CHEM 361A - Lecture 4 Activity

Enthalpy

# In Class

1. Make the following table and fill in as much as you can:

Table 1: Table of thermodynamic properties.

| | Isothermal | Adiabatic | Isobaric | Isochoric |
|---|---|---|---|---|
| q | | | | |
| w | | | | |
| $\Delta U$ | | | | |
| $\Delta H$ | | | | |

2. Consider an isothermal, reversible expansion of 1.5 moles of Neon gas.

   (a) What is the $C_{p,m}$ for this gas?

   (b) If the gas expands from 1.3 L to 5.4 L against an external pressure of 1 atm, what is the $\Delta H$ of the process? Assume that Neon behaves ideally.

3. Calculate the standard enthalpy of formation of diamond, given that:

   - $\mathrm{C(graphite) + O_2 \longrightarrow CO_2(g)} \quad \Delta_r H^{\ominus} = -393.5\ \mathrm{kJ\ mol^{-1}}$
   - $\mathrm{C(diamond) + O_2 \longrightarrow CO_2(g)} \quad \Delta_r H^{\ominus} = -395.4\ \mathrm{kJ\ mol^{-1}}$

4. Given the following two combustion reactions:

   - $\mathrm{CH_4(g) + 2\,O_2(g) \longrightarrow CO_2(g) + 2\,H_2O\,(g)}$
   - $\mathrm{C_2H_4(g) + 6\,O_2(g) \longrightarrow 2\,CO_2(g) + 2\,H_2O\,(g)}$

   which one yields the larger explosion at 1 bar?

5. The difference between $\Delta$H and $\Delta$U

   At 373.15 K and 1 atm, the volume of liquid water and steam are $1.88 \times 10^{-5}$ m$^3$ and $3.06 \times 10^{-2}$ m$^3$, respectively. Given that the heat of vapourization ($\Delta_{vap}$H) of water is 40.79 kJ mol$^{-1}$, calculate $\Delta$U for 1 mol in the following process:

$$\mathrm{H_2O(l, 373.15\,K, 1\,atm) \longrightarrow H_2O(g, 373.15\,K, 1\,atm)}$$

# Homework

6. Calculating $\Delta$H

   (a) If 3.0 moles of Argon gas (a monatomic gas) is heated from 298 K to 368 K, determine $\Delta H$ for this process. ($\Delta H = 4365$ J)

   (b) Calculate the enthalpy of formation of naphthalene ($C_{10}H_8$) based on the following combustion reaction ($\Delta H_f^\ominus = 72.7$ kJ mol$^{-1}$):

   $$C_{10}H_8(s) + 12\,O_2(g) \longrightarrow 10\,CO_2(g) + 4\,H_2O(l) \qquad \Delta_r H^\ominus = -5151.0 \text{ kJ mol}^{-1}$$

   (c) Consider the following reaction:

   $$2\,CH_3OH(l) + 3\,O_2(g) \longrightarrow 4\,H_2O(l) + 2\,CO_2(g) \qquad \Delta_r H^\ominus = -1452.8 \text{ kJ mol}^{-1}$$

   What is the value of $\Delta_r H^\ominus$ if

   i. the order of the reaction is reversed? ($\Delta_r H^\ominus = 1452.8$ kJ mol$^{-1}$)

   ii. water vapour instead of liquid water is the product? ($\Delta_r H^\ominus = -1276.8$ kJ mol$^{-1}$)

7. Calculate $\Delta_r H^\ominus$ (206.2 kJ mol$^{-1}$) and $\Delta_r U^\ominus$ (201.2 kJ mol$^{-1}$) at 298.15 K for the following reaction

   $$CH_4(g) + H_2O(g) \longrightarrow CO(g) + 3\,H_2(g)$$

8. Kirchhoff's Law

   (a) The hydrogenation for ethylene is

   $$C_2H_4(g) + H_2(g) \longrightarrow C_2H_6(g)$$

   Calculate the change in enthalpy of hydrogenation from 298 K to 398 K. The values of $C_{p,m}^\ominus$ for ethylene, ethane and hydrogen are 43.6 J K$^{-1}$ mol$^{-1}$, 52.7 J K$^{-1}$ mol$^{-1}$ and 28.8 J K$^{-1}$ mol$^{-1}$, respectively. Assume the heat capacities are temperature independent. ($\Delta_r H^\ominus(T') - \Delta_r H^\ominus(T) = -1970$ J mol$^{-1}$)

   (b) The standard molar enthalpy of formation of molecular oxygen ($O_2$) at 298 K is zero. What is the value at 315 K? Hint: Use $C_{p,m} = 29.4$ J K$^{-1}$ mol$^{-1}$. ($\Delta_r H^\ominus(315K) = 500$ J mol$^{-1}$)