Exercise 16.1d

Hess's Law & Enthalpy of Formation

Name: ______________________

Date:________________ Per:________

Germain Henri Hess, in 1840, discovered a very useful principle which is named for him:

The enthalpy of a given chemical reaction is constant, regardless of the reaction happening in one step or many steps.

Hess' Law is usually presented like this: $\Delta H°_{rxn} = \Sigma\ \Delta H°_f$ (products) - $\Sigma\ \Delta H°_f$ (reactants)

Or this: $\Delta H°_{rxn} = \Sigma\ \Delta H°_{f,\ products} - \Sigma\ \Delta H°_{f,\ reactants}$

Hess' Law states that the heat evolved in a given process can be expressed as the sum of the heats of several processes that, when added, yield the process of interest. Because enthalpy is a state function, if the reactants and products remain the same, it doesn't matter how the reaction is carried out.

Some general rules relating to Hess' Law:

- The standard enthalpy of formation for an element in its standard state is zero.
- When a reaction is reversed, the sign of ΔH is changed.
- If you modify the coefficients of a reaction, multiply ΔH by the same factor.

DIRECTIONS: Answer the following in the space provided.

1. Given the following data:

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

   Calculate $\Delta H°$ for the reaction: $NO(g) + O(g) \rightarrow NO_2(g)$

2. Given the following data:

   $N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$ $\Delta H° = 67.7$ kJ
   $N_2(g) + 2O_2(g) \rightarrow N_2O_4(g)$ $\Delta H° = 9.7$ kJ

   Calculate $\Delta H°$ for the dimerization of NO_2: $2NO_2(g) \rightarrow N_2O_4(g)$

3. The bombardier beetle uses an explosive discharge as a defensive measure. The chemical reaction involved is the oxidation of hydroquinone by hydrogen peroxide to produce quinone and water;

   $C_6H_4(OH)_2(aq) + H_2O_2(aq) \rightarrow C_6H_4O_2(aq) + 2H_2O(l)$

   Calculate $\Delta H°$ for the reaction from the following data:

   $C_6H_4(OH)_2(aq) \rightarrow C_6H_4O_2(aq) + H_2(g)$ $\Delta H° = +177.4$ kJ
   $H_2(g) + O_2(g) \rightarrow H_2O_2(aq)$ $\Delta H° = -191.2$ kJ
   $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(g)$ $\Delta H° = -241.8$ kJ
   $H_2O(g) \rightarrow H_2O(l)$ $\Delta H° = -43.8$ kJ

Answers: 1) -233 kJ 2) -58.0 kJ 3) -202.6 kJ 4) 28.4 kJ 5) -622.4 kJ 6) -1788.7 kJ 7) -1076.1 kJ 8) -3655.4 kJ

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4. Given the following data:

$H_2(g) + ½O_2(g) \rightarrow H_2O(l)$ $\Delta H° = -285.8$ kJ

$N_2O_5(g) + H_2O(l) \rightarrow 2HNO_3(l)$ $\Delta H° = -76.6$ kJ

$\frac{1}{2} N_2(g) + \frac{3}{2} O_2(g) + \frac{1}{2} H_2(g) \rightarrow HNO_3(l)$ $\Delta H° = -174.1$ kJ

Calculate the $\Delta H°$ for the reaction: $2N_2(g) + 5O_2(g) \rightarrow 2 N_2O_5(g)$

DIRECTIONS: Use the data at right to calculate the ΔH for each reaction.
(N.B. Heat of formation of elements is 0.)

Compound	Enthalpy of Formation
$N_2H_4(l)$	+ 50.6 kJ/mol
$H_2O(g)$	– 241.8 kJ/mol
$H_2O(l)$	– 285.9 kJ/mol
$CO_2(g)$	– 393.5 kJ/mol
$C_3H_6O(l)$	– 249.5 kJ/mol
$CS_2(l)$	+ 89.0 kJ/mol
$SO_2(g)$	– 296.8 kJ/mol
C_6H_{12} (l)	– 156.4 kJ/mol

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

6. $C_3H_6O(l) + 4 O_2(g) \rightarrow 3 CO_2(g) + 3 H_2O(l)$

7. $CS_2(l) + 3 O_2(g) \rightarrow CO_2(g) + 2 SO_2(g)$

8. The combustion of C_6H_{12}

Answers: 1) -233 kJ 2) -58.0 kJ 3) -202.6 kJ 4) 28.4 kJ 5) -622.4 kJ 6) -1788.7 kJ 7) -1076.1 kJ 8) -3655.4 kJ