Example: Calculate the  $\Delta H$  for formation of benzene from its elements given the following information: The desired reaction is:  $6C \text{ (graphite)} + 3H_2 \text{ (g)} \rightarrow C_6H_6 \text{ (l)} \Delta H^{\circ} f = ?$ 

The following reactions must be added or subtracted to obtain the desired reaction.

(1)  $2C_6H_6(l) + 15O_2(g) \rightarrow 12CO_2(g) + 6H_2O(l)$ 

 $\Delta H^{\circ} rxn = -6534.8 \text{ kJ}$  $\Delta$ H°rxn = -393.51 kJ

(2) C (graphite) +  $O_2(g) \rightarrow CO_2(g)$ 

(3)  $H_2(g) + \frac{1}{2} O_2(g) \rightarrow H_2O(l)$ 

 $\Delta H^{\circ} rxn = -285.83 \text{ kJ}$ 

reaction (1) has  $C_6H_6(l)$  as a reactant... so reverse it

reaction (2) has C(graphite) as a reactant ... so do not reverse

reaction (3) has  $H_2(g)$  as a reactant... so do not reverse

$$12\text{CO}_2(g) + 6\text{H}_2\text{O}(1) \rightarrow 2\text{C}_6\text{H}_6(l) + 15\text{O}_2(g)$$
  
C (graphite) + O<sub>2</sub>(g) \rightarrow CO<sub>2</sub>(g)

 $\Delta H^{\circ}_{1}$  reversed = +6534.8 kJ

 $H_2(g) + \frac{1}{2} O_2(g) \rightarrow H_2O(l)$ 

 $\Delta H_{2}^{\circ} = -393.51 \text{ kJ}$  $\Delta H^{\circ}_{3} = -285.83 \text{ kJ}$ 

need 1 mol of  $C_6H_6(l)$ , so multiply reaction (1) by  $\frac{1}{2}$ need 6 mol of C(graphite), so multiply reaction (2) by 6 need 3 mol of H<sub>2</sub> (g), so multiply reaction (3) by 3

$$6\text{CO}_2(g) + 3\text{H}_2\text{O}(1) \rightarrow \text{C}_6\text{H}_6(l) + 7\frac{1}{2}\text{O}_2(g)$$
  
 $6\text{C}(\text{graphite}) + 6\text{O}_2(g) \rightarrow 6\text{CO}_2(g)$ 

$$\Delta H^{\circ}_{1}$$
 reversed \*  $\frac{1}{2}$  = +6534.8 kJ \*  $\frac{1}{2}$  =3267.4 kJ  $\Delta H^{\circ}_{2}$  \* 6 = -393.51 kJ \* 6 = -2361.06 kJ

 $3H_2(g) + 1\frac{1}{2}O_2(g) \rightarrow 3H_2O(l)$ 

 $\Delta H^{\circ}_{3} *3 = -285.83 \text{ kJ} *3 = -857.49 \text{ kJ}$ 

SUM<sub>z</sub>-----

 $\begin{array}{l} 6CO_{2}\left(g\right) + 3H_{2}O\left(I\right) + 6C\left(graphite\right) + 3H_{2}\left(g\right) + 7\frac{1}{2}O_{2}\left(g\right) \\ \rightarrow C_{6}H_{6}\left(I\right) + 7\frac{1}{2}O_{2}\left(g\right) + 6CO_{2}\left(g\right) + 3H_{2}O\left(I\right) \end{array} \right) \\ = +48.9 \text{ kJ}$ 

net reaction: 6C (graphite) +  $3H_2(g) \rightarrow C_6H_6(l)$