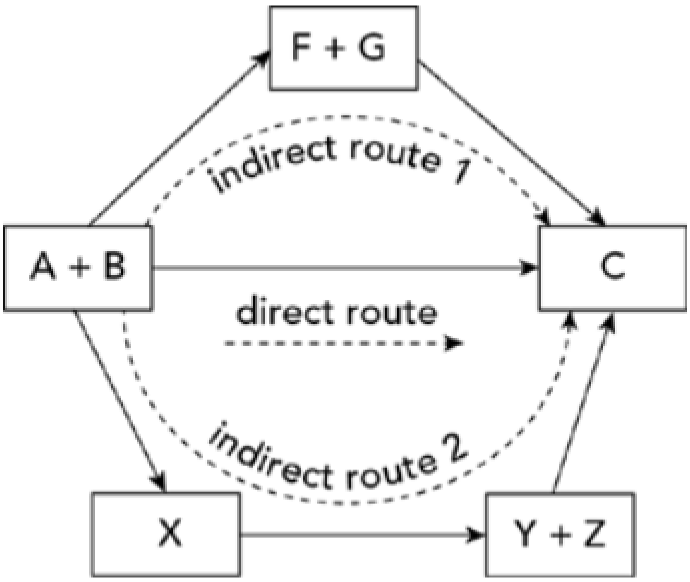
Hess’s Law

Some reactions, such as the formation of methane from carbon and hydrogen, cannot be done in a laboratory easily because the reaction does not occur in normal conditions. And so we need another way to measure the enthalpy change of this reaction.

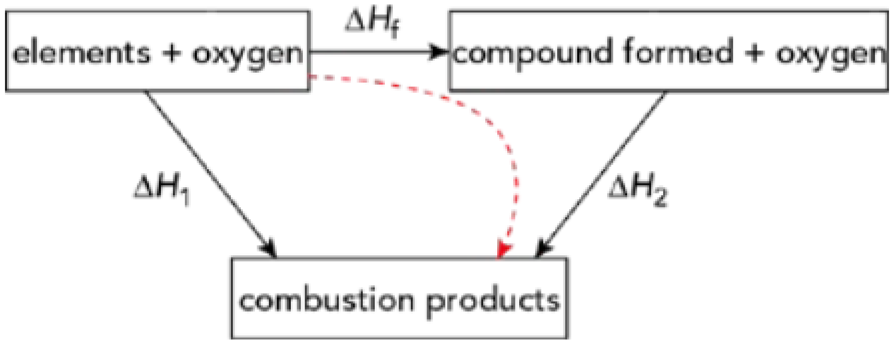
> Energy cannot be created nor destroyed, only change from one form to another.

This can be applied to enthalpy change as **Hess’s Law**.

> **Hess’s law states that if a reaction can take place by more than one route, the *overall enthalpy change is the same* regardless of which route was taken, as long as the initial conditions and final condidtions are the same.**



Using Hess’s law and enthalpies of combustion to calculate an enthalpy of formation



For example, let’s say that we are finding the standard enthalpy change of formation of ethane. We are given these combustion equations:

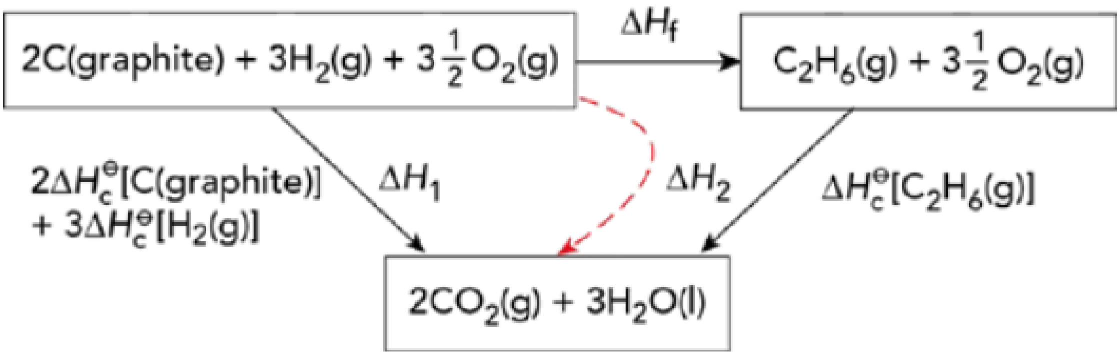
$C + O_2 \rightarrow CO_2 \quad \Delta H_c^{\phi}\ [C] = -393\ kJ\ mol^{-1} \quad -1$

$H_2 + \frac{1}{2}O_2 \rightarrow H_2O \quad \Delta H_c^{\phi}\ [H_2] = -285\ kJ\ mol^{-1} \quad -2$

$C_2H_6 + 3\frac{1}{2}O_2 \rightarrow 2CO_2 + 3H_2O \quad \Delta H_c^{\phi}[C_2H_6] = -1560\ kJ\ mol^{-1} \quad -3$

To solve this:

1. The formation of ethane is $2C + 3H_2 + 3\frac{1}{2}O_2 \rightarrow C_2H_6 + 3\frac{1}{2}O_2$
    a. Oxygen can be ignored because it is an element.
2. Draw an energy cycle



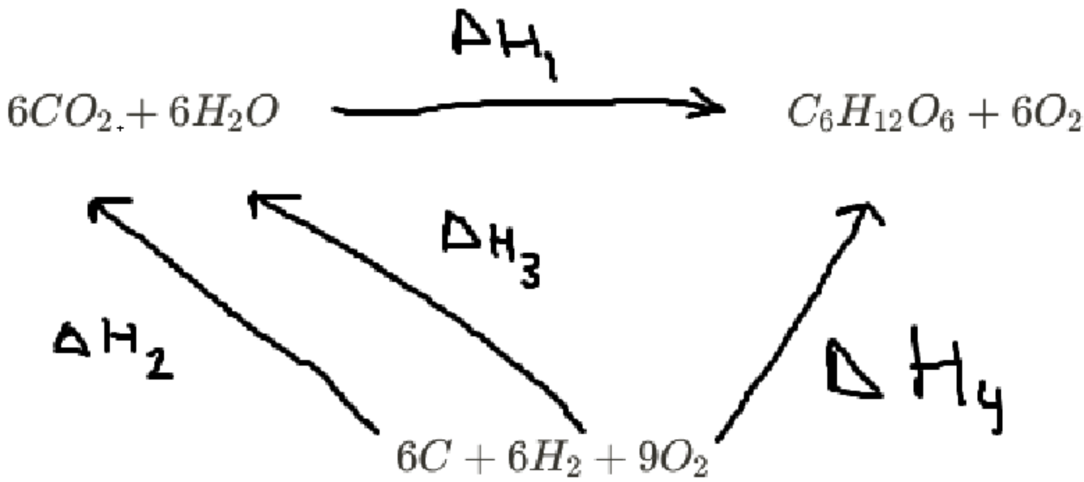
3. We can also see that in the given enthalpy changes, 3 = 2 + 1
4. So we substitute their enthalpy change of combustions in the equation $C_2H_6 \rightarrow 2C + 3H_2$.
5. $\Delta H_f + (-1560\ kJ\ mol^{-1}) = 2(-393\ kJ\ mol^{-1}) + 3(-285\ kJ\ mol^{-1})$
6. $\Delta H_f = -81\ kJ\ mol^{-1}$

Using Hess's law and enthalpy of formation to calculate enthalpy of reaction

Let's find the enthalpy to form 1 mole of glucose from carbon dioxide and water using the table below.

Enthalpy change	$kJ\ mol^{-1}$
$\Delta H_f^{\phi}\ [CO_2(g)]$	-393
$\Delta H_f^{\phi}\ [H_2O(l)]$	-286
$\Delta H_f^{\phi}\ [C_6H_{12}O_6(s)]$	-1273

1. Draw an energy cycle



2. We want ΔH_1, ΔH_2 is the formation of carbon dioxide, which we know. ΔH_3 is the formation of water, which we know. Finally, ΔH_4 is the formation of glucose, which we also know. Oxygen can be ignored because it is an element.
3. Using Hess's law, $\Delta H_4 = \Delta H_1 + \Delta H_2 + \Delta H_3$, so $\Delta H_1 = \Delta H_4 - \Delta H_2 - \Delta H_3$
4. $\Delta H_1 = -1273 - 6(-393) - 6(-286)$
5. $\Delta H_1 = +2801\ kJ\ mol^{-1}$

Pro tip

You can use $\Delta H_r = \Sigma\Delta H(\text{reactants}) - \Sigma\Delta H(\text{products})$ to solve quickly.