Strategy for Solving Hess's Law Problems:

Consider the problem:

Use:	(a)	$FeO(s) + H_2(g) \longrightarrow Fe(s) + H_2O(g)$	$\Delta H = +24.7$ kJ
	(b)	$3\ FeO(s) + \frac{1}{2}\ O_2(g) \longrightarrow Fe_3O_4(s)$	$\Delta H = -317.6$ kJ
	(c)	$H_2(g) + \frac{1}{2}\ O_2(g) \longrightarrow H_2O(g)$	$\Delta H = -241.8$ kJ

To calculate ΔH for the reaction:

$$3\ Fe(s) + 4\ H_2O(g) \longrightarrow Fe_3O_4(s) + 4\ H_2(g) \qquad \Delta H = ?$$

For purposes of discussion we will call " $3\ Fe(s) + 4\ H_2O(g) \longrightarrow Fe_3O_4(s) + 4\ H_2(g)$ " the **target equation** and equations (a) , (b) , and (c) the **data equations**.

The goal in this problem is to find a way to add the data equations together to arrive at the target equation. Then the corresponding ΔH values can be added together to arrive at the target ΔH.

Step 1: Select one of the constituents of the target equation. Choose from either the reactant side or the product side. Often the first reactant is convenient. Sometimes it makes sense to use the major product. The selected constituent should appear in only one data equation. **For this example we will choose $Fe_3O_4(s)$**.

Step 2: Find the data equation that contains the constituent selected in step 1. If the constituent is in more than one data equation, return to Step 1 and choose a different constituent. **Data equation (b) has $Fe_3O_4(s)$.**

Step 3: Write the chosen data equation so that the selected constituent is on the same side of the arrow as it is in the target equation. That is, if the selected constituent is a product in both target and data equations, or if it is a reactant in both, then write the data equation as it appears in the data. If the selected constituent is a product in one equation (target or data) and a reactant in the other, then reverse the data equation (interchange products and reactants) and change the sign of the ΔH value before writing it.

In our example, $Fe_3O_4(s)$, is on the right in both target and data equation so:

$$\mathbf{3\ FeO(s) + \frac{1}{2}\ O_2(g) \longrightarrow Fe_3O_4(s) \qquad \Delta H = -317.6\ kJ}$$

Step 4: If the coefficient on the selected constituent in the data equation is different from the coefficient on the selected constituent in the target equation, multiply the whole data equation (all components and the ΔH value) by the number (may be fractional) that will make them equal. **In our example both have coefficient =1, so no multiplication is necessary (or multiply by 1.)**

Step 5: Choose another constituent in the target equation and follow steps 2 through 4 above. In the new step 3 (which I we can call step 5-3) write the new equation under the previous data so that the equations can be added easily.

Step 5-1 **Choose Fe(s)**

Step 5-2 **The data equation with Fe(s) is equation (a).**

Step 5-3 **The target and data equations have Fe(s) on opposite sides so reverse (a).**

$3\ FeO(s) + \frac{1}{2}\ O_2(g) \longrightarrow Fe_3O_4(s) \qquad \Delta H = -317.6\ kJ$

$\mathbf{Fe(s) + H_2O(g) \longrightarrow FeO(s) + H_2(g) \qquad \Delta H = -24.7\ kJ}$

Step 5-4 **The coefficient of Fe(s) in the target equation is 3 so multiply equation (a) [reversed] by 3. So:**

$3\ FeO(s) + \frac{1}{2}\ O_2(g) \longrightarrow Fe_3O_4(s) \qquad \Delta H = -317.6\ kJ$

$\mathbf{3}\ Fe(s) + \mathbf{3}\ H_2O(g) \longrightarrow \mathbf{3}\ FeO(s) + \mathbf{3}\ H_2(g) \qquad \Delta H = -24.7\ kJ\mathbf{\times 3}$

Step 6: Continue applying step 5 until all constituents of the target equation are accounted for, or it may be necessary of convenient at some point to eliminate constituents in the data equations that are not in the target equation. To eliminate constituents go to step 7 and following.

Step 7: In the accumulation of data equations cross out constituents that appear on both sides of the arrow. **In our example the 3 FeO(s) terms cancel.**

$\cancel{3\ FeO(s)} + \frac{1}{2}\ O_2(g) \longrightarrow Fe_3O_4(s) \qquad \Delta H = -317.6\ kJ$

$3\ Fe(s) + 3\ H_2O(g) \longrightarrow \cancel{3\ FeO(s)} + 3\ H_2(g) \qquad \Delta H = -24.7\ kJ\times 3$

Step 8: Choose a constituent in the already selected data equations that is not in the target equation. **In our example $\frac{1}{2}\ O_2(g)$ is not in the target equation.**

Step 9: Choose a data equation not already selected with the chosen constituent. **In our example this is equation (c).**

Step 10: Write the equation forwards or backwards and multiply by a multiplier as necessary to cancel the chosen constituent from the data equations. **In our example equation (c) must be reversed (and multiplied by 1) to cancel $\frac{1}{2}\ O_2(g)$**.

$\cancel{3\ FeO(s)} + \frac{1}{2}\ O_2(g) \longrightarrow Fe_3O_4(s) \qquad \Delta H = -317.6\ kJ$

$3\ Fe(s) + 3\ H_2O(g) \longrightarrow \cancel{3\ FeO(s)} + 3\ H_2(g) \qquad \Delta H = -24.7\ kJ\times 3$

$\mathbf{H_2O(g) \longrightarrow H_2(g) + \frac{1}{2}\ O_2(g) \qquad \Delta H = +241.8\ kJ}$

Step 11: Apply steps 7 through 10 as many times as necessary to arrive at the target equation.

$\cancel{3\ FeO(s)} + \cancel{\frac{1}{2}\ O_2(g)} \longrightarrow Fe_3O_4(s) \qquad \Delta H = -317.6\ kJ$

$3\ Fe(s) + 3\ H_2O(g) \longrightarrow \cancel{3\ FeO(s)} + 3\ H_2(g) \qquad \Delta H = -24.7\ kJ\times 3$

$H_2O(g) \longrightarrow H_2(g) + \cancel{\frac{1}{2}\ O_2(g)} \qquad \Delta H = +241.8\ kJ$

Step 12: Add the data equations together and the ΔH values together to arrive at the problem solution.

$\cancel{3\ FeO(s)} + \cancel{\frac{1}{2}\ O_2(g)} \longrightarrow Fe_3O_4(s) \qquad \Delta H = -317.6\ kJ$

$3\ Fe(s) + 3\ H_2O(g) \longrightarrow \cancel{3\ FeO(s)} + 3\ H_2(g) \qquad \Delta H = -24.7\ kJ\times 3$

$H_2O(g) \longrightarrow H_2(g) + \cancel{\frac{1}{2}\ O_2(g)} \qquad \Delta H = +241.8\ kJ$

$\mathbf{3\ Fe(s) + 4\ H_2O(g) \longrightarrow Fe_3O_4(s) + 4\ H_2(g) \qquad \Delta H = -149.9\ kJ}$