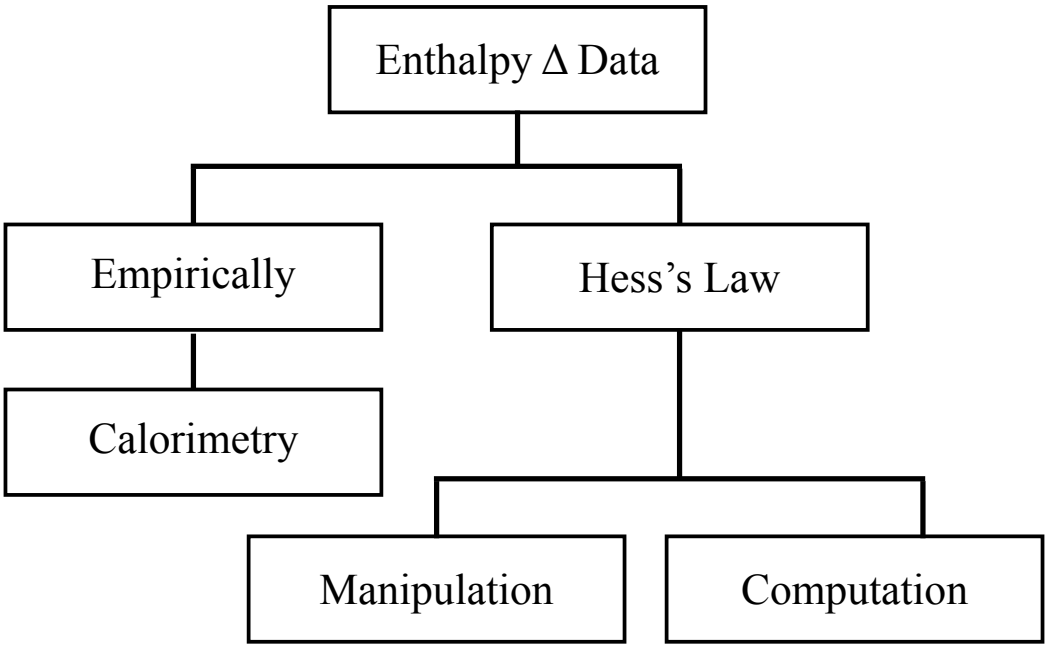
Calorimetry & Hess's Law

1st Law and Enthalpy

Heat of Reaction Sample Problem

- How much heat is released when 4.50 grams of methane gas is burned in an open container?
- $CH_{4(g)} + 2\ O_{2(g)} \Rightarrow 2\ H_2O_{(l)} + CO_{2(g)} \quad \Delta H = -890\ kJ$

$$X + Y \Rightarrow W + Z \quad \Delta H = kJ$$



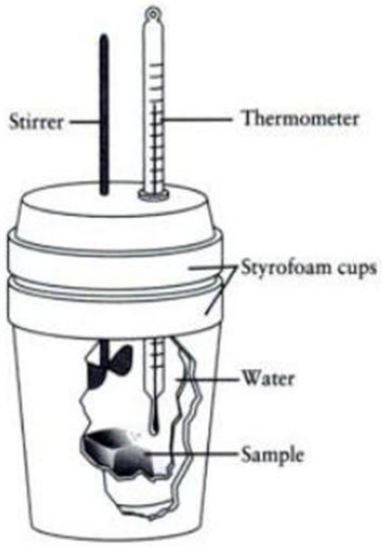
Calorimetry and Hess's Law

Ways of Dealing with Heat

- Heat Capacity
  - The amount of energy needed to raise a system's temperature 1˚C
    - denoted "H_c"
    - $H_c = q/\Delta T$
    - J/c˚
- Specific Heat
  - The amount of energy needed to raise 1 gram of a substance's temperature 1˚C
    - denoted "c"
    - $q = mc\Delta T$
    - J/g·c˚

Calorimetry and Hess's Law

Coffee Cup Calorimetry (Constant Pressure)



(a) Coffee-cup calorimeter
(constant pressure)

Calorimetry and Hess's Law

Calorimetry

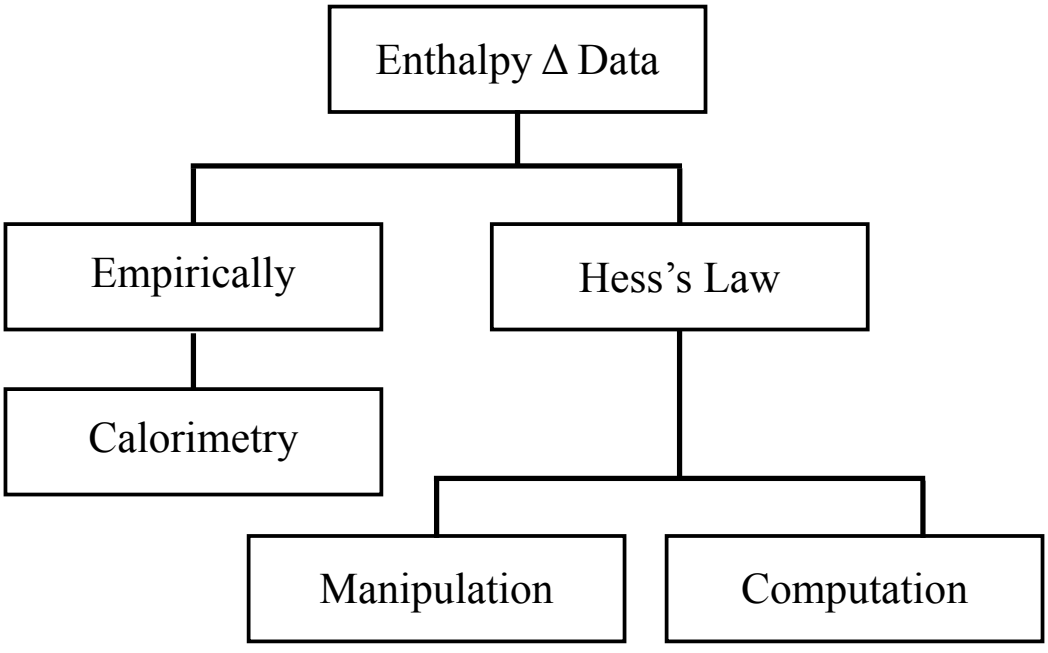
- Coffee-cup calorimeters
  - Require that reactions happen in solution
  - Merely an insulated reaction
  - Measures the temperature change of the solvent
  - The System
    - The reactants and products
  - The Surroundings
    - The solvent (water)
  - $q = mc\Delta T$

Calorimetry and Hess's Law

Calorimetry

- When a 3.25 g sample of solid sodium hydroxide was dissolved in a calorimeter in 100.0 g of water, the temperature rose from 23.9˚C to 32.0˚C. Calculate ΔH (in kj/mole NaOH) for the solution process. Assume it's a perfect calorimeter and that the specific heat of the solution is the same as that of pure water.
- $NaOH_{(s)} \Longrightarrow Na^{+}_{(aq)} + OH^{-}_{(aq)}$

$X + Y \Rightarrow W + Z \quad \Delta H = kJ$



Calorimetry and Hess's Law

Hess's Law

- If a reaction can be broken down into a series of steps, the sum of the enthalpy changes associated with the steps will equal the enthalpy change of the complete change.
- Two problem solving approaches
  - Manipulation
  - Computation using Heats of Formation

Calorimetry and Hess's Law

Hess's Law by Manipulation

- Calculate the enthalpy of combustion of C to CO.

$$C_{(s)} + O_{2(g)} \Rightarrow CO_{2(g)} \quad \Delta H = -393.5 \text{ kJ}$$

$$CO_{(g)} + 1/2\ O_{2(g)} \Rightarrow CO_{2(g)} \quad \Delta H = -283.0 \text{ kJ}$$

Calorimetry and Hess's Law

Enthalpies of Formation

- The change in energy for the reaction forming 1 mol of a compound from its component elements
- ΔH°_f
  - The $^\circ$ symbol indicated standard conditions
    - Generally pure substances at 25°C (298K) and 1 atm of pressure
- See table 5.3 (page 184)
- All diatomic elements are assumed to have ΔH°_f of 0 kJ

Calorimetry and Hess's Law

Heat of Formation

$$2\ HCl + Ca(OH)_2 \Rightarrow CaCl_2 + 2\ H_2O$$

$$\tfrac{1}{2}\ H_2 + \tfrac{1}{2}\ Cl_2 \Rightarrow HCl$$

$$Ca + O_2 + H_2 \Rightarrow Ca(OH)_2$$

$$Ca + Cl_2 \Rightarrow CaCl_2$$

$$H_2 + 1/2\ O_2 \Rightarrow H_2O$$

Calorimetry and Hess's Law

Heat of Formation

- $\Delta H^\circ rxn = \sum n\Delta H^\circ_{f(products)} - \sum n\Delta H^\circ_{f(reactants)}$
- Calculate the standard enthalpy change for the combustion of 1 mol of benzene, C_6H_6, to CO_2 and H_2O

$$C_6H_{6(l)} + \quad O_{2(g)} \Rightarrow \quad CO_{2(g)} + \quad H_2O_{(l)}$$

$$C_6H_{6(l)} + 15/2\ O_{2(g)} \Rightarrow 6\ CO_{2(g)} + 3\ H_2O_{(l)}$$

Calorimetry and Hess's Law

Homework

- 5.49a&b, 50, 51, 56, 63, 65, 69, 75 a&b
- Summarize chapter 19
  - Use the 4 quadrant format you used with chapter 5