

* 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 $\Delta V = 600.0$ mL against a constant external pressure $p_{\text{ex}} = 2.50$ atm. During the process, 2200. J of heat is added to the system. Find q , w , and ΔU for the process. (NOTE: $1 \text{ L}\cdot\text{atm} = 101.3 \text{ J}$).

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

$$p_{\text{ex}} = 2.50 \text{ atm} \quad \Delta V = 600.0 \text{ mL} = 0.6000 \text{ L}$$

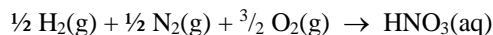
$$\text{So } w = -(2.50 \text{ atm})(0.6000 \text{ L}) = -1.50 \text{ L}\cdot\text{atm} (101.3 \text{ J/L}\cdot\text{atm}) = -152. \text{ J}$$

Heat is added to the system, and so q is positive. $q = 2200 \text{ J}$

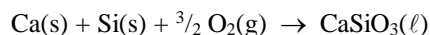
$$\text{From the first law, } \Delta U = q + w = 2200 \text{ J} + (-152. \text{ J}) = 2048 \text{ J}$$

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) $\text{HNO}_3(\text{aq})$



b) $\text{CaSiO}_3(\ell)$



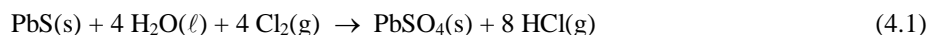
Remember the formation reaction produces exactly 1 mole of one product from elements in their standard (thermodynamically most stable) state.

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

	$\Delta S_{\text{sys}} (\text{J/K})$	$\Delta S_{\text{surr}} (\text{J/K})$	$\Delta S_{\text{univ}} (\text{J/K})$	spontaneous (yes or no)
process 1	18.6	- 27.8	<u> - 9.2 </u>	<u> no </u>
process 2	- 3.6	<u> 22.3 </u>	18.7	<u> yes </u>
process 3	<u> - 61.6 </u>	58.4	- 3.2	<u> no </u>

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

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



Substance	ΔH°_f (kJ/mole)	ΔG°_f (kJ/mole)	S° (J/mole·K)
$\text{Cl}_2(\text{g})$	0.0	0.0	223.0
$\text{HCl}(\text{g})$	- 92.3	- 95.3	187.0
$\text{H}_2\text{O}(\ell)$	- 285.8	- 237.2	69.9
$\text{PbS}(\text{s})$	- 94.3	- 92.7	91.2
$\text{PbSO}_4(\text{s})$	- 918.4	- 811.2	147.3

a) $\Delta H^\circ_{\text{rxn}}$ and $\Delta S^\circ_{\text{rxn}}$

$$\begin{aligned} \Delta H^\circ_{\text{rxn}} &= [\Delta H^\circ_f(\text{PbSO}_4(\text{s})) + 8 \Delta H^\circ_f(\text{HCl}(\text{g}))] - [\Delta H^\circ_f(\text{PbS}(\text{s})) + 4 \Delta H^\circ_f(\text{H}_2\text{O}(\ell)) + 4 \Delta H^\circ_f(\text{Cl}_2(\text{g}))] \\ &= [(- 918.4) + 8 (- 92.3)] - [(- 94.3) + 4 (- 285.8) + 4 (0.0)] \\ &= [- 1656.8] - [- 1237.5] = - 419.3 \text{ kJ/mol} \end{aligned}$$

$$\begin{aligned} \Delta S^\circ_{\text{rxn}} &= [S^\circ(\text{PbSO}_4(\text{s})) + 8 S^\circ(\text{HCl}(\text{g}))] - [S^\circ(\text{PbS}(\text{s})) + 4 S^\circ(\text{H}_2\text{O}(\ell)) + 4 S^\circ(\text{Cl}_2(\text{g}))] \\ &= [(147.3) + 8 (187.0)] - [(91.2) + 4 (69.9) + 4 (223.0)] \\ &= [1643.3] - [1262.8] = 380.5 \text{ J/mol}\cdot\text{K} \end{aligned}$$

Note that $\Delta H^\circ_{\text{rxn}}$ has units of kJ/mol, and $\Delta S^\circ_{\text{rxn}}$ 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_{sys} , ΔS_{surr} , and ΔS_{univ}

For a chemical reaction at standard conditions

$$\Delta S_{\text{sys}} = \Delta S^\circ_{\text{rxn}} = 380.5 \text{ J/mol}\cdot\text{K}$$

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

$$\Delta S_{\text{univ}} = \Delta S_{\text{sys}} + \Delta S_{\text{surr}} = (380.5) + (1407.0) = 1787.5 \text{ J/mol}\cdot\text{K}$$

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

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