CHAPTER 10		BLM 10.1.3
OVERHEAD	# Using Hess's Law to Determine Enthalpy Change for Formation Reactions	

Sample Problem

From the following information, calculate the enthalpy of formation of solid phosphorus pentachloride as shown in the equation below:

$$\frac{1}{4}P_4(s) + \frac{5}{2}Cl_2(g) \rightarrow PCl_5(s)\ \Delta H° = ?$$

(1) $P_4(s) + 6Cl_2(g) \rightarrow 4PCl_3(\ell)\ \Delta H° = -1272\ kJ$
(2) $PCl_3(\ell) + Cl_2(g) \rightarrow PCl_5(s)\ \Delta H° = -125\ kJ$

What Is Required?

You need to manipulate and add equations (1) and (2) along with their enthalpy changes to obtain the overall equation.

What Is Given?

You know the overall equation and the thermochemical equations for reactions (1) and (2).

Plan Your Strategy

The overall equation contains fractions. To simplify your manipulations of equations (1) and (2), you may find it easier to first find the enthalpy change for the overall equation with whole-number coefficients and then divide to obtain the true overall equation at the end of the problem.

First, balance the overall equation with whole numbers by multiplying the coefficients by 4:

$$P_4(s) + 10Cl_2(g) \rightarrow 4PCl_5(s)\ \Delta H° = ?$$

Second, manipulate equations (1) and (2).

- Equation (1) can be used as written to obtain $P_4(s)$ as a reactant.
- Equation (2) has $PCl_5(s)$ on the correct side of the equation but not in the correct stoichiometric quantities. Multiply equation (2) by 4.

Act on Your Strategy

(1) $P_4(s) + 6Cl_2(g) \rightarrow \cancel{4PCl_3(\ell)}$ $\quad \Delta H° = -1272\ kJ$

(2) × 4 $\cancel{4PCl_3(\ell)} + 4Cl_2(g) \rightarrow 4PCl_5(s)$ $\quad \Delta H° = 4(-125\ kJ)$

$P_4(s) + 10Cl_2(g) \rightarrow 4PCl_5(s)$ $\quad \Delta H° = -1272\ kJ + 4(-125\ kJ)$
$= -1772\ kJ$

The desired overall equation is for the formation of only 1 mol of $PCl_5(s)$. Therefore, divide the equation and corresponding $\Delta H°$ by 4, thus giving the following solution.

$$\frac{1}{4}P_4(s) + \frac{5}{2}Cl_2(g) \rightarrow PCl_5(s) \qquad \Delta H° = \frac{-1772\ kJ}{4}$$
$$= -443\ kJ$$

Therefore, the enthalpy of formation of phosphorus pentachloride is $\Delta H° = -443$ kJ/mol.

Check Your Solution

The equations and the $\Delta H°$ have been adjusted and are added correctly to the overall equation. Substances not appearing in the overall equation have been cancelled. The final answer has the same precision as the $\Delta H°$ used in the calculations (no digits after the decimal point).