

## Problem Set 7

### Problems

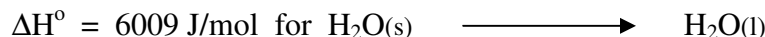
1. From the following data at 25°C:

<u>Rxn</u>	<u><math>\Delta H^\circ</math></u>
$\text{Fe}_2\text{O}_3(\text{s}) + 3 \text{C}(\text{gr}) \longrightarrow 2 \text{Fe}(\text{s}) + 3 \text{CO}(\text{g})$	492.6
$\text{FeO}(\text{s}) + \text{C}(\text{gr}) \longrightarrow \text{Fe}(\text{s}) + \text{CO}(\text{g})$	155.8
$\text{C}(\text{gr}) + \text{O}_2(\text{g}) \longrightarrow \text{CO}_2(\text{g})$	- 393.51
$\text{CO}(\text{g}) + \frac{1}{2} \text{O}_2(\text{g}) \longrightarrow \text{CO}_2(\text{g})$	-282.98

Compute the Standard Heats of Formation of  $\text{FeO}(\text{s})$  and  $\text{Fe}_2\text{O}_3(\text{s})$ .

[Ans. -266.3 kJ/mol, -824.2 kJ/mol]

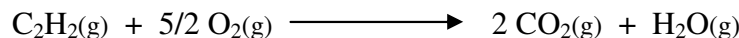
2. Every afternoon a man eats a candy bar containing 3 oz of Sucrose. At night he has a drink of whiskey containing 2 oz of Alcohol. He wants to lose some weight. Is he better off giving up the candy bar or the whiskey?  $\Delta H_f^\circ(298.15) = -2220$  kJ/mol. Other data can be found in the handouts. (Problem shamelessly stolen from *Bromberg*, again.)
3. Calculate the Final Temperature of the system if 20g of Ice at  $-5^\circ\text{C}$  is added to 100g of Water at  $21^\circ\text{C}$  in a Dewar flask. The following data may prove to be useful:



$$C_{p,\text{H}_2\text{O}(\text{s})} = 37.7 \text{ J/K mol}$$

$$C_{p,\text{H}_2\text{O}(\text{l})} = 75.3 \text{ J/K mol}$$

4. Using data for  $C_p(T)$  and  $\Delta H_f^\circ$  in previous handouts, determine  $\Delta H_{\text{rxn}}^\circ(1000)$  for:



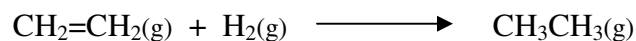
5. Combustion of a 3.386g sample of *cis*-Maleic Acid  $(\text{CHCO}_2\text{H})_2$ ,  $M = 116.07$  g/mol, in an adiabatic bomb calorimeter produced a temperature rise of  $4.193^\circ$  from an initial temperature of  $25^\circ\text{C}$ . The heat capacity of the entire calorimeter system (bomb, contents, and bath) was determined by electrical calibration to be 9471 J/K.

- a) Calculate  $\Delta U_{\text{comb}}(298)$  for one mole of Maleic Acid.

- b) Calculate  $\Delta H_{\text{comb}}^{\circ}(298)$  for one mole of Maleic Acid.  
 c) Calculate  $\Delta H_f^{\circ}(298)$  for one mole of Maleic Acid.

[Ans. -1361.3 kJ/mol, -1363.8 kJ/mol, -781.9 kJ/mol]

6. A current of 1.835 A is passed through a 10.00  $\Omega$  precision resistor in a bomb calorimeter for 400 sec to calibrate the calorimeter. The measured temperature increase is 2.436 K. When 0.3g of graphite is completely burned in the calorimeter, the temperature rise is 1.782 K. The bomb was charged with  $O_2$  at a pressure of 1 MPa. The density of Graphite is 2.25 g/cm<sup>3</sup>. Calculate the molar values of  $\Delta U_{\text{comb}}$  and  $\Delta H_{\text{comb}}$  for the combustion of Graphite.
7. A small catalytic hydrogenation unit has a heat capacity of 300 cal/K. What will its rate of heating be if an equimolar mixture of Ethylene and Hydrogen is passed through it at the rate of 2 mmol of mixture per minute. Assume complete reaction:

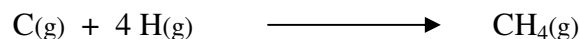


Data:

Substance	State	$\Delta H_f^{\circ}(298.15)$ kcal/mol
Ethylene	<i>g</i>	+ 12.50
Ethane	<i>g</i>	- 20.24

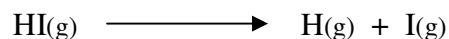
[Ans. 0.109°C/min]

8. The Heat of Sublimation of Graphite to Carbon atoms has been estimated as 170 kcal/mole. The dissociation of molecular Hydrogen into atoms has  $\Delta H^{\circ}(298.15\text{K}) = 103.2$  kcal/mole. From these data and the value for the Heat of Formation of Methane, calculate  $\Delta H^{\circ}(298.15\text{K})$  for:



Estimate the C-H bond energy in Methane.

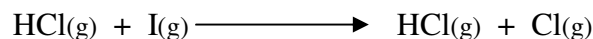
9.  $\Delta H^{\circ}(298)$  is 71.4 kcal for the reaction:



$C_p$  for HI is:

$$C_p[\text{cal/K mol}] = 5.00 + 10^{-3}T$$

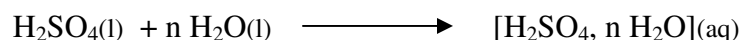
The bond energy of HCl at 25°C is 103 kcal/mol. Calculate  $\Delta H^{\circ}(1000)$  for the atomization of HI and  $\Delta H^{\circ}(298)$  for the following reaction:



Make appropriate assumptions.

10. Dissolving Sulfuric Acid in Water produces considerable heat; enough to boil the Water if sufficiently concentrated.

The Integral Heat of Solution  $\Delta H_{IS}$  is the heat of reaction at a specified temperature and pressure when one mole of solute is dissolved in enough pure solvent to produce a solution of the given concentration. For  $H_2SO_4$  in Water this equals the enthalpy change for the following process:



where  $[H_2SO_4, n H_2O]$  represents a solution consisting of 1 mole  $H_2SO_4$  in  $n$  mole of Water.

The Differential Heat of Solution  $\Delta H_{DS}(T, P, n_2/n_1)$  is the heat of solution per mole solute ( $n_2$ ) added under conditions in which the concentration of the solute is changed only differentially. It can be shown that:

$$\begin{aligned} \Delta H_{DS}(T, P, n_2/n_1) &= \left( \frac{\partial(n_2 \Delta H_{IS})}{\partial n_2} \right)_{n_1, T, P} \\ &= \Delta H_{IS}(T, P, m) + m \left( \frac{\partial \Delta H_{IS}(T, P, m)}{\partial m} \right)_{T, P} \end{aligned}$$

where  $m$  is the solution's molality.

The following data has been obtained for aqueous Sulfuric Acid solutions.

<u>Substance &amp; Description</u>	<u>State</u>	<u><math>\Delta H_f^\circ(298.15)</math> kJ/mol</u>
$H_2SO_4$	<i>l</i>	- 813.99
in 1 $H_2O$	<i>aq</i>	- 841.79
in 2 $H_2O$	<i>aq</i>	- 855.44
in 4 $H_2O$	<i>aq</i>	- 867.88
in 10 $H_2O$	<i>aq</i>	- 880.53
in 20 $H_2O$	<i>aq</i>	- 884.92
in 100 $H_2O$	<i>aq</i>	- 887.64

Use this data to determine  $\Delta H_{IS}$  at each Tabulated concentration. Plot these results as a function of solution molality ( $m$ ). Use this plot to determine  $\Delta H_{DS}$  at solution concentrations of 10m, 20m, 30m and 40m.