above and the information on the accompanying chart to find the value of ΔS̊ for the reaction given. (at 298 K) ( 3 pts)

DG from the chart is -190.54. DS = (DH - DG)/298 = 0.0199 kJ or 19.9 J/molK