Math Tutor HESS'S LAW

You may have seen a popular comic strip in which a little boy takes a long, twisting path between the school-bus stop and home. No matter which path the boy takes, the result is always the same: He goes from the bus stop to the door of his house. Hess's law covers a similar situation in thermochemistry. No matter which or how many steps occur in the process of changing one or more substances into one or more other substances, the overall change in enthalpy is always the same. Hess's law can be used, for example, to predict the enthalpy change, ΔH^0, of a reaction without actually carrying out the reaction.

SAMPLE

Determine ΔH for the burning of carbon disulfide in oxygen.

$$CS_2(l) + 3O_2(g) \longrightarrow CO_2(g) + 2SO_2(g) \quad \Delta H^0 = ?$$

Use the following information:

$$C(s) + O_2(g) \longrightarrow CO_2(g) \quad \Delta H_f^0 = -393.5 \text{ kJ/mol}$$
$$S(s) + O_2(g) \longrightarrow SO_2(g) \quad \Delta H_f^0 = -296.8 \text{ kJ/mol}$$
$$C(s) + 2S(s) \longrightarrow CS_2(l) \quad \Delta H_f^0 = 87.9 \text{ kJ/mol}$$

Rearrange the given equations in a way that will put the reactants of the above equation on the left and the products on the right.

1. $\cancel{C(s)} + O_2(g) \longrightarrow CO_2(g) \qquad \Delta H_f^0 = -393.5 \text{ kJ/mol}$
2. $\cancel{2S(s)} + 2O_2(g) \longrightarrow 2SO_2(g) \qquad \Delta H^0 = 2(-296.8 \text{ kJ})$
3. $CS_2(l) \longrightarrow \cancel{C(s)} + \cancel{2S(s)} \qquad \Delta H^0 = -87.9 \text{ kJ}$

SUM: $CS_2(l) + 3O_2(g) \longrightarrow CO_2(g) + 2SO_2(g)$

Notice that equation 2 is double the original equation $S(s) + O_2(g) \longrightarrow SO_2(g)$. The reason for this is that $2SO_2$ are needed on the product side to match the $2SO_2$ in $CS_2(l) + 3O_2(g) \longrightarrow CO_2(g) + 2SO_2(g)$. The third equation is the reverse of the original, putting CS_2 on the reactant side of the final equation. The sign of ΔH is likewise reversed. The value of ΔH^0 is the sum of the ΔH^0 values for the three added equations.

$\Delta H^0 = -393.5 \text{ kJ} + 2(-296.8 \text{ kJ}) + (-87.9 \text{ kJ})$

$\Delta H^0 = -1075.0 \text{ kJ}$

PRACTICE PROBLEMS

1. Calculate ΔH^0 for the complete oxidation of sulfur to sulfur trioxide.

$$S(s) + \tfrac{3}{2}O_2(g) \longrightarrow SO_3(g)$$

Use the following information.

$S(s) + O_2(g) \longrightarrow SO_2(g) \qquad \Delta H_f^0 = -296.8 \text{ kJ/mol}$

$SO_2(g) + \tfrac{1}{2}O_2(g) \longrightarrow SO_3(g) \qquad \Delta H_f^0 = -99.2 \text{ kJ/mol}$

2. Calculate ΔH^0 for the reaction in which zinc sulfide ore is roasted to obtain zinc oxide.

$$ZnS(s) + \tfrac{3}{2}O_2(g) \longrightarrow ZnO(s) + SO_2(g)$$

Use the following information.

$Zn(s) + \tfrac{1}{2}O_2(g) \longrightarrow ZnO(s) \qquad \Delta H_f^0 = -348.0 \text{ kJ/mol}$

$Zn(s) + S(s) \longrightarrow ZnS(s) \qquad \Delta H_f^0 = -203.0 \text{ kJ/mol}$

$S(s) + O_2(g) \longrightarrow SO_2(g) \qquad \Delta H_f^0 = -296.8 \text{ kJ/mol}$