In order to calculate the change in enthalpy for this reaction, we can use the combustion reactions of the elements, carbon and hydrogen, and of methane.

$$C(s) + O_2(g) \longrightarrow CO_2(g) \qquad \Delta H_c^0 = -393.5 \text{ kJ}$$
$$H_2(g) + \tfrac{1}{2}O_2(g) \longrightarrow H_2O(l) \qquad \Delta H_c^0 = -285.8 \text{ kJ}$$
$$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(l) \qquad \Delta H_c^0 = -890.8 \text{ kJ}$$

The general principles for combining thermochemical equations follow.

1. If a reaction is reversed, the sign of ΔH is also reversed.
2. Multiply the coefficients of the known equations so that when added together they give the desired thermochemical equation. Multiply the ΔH by the same factor as the corresponding equation.

In this case, reverse the combustion equation for methane, and remember to change the sign of ΔH from negative to positive. This will change the exothermic reaction to an endothermic one.

$$CO_2(g) + 2H_2O(l) \longrightarrow CH_4(g) + 2O_2(g) \qquad \Delta H^0 = +890.8 \text{ kJ}$$

Now we notice that 2 moles of water are used as a reactant; therefore, 2 moles of water will be needed as a product. In the combustion reaction for hydrogen as it is written, it only produces one mole of water. We must multiply the coefficients of this combustion reaction and the value of ΔH by 2 in order to obtain the desired quantity of water.

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(l) \qquad \Delta H_c^0 = 2(-285.8 \text{ kJ})$$

We are now ready to add the three equations together using Hess's law to give the enthalpy of formation for methane and the balanced equation.

$$C(s) + \cancel{O_2(g)} \longrightarrow \cancel{CO_2(g)} \qquad \Delta H_c^0 = -393.5 \text{ kJ}$$
$$2H_2(g) + \cancel{O_2(g)} \longrightarrow \cancel{2H_2O(l)} \qquad \Delta H_c^0 = 2(-285.8 \text{ kJ})$$
$$\cancel{CO_2(g)} + \cancel{2H_2O(l)} \longrightarrow CH_4(g) + \cancel{2O_2(g)} \qquad \Delta H^0 = +890.8 \text{ kJ}$$
$$C(s) + 2H_2(g) \longrightarrow CH_4(g) \qquad \Delta H_f^0 = -74.3 \text{ kJ}$$

Hess's law says that the enthalpy difference between reactants and products is independent of pathway. Therefore, any enthalpy of reaction may be calculated using enthalpies of formation for all the substances in the reaction of interest, without knowing anything else about how the reaction occurs. Mathematically, the overall equation for enthalpy change will be in the form of the equation shown below.

$$\Delta H^0 = \text{sum of } [(\Delta H_f^0 \text{ of products}) \times (\text{mol of products})] - \text{sum of } [(\Delta H_f^0 \text{ of reactants}) \times (\text{mol of reactants})]$$

An example using Hess's law is shown in **Sample Problem B.**