CHM 1046 - JOENS WORKSHEET #3 Due date: M,W,F Wednesday, September 14
T,R Thursday, September 15

* While I prefer you turn in a hard copy of the worksheet, I will accept scanned copies sent to my email address, joensj@fiu.edu

Section: (circle one) M,W,F Tu,Tr

For problems involving calculations you must show your work for credit.

1) For a particular process a system expands by an amount ΔV = 600.0 mL against a constant external pressure p_{ex} = 2.50 atm. During the process, 2200. J of heat is added to the system. Find q, w, and ΔU for the process. (NOTE:1 L·atm = 101.3 J).

For mechanical work, $w = -p_{ex} \Delta V$ Since the system expands, we expect $w < 0$

p_{ex} = 2.50 atm ΔV = 600.0 mL = 0.6000 L

So $w = -(2.50 \text{ atm})(0.6000 \text{ L}) = -1.50 \text{ L·atm}\ (101.3 \text{ J/L·atm}) = -152. \text{ J}$

Heat is added to the system, and so q is positive. q = 2200 J

From the first law, $\Delta U = q + w = 2200 \text{ J} + (-152. \text{ J}) = 2048 \text{ J}$

2) Give the correctly balanced formation reaction for the following substances. Be sure to indicate the state (s, ℓ, g, aq) for all reactants and products.

a) $HNO_3(aq)$

$\frac{1}{2} H_2(g) + \frac{1}{2} N_2(g) + \frac{3}{2} O_2(g) \rightarrow HNO_3(aq)$

b) $CaSiO_3(\ell)$

$Ca(s) + Si(s) + \frac{3}{2} O_2(g) \rightarrow CaSiO_3(\ell)$

Remember the formation reaction produces exactly 1 mole of one product from elements in their standard (thermodynamically most stable) state.

3) For the chart below, fill in the missing information.

	ΔS_{syst} (J/K)	ΔS_{surr} (J/K)	ΔS_{univ} (J/K)	spontaneous (yes or no)
process 1	18.6	– 27.8	**– 9.2**	**no**
process 2	– 3.6	**22.3**	18.7	**yes**
process 3	**– 61.6**	58.4	– 3.2	**no**

Use $\Delta S_{univ} = \Delta S_{syst} + \Delta S_{surr}$, and for a spontaneous process $\Delta S_{univ} > 0$

4) Using the table of thermochemical data below (for T = 298. K) find the following for the chemical reaction

$$PbS(s) + 4\ H_2O(\ell) + 4\ Cl_2(g) \rightarrow PbSO_4(s) + 8\ HCl(g) \qquad (4.1)$$

Substance	$\Delta H°_f$(kJ/mole)	$\Delta G°_f$(kJ/mole)	$S°$(J/mole·K)
$Cl_2(g)$	0.0	0.0	223.0
$HCl(g)$	– 92.3	– 95.3	187.0
$H_2O(\ell)$	– 285.8	– 237.2	69.9
$PbS(s)$	– 94.3	– 92.7	91.2
$PbSO_4(s)$	– 918.4	– 811.2	147.3

a) $\Delta H°_{rxn}$ and $\Delta S°_{rxn}$

$\Delta H°_{rxn} = [\ \Delta H°_f(PbSO_4(s)) + 8\ \Delta H°_f(HCl(g))\ ] - [\ \Delta H°_f(PbS(s)) + 4\ \Delta H°_f(H_2O(\ell)) + 4\ \Delta H°_f(Cl_2(g))\ ]$

$= [\ (-918.4) + 8\ (-92.3)\ ] - [\ (-94.3) + 4\ (-285.8) + 4\ (0.0)\ ]$

$= [\ -1656.8\ ] - [\ -1237.5\ ] = -419.3$ kJ/mol

$\Delta S°_{rxn} = [\ S°(PbSO_4(s)) + 8\ S°(HCl(g))\ ] - [\ S°(PbS(s)) + 4\ S°(H_2O(\ell)) + 4\ S°(Cl_2(g))\ ]$

$= [\ (147.3) + 8\ (187.0)\ ] - [\ (91.2) + 4\ (69.9) + 4\ (223.0)\ ]$

$= [\ 1643.3\ ] - [\ 1262.8\ ] = 380.5$ J/mol·K

Note that $\Delta H°_{rxn}$ has units of kJ/mol, and $\Delta S°_{rxn}$ has units of J/mol·K. These represent the changes that occur when 1 mole of reaction is carried out for standard conditions at T = 298. K

b) ΔS_{syst}, ΔS_{surr}, and ΔS_{univ}

For a chemical reaction at standard conditions

$\Delta S_{syst} = \Delta S°_{rxn} = 380.5$ J/mol·K

$$\Delta S_{surr} = -\frac{\Delta H°_{rxn}}{T} = -\left(\frac{-419.3\ \text{kJ/mol})\ (1000\ \text{J/1 kJ})}{(298\ \text{K})}\right) = 1407.0\ \text{J/mol·K}$$

$\Delta S_{univ} = \Delta S_{syst} + \Delta S_{surr} = (380.5) + (1407.0) = 1787.5$ J/mol·K

c) Is the reaction spontaneous for standard conditions and at T = 298 K (yes/no and a brief justification for your answer)?

Yes. Since $\Delta S_{univ} > 0$, the reaction is spontaneous.