5.4 Review

Summary

- Hess's law states that the enthalpy change of a process is the same whether the process takes place in one step or in a series of steps.
- By applying Hess's law, we can manipulate and combine different chemical equations to determine the enthalpy change of a reaction of interest.

Questions

1. (a) State Hess's law in your own words.
   (b) In a correct equation for a reverse reaction, what happens to the sign and magnitude of ΔH?
   (c) When you multiply the coefficients of a balanced equation by a constant, what changes must you make to the sign and magnitude of ΔH? K/U
2. Explain how Hess's law is consistent with the law of conservation of energy. K/U
3. What characteristic of enthalpy change is the basis of Hess's law? K/U
4. Phosphorus burns spontaneously in air to produce tetraphosphorus decaoxide, $P_4O_{10}(s)$:

   $4\ P(s) + 5\ O_2(g) \rightarrow P_4O_{10}(s)$

   Using the following thermochemical equations, determine:
   (a) the enthalpy of combustion for phosphorus
   (b) the molar enthalpy of combustion for phosphorus, expressed in kJ/mol K/U T/I

   $4\ P(s) + 3\ O_2(g) \rightarrow P_4O_6(s) \quad \Delta H = -1640\ kJ$
   $P_4O_6(s) + 2\ O_2(g) \rightarrow P_4O_{10}(s) \quad \Delta H = -1344\ kJ$

5. Nitric oxide gas, NO(g), can be oxidized in air to produce nitrogen dioxide gas, $NO_2(g)$:

   $2\ NO(g) + O_2(g) \rightarrow 2\ NO_2(g)$

   Determine the enthalpy change for this reaction using any of these thermochemical equations: K/U T/I

   $O_2(g) \rightarrow 2\ O(g) \quad \Delta H = +495\ kJ$
   $NO(g) + O_3(g) \rightarrow NO_2(g) + O_2(g) \quad \Delta H = -199\ kJ$
   $2\ O_3(g) \rightarrow 3\ O_2(g) \quad \Delta H = -427 kJ$

6. Liquid hydrazine, $N_2H_4(l)$, is a rocket fuel. It combusts in oxygen gas to form nitrogen gas and liquid water:

   $N_2H_4(l) + O_2(g) \rightarrow N_2(g) + 2\ H_2O(l)$

   Use the following thermochemical equations to calculate the enthalpy change for the combustion of liquid hydrazine: K/U T/I

   $2\ NH_3(g) + 3\ N_2O(g) \rightarrow 4\ N_2(g) + 3\ H_2O(l) \quad \Delta H = -1010\ kJ$
   $N_2O(g) + 3\ H_2(g) \rightarrow N_2H_4(l) + H_2O(l) \quad \Delta H = -317\ kJ$
   $2\ NH_3(g) + \frac{1}{2}\ O_2(g) \rightarrow N_2H_4(l) + H_2O(l) \quad \Delta H = -143\ kJ$
   $H_2(g) + \frac{1}{2}\ O_2(g) \rightarrow H_2O(l) \quad \Delta H = -286\ kJ$

7. Solid calcium carbide, $CaC_2(s)$, reacts with liquid water to produce ethyne, $C_2H_2(g)$ (acetylene):

   $CaC_2(s) + 2\ H_2O(l) \rightarrow Ca(OH)_2(aq) + C_2H_2(g)$

   Using the following thermochemical equations, calculate the enthalpy change for this reaction: K/U T/I

   $Ca(s) + 2\ C_{graphite}(s) \rightarrow CaC_2(s) \quad \Delta H = -62.8 kJ$
   $Ca(s) + \frac{1}{2}\ O_2(g) \rightarrow CaO(s) \quad \Delta H = -635.5\ kJ$
   $CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq) \quad \Delta H = -653.1\ kJ$
   $C_2H_2(g) + \frac{5}{2}\ O_2(g) \rightarrow 2\ CO_2(g) + H_2O(l) \quad \Delta H = -1300.\ kJ$
   $C_{graphite}(s) + O_2(g) \rightarrow CO_2(g) \quad \Delta H = -393.5\ kJ$

8. The neutralization reaction between lithium hydroxide solution, LiOH(aq), and hydrochloric acid, HCl(aq), will produce water and aqueous lithium chloride, LiCl(aq). Using the following thermochemical equations, determine the enthalpy of neutralization for 1 mol of aqueous lithium hydroxide: K/U T/I

   $\frac{1}{2}\ H_2(g) + \frac{1}{2}\ Cl_2(g) \rightarrow HCl(g) \quad \Delta H = -92.3\ kJ$
   $H_2(g) + \frac{1}{2}\ O_2(g) \rightarrow H_2O(l) \quad \Delta H = -285.8\ kJ$
   $Li(s) + \frac{1}{2}\ Cl_2(g) \rightarrow LiCl(s) \quad \Delta H = -815.0\ kJ$
   $Li(s) + \frac{1}{2}\ O_2(g) + \frac{1}{2}\ H_2(g) \rightarrow LiOH(s) \quad \Delta H = -487.0\ kJ$
   $LiOH(s) \rightarrow LiOH(aq) \quad \Delta H = -19.2\ kJ$
   $HCl(g) \rightarrow HCl(aq) \quad \Delta H = -77.0\ kJ$
   $LiCl(s) \rightarrow LiCl(aq) \quad \Delta H = -36.0\ kJ$

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