CHAPTER 10	Using Hess's Law to Determine Enthalpy Change	BLM 10.1.2
OVERHEAD		

Sample Problem

One of the methods that the steel industry uses to obtain metallic iron is to react iron(III) oxide, $Fe_2O_3(s)$, with carbon monoxide, $CO(g)$, as shown in the balanced equation below:

$$Fe_2O_3(s) + 3CO(g) \rightarrow 3CO_2(g) + 2Fe(s)$$

Determine the enthalpy change of this reaction, given the following equations and their enthalpy changes.

(1) $CO(g) + \frac{1}{2} O_2(g) \rightarrow CO_2(g) \qquad \Delta H° = -283.0 \text{ kJ}$

(2) $2Fe(s) + \frac{3}{2} O_2(g) \rightarrow Fe_2O_3(s) \qquad \Delta H° = -824.2 \text{ kJ}$

What Is Required?

You need to manipulate equations (1) and (2), along with their enthalpy changes, so they add up to the overall equation:

$$Fe_2O_3(s) + 3CO(g) \rightarrow 3CO_2(g) + 2Fe(s)$$

What Is Given?

You know the chemical equations for reactions (1) and (2), and you know their corresponding enthalpy changes.

Plan Your Strategy

Step 1 Examine equations (1) and (2) to see how they compare with the overall equation. Decide how you need to manipulate equations (1) and (2) so that they add to the overall equation. (Reverse the equation, multiply the equation by a coefficient, do both, or do neither.) Remember to adjust $\Delta H°$ accordingly for each equation.

Step 2 Write the manipulated equations so that their equation arrows line up. Add the reactants and products on each side, and cancel substances that appear on both sides in equal amounts.

Step 3 Ensure that you have obtained the overall equation. Add $\Delta H°$ for the combined equation.

Using Hess's Law to Determine Enthalpy Change (continued)

Act on Your Strategy

Step 1

- Equation (1) has CO(g) as a reactant and $CO_2(g)$ as a product, as does the overall equation. The stoichiometric coefficients do not match the coefficients of the overall equation, however. To achieve the same coefficients, you must multiply equation (1) by 3.
- Equation (2) has the required stoichiometric coefficients, but Fe(s) and $Fe_2O_3(s)$ are on the wrong sides of the equation. You need to reverse equation (2) and, therefore, change the sign of the $\Delta H°$.
- **Note:** Since oxygen gas, $O_2(g)$, is present in both equations that you are manipulating, do not use $O_2(g)$ to decide on how to manipulate the equations. Always start with a chemical species that is present in only one of the equations and is also present in the overall equation.

Step 2

3 × (1) $3CO(g) + \frac{3}{2}O_2(g) \rightarrow 3CO_2(g)$ $\Delta H° = 3(-283.0\text{ kJ})$

–1 × (2) $Fe_2O_3(s) \rightarrow 2Fe(s) + \frac{3}{2}O_2(g)$ $\Delta H° = -1(-824.2\text{ kJ})$

$$Fe_2O_3(s) + 3CO(g) \rightarrow 3CO_2(g) + 2Fe(s)$$

Step 3

$Fe_2O_3(s) + 3CO(g) \rightarrow 3CO_2(g) + 2Fe(s)$

$\Delta H° = 3(-283.0\text{ kJ}) + (-1(-824.2\text{ kJ}))$

$= -24.8\text{ kJ}$

The manipulated equations add to the overall equation. Therefore, the sum of the manipulated enthalpy changes is the enthalpy change of the overall equation:

$$Fe_2O_3(s) + 3CO(g) \rightarrow 3CO_2(g) + 2Fe(s) \quad \Delta H° = -24.8\text{ kJ}$$

Check Your Solution

The equations added correctly to the overall equation. Check to ensure that you adjusted $\Delta H°$ accordingly for each equation. Because you added the $\Delta H°$ values, the final answer will be as precise as the least precise number used in the calculation. The final answer has one digit after the decimal point, which is correct.