Hess's Law

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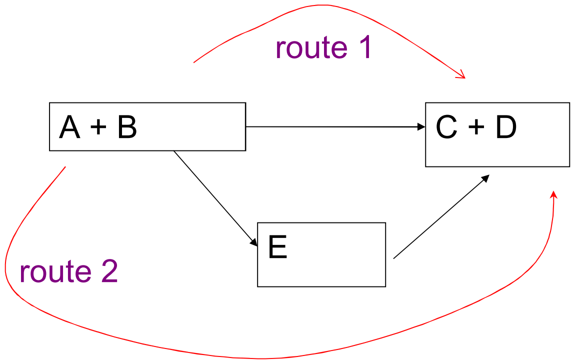
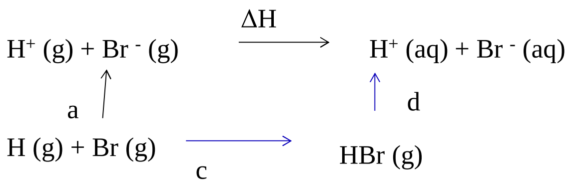
Hess's Law

Hess's law is a version of the first law of thermodynamics, which is that energy is always conserved.

Hess's law states that total enthalpy change for a reaction is independent of the route by which the chemical change takes place



There are two routes to go from A+B to C+D. Hess's law states that the energy change for both routes will be the same.

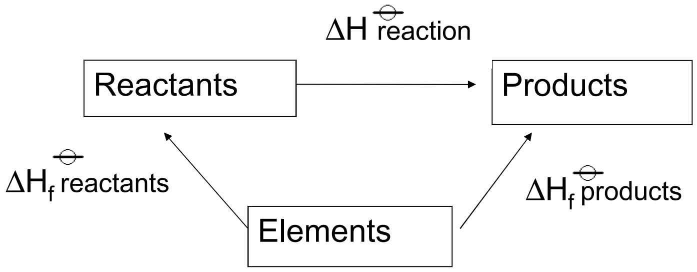


In this example one route is arrow **'a'** plus **ΔH**
The second route is shown by arrows **'c'** plus arrow '**d**'

So **a**+ **ΔH** = **c + d**
And rearranged
ΔH = c + d - a

Using Hess's law to determine enthalpy changes of reaction from enthalpy changes of formation.

Enthalpies of formation can be used to calculate any enthalpy change for a reaction



In general

$\Delta H^{\ominus}$ reaction = Σ $\Delta H_f^{\ominus}$ products - Σ $\Delta H_f^{\ominus}$ reactants

Standard enthalpy change of formation

The standard enthalpy change of formation of a compound is the energy transferred when 1 mole of the compound is formed from its elements under standard conditions (298K and 100kPa), all reactants and products being in their standard states

Symbol $\Delta H_f^{\ominus}$

Equations representing enthalpy change of formation

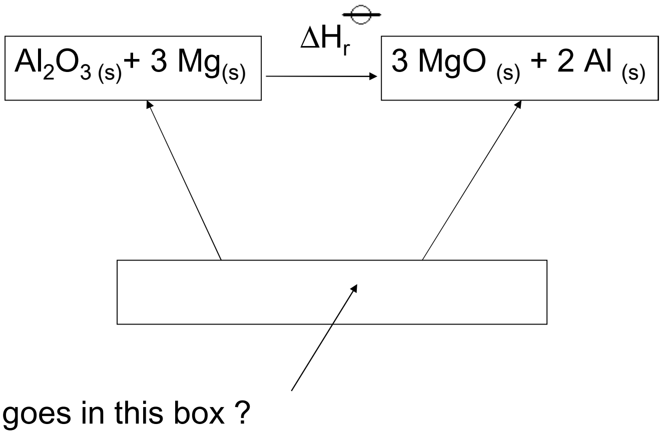
$Mg (s) + Cl_2 (g) \rightarrow MgCl_2 (s)$

$2Fe (s) + 1.5 O_2 (g) \rightarrow Fe_2O_3 (s)$

Example

What is the enthalpy change for this reaction ?

$Al_2O_3 + 3\ Mg \rightarrow 3\ MgO + 2\ Al$



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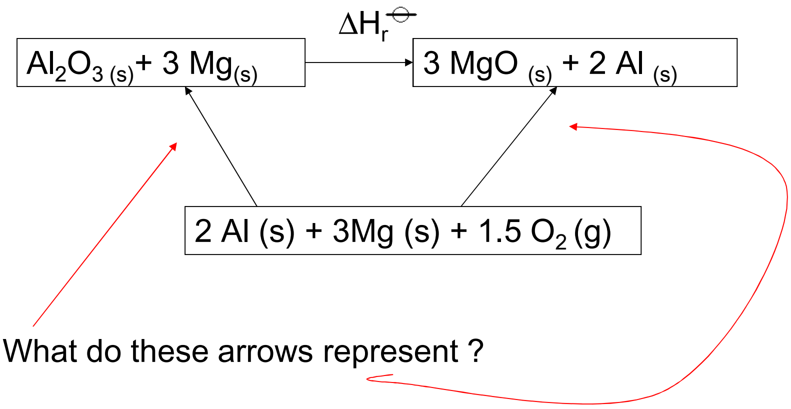

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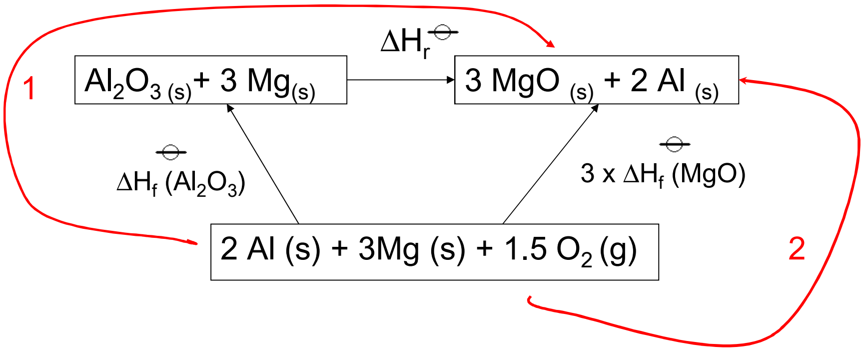
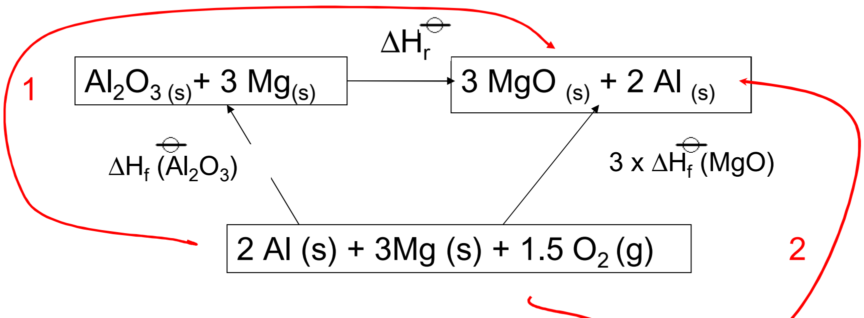


What are the two routes ?



By applying Hess's law the enthalpy change for Route 1 = enthalpy change for route 2

$3 \times \Delta H_f^{\ominus}(MgO) = \Delta H_f^{\ominus}(Al_2O_3) + \Delta H_r^{\ominus}$

rearrange to give $\Delta H_r^{\ominus}$: $\Delta H_r^{\ominus} = 3 \times \Delta H_f^{\ominus}(MgO) - \Delta H_f^{\ominus}(Al_2O_3)$

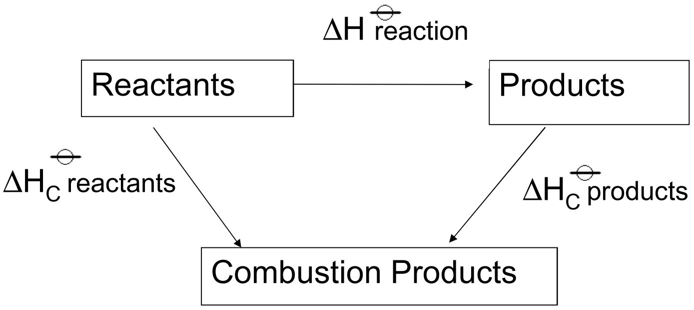
$\Delta H_r^{\ominus} = (3 \times -601.7) - -1675.7$

$= -129.4\ kJ\ mol^{-1}$

$\Delta H_r^{\ominus} = -129\ kJ\ mol^{-1}$ to 3sf

Using Hess's law to determine enthalpy changes of reaction from enthalpy changes of combustion.

Enthalpies of combustion can be used to calculate enthalpy changes for some reactions reaction



In general

$\Delta H^\ominus$ reaction = **Σ** $\Delta H_c^\ominus$ reactants - **Σ** $\Delta H_c^\ominus$ products

Standard enthalpy change of Combustion

The standard enthalpy of combustion of a substance is defined as the enthalpy change that occurs when one mole of a substance is combusted completely under standard conditions. (298K and 100kPa), all reactants and products being in their standard states

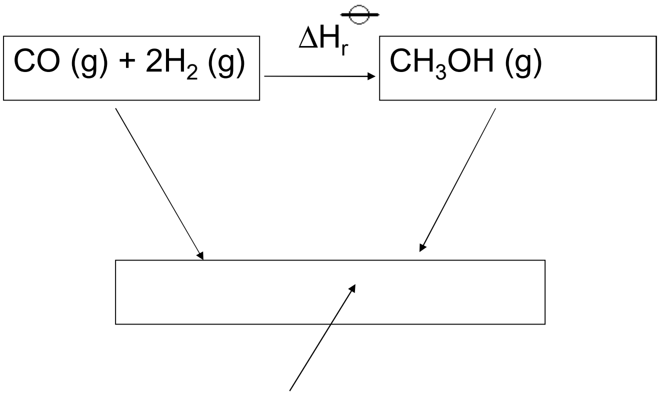
Symbol $\Delta H_c^\ominus$

CH_4 (g) + $2O_2$ (g) → CO_2 (g) + 2 H_2O (l)

Incomplete combustion will lead to soot (carbon), carbon monoxide and water. It will be less exothermic than complete combustion.

Example

Work out the enthalpy change for this reaction from heats of combustion?
$CO\ (g) + 2H_2\ (g) \rightarrow CH_3OH\ (g)$



What goes in this box ?

Example

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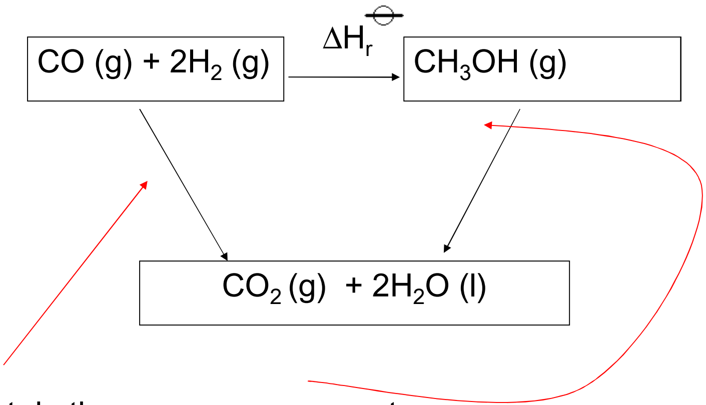
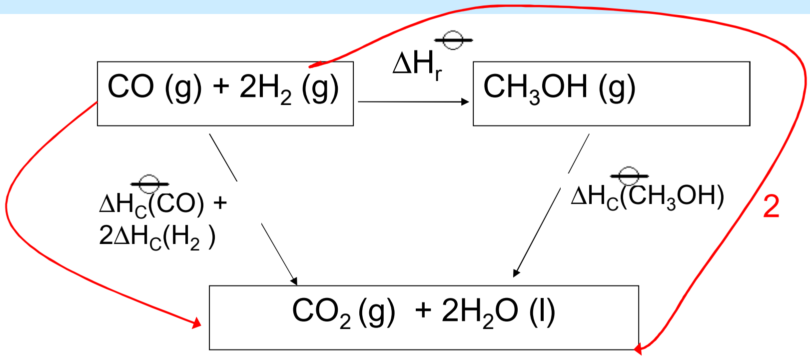


What do these arrows represent

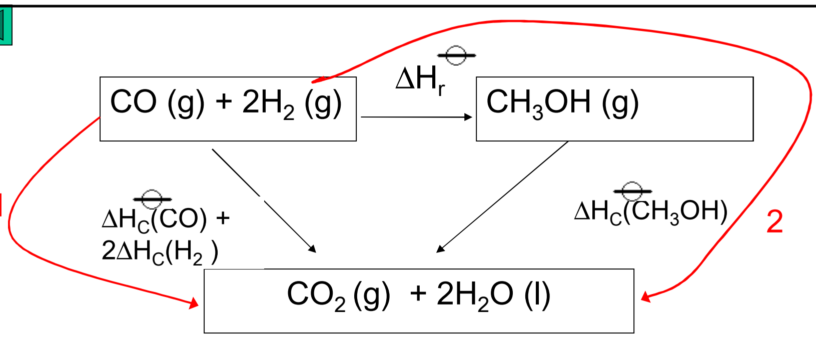
Example

Work out the enthalpy change for this reaction from heats of combustion?

$CO\ (g) + 2H_2\ (g) \rightarrow CH_3OH\ (g)$



What are the two routes?



By applying Hess's law the enthalpy change for Route 1 = enthalpy change for route 2

$\Delta H_C^{\ominus}(CO) + 2 \times \Delta H_C^{\ominus}(H_2) = \Delta H_C^{\ominus}(CH_3OH) + \Delta H_r^{\ominus}$

rearrange to give $\Delta H_r^{\ominus}$: $\Delta H_r^{\ominus} = \Delta H_C^{\ominus}(CO) + 2 \times \Delta H_C^{\ominus}(H_2) - \Delta H_C^{\ominus}(CH_3OH)$

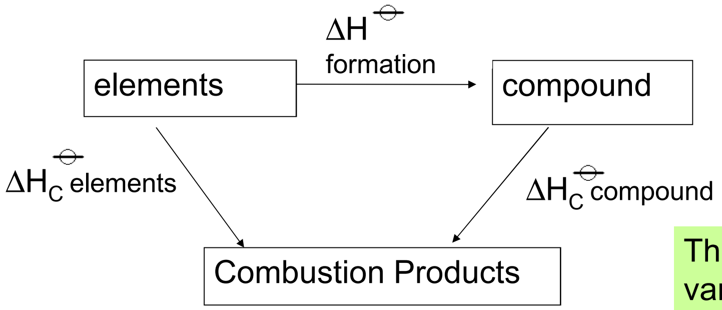
$\Delta H_r^{\ominus} = -283 + 2\times -245 - -671$

$= -102\ kJ\ mol^{-1}$

$\Delta H_r^{\ominus} = -102\ kJ\ mol^{-1}$ to 3sf

Using Hess's law to determine enthalpy changes of formation from enthalpy changes of combustion.

Enthalpies of combustion can be used to calculate the enthalpy change of formation for a combustible compound



This is a variation of the other cycle using ΔHc

In general

$\Delta H^{\ominus}$ formation = **Σ** $\Delta H^{\ominus}_{c}$element - **Σ** $\Delta H^{\ominus}_{c}$ compound