



Heat- Part II

Chapter 6 – Zumdahl
Dr. Bryan



Measuring Heat

- Heat can be measured under “two” specific conditions
- Heat at constant volume (q_v)
- Heat at constant pressure (q_p)

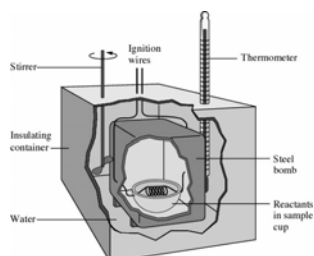
Heat measured at constant volume

$$\Delta E = q + w$$

$$q = \Delta E - w \quad (w = -P\Delta V)$$

$$q = \Delta E + P\Delta V$$

$$q_v = \Delta E \quad (\text{since } \Delta V=0)$$



(Bomb Calorimeter
Zumdahl Figure 6.6)

Heat measured at constant pressure

$$\Delta E = q + w$$

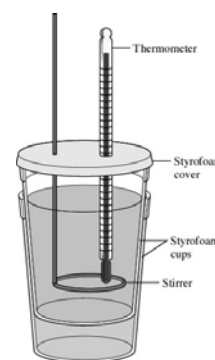
$$q = \Delta E - w \quad (w = -P\Delta V)$$

$$q = \Delta E + P\Delta V$$

$$q_p = \Delta H \quad (\text{called enthalpy})$$

$$\Delta H = \Delta E + P\Delta V$$

$$\Delta H = \Delta E + \Delta n_g RT$$



(Coffee Cup Calorimeter
Zumdahl Figure 6.5)

What is enthalpy?

- Heat gained or lost by a chemical reaction under conditions of constant pressure.
- The most common way to measure heat.
- Symbol is ΔH (with many different subscripts and superscripts)!

Heat flow in chemical reactions

- Reactants \rightarrow Products + heat,
 $\Delta H < 0$, exothermic reaction
- Reactants + heat \rightarrow Products,
 $\Delta H > 0$, endothermic reaction

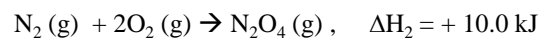
Heat flow and stoichiometry

- $\text{N}_2(\text{g}) + 2 \text{O}_2(\text{g}) \rightarrow 2 \text{NO}_2(\text{g})$, $\Delta H = +68\text{kJ}$
- How much energy is required when 25.0 grams of $\text{NO}_2(\text{g})$ is formed from $\text{N}_2(\text{g})$ and $\text{O}_2(\text{g})$?

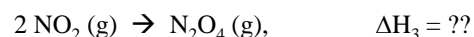
Hess's Law (Part I)

- Enthalpy changes (ΔH) are state functions
- You can:
 - a. reverse chemical reactions
 - b. multiply chemical reactions by numbers
 - c. add chemical reactions

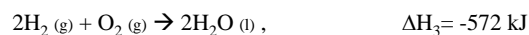
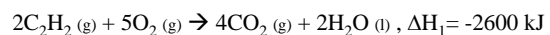
Example #1 (Hess's Law)



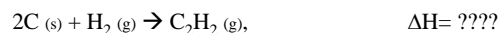
Calculate ΔH for:



Example #2 (Hess's Law)



Calculate the ΔH for the following reaction;



Hess's Law (Part II)

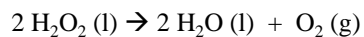
$$\Delta H^\circ_{\text{rxn}} = \sum n_{\text{P}}\Delta H^\circ_{\text{f,P}} - \sum n_{\text{R}}\Delta H^\circ_{\text{f,R}}$$

$\Delta H^\circ_{\text{f}}$ = the standard enthalpy of formation
(often tabulated at 298K, 1 atm)

Example #3 (Hess's Law)

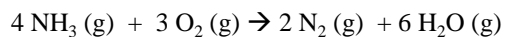
- What is the chemical reaction for $\Delta H^\circ_{\text{f}}$ of $\text{NH}_4\text{NO}_3(\text{s})$?
- By the way . . .the value is -365.6 kJ !
(Many values are listed in the Appendix of your textbook.)

Example #4 (Hess's Law)



Calculate the ΔH_{rxn} using ΔH_f° .

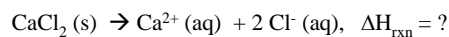
Example #5 (Hess's Law)



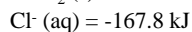
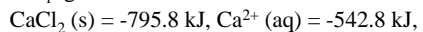
Calculate the ΔH_{rxn} using ΔH_f° .

Example #6 (Hess's Law)

Calculate ΔH_{rxn} for the reaction below:



ΔH_f° given below:



If 6.00 grams of CaCl_2 is dissolved in 100. mL of water at room conditions, what will be the temperature change for the water?

Chemical Reactions and work

$$\Delta H = \Delta E + \Delta n_g RT$$

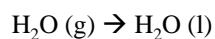
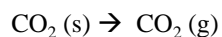
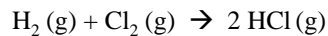
$$\text{work} = w = -P\Delta V = -\Delta n_g RT$$

$$\Delta n_g = n_p - n_R$$

$w > 0$ (compression), $w < 0$ (expansion)

Examples . . .

Chemical Reactions and work



Example #7

- Calculate ΔH , ΔE , and w for the following reaction at 298K and 1 atm:

