

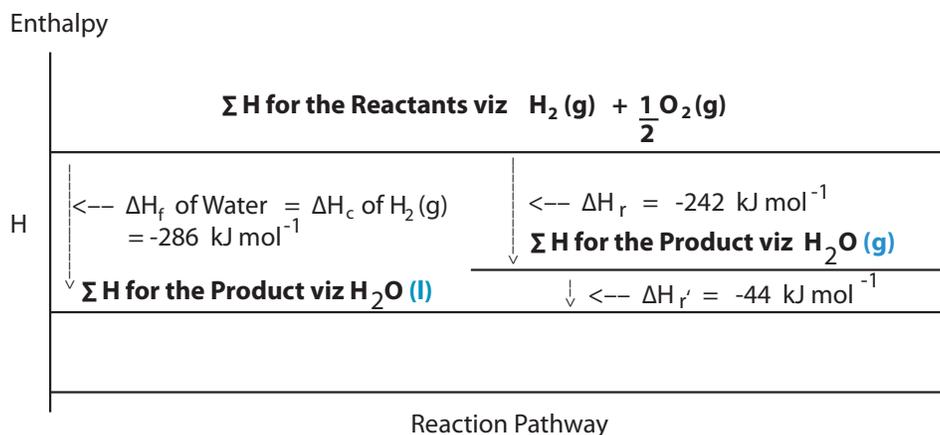
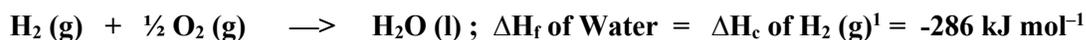
[This is a blog for First Year students: 24th December 2018]

It is not possible to measure Enthalpy, but it is easy to measure the change in Enthalpy, ΔH .

A simple Enthalpy Profile Diagram (for the formation of steam and water)

(It can also be called a Born-Haber diagram.)

- The diagram that follows is the Enthalpy Profile Diagram for the Reaction Equation



NB You can see that when **gaseous molecules of Water** are formed (i.e. when “steam” is formed), then $\Delta H_r = -242 \text{ kJ mol}^{-1}$, and if those gaseous molecules are allowed to cool down to **liquid Water** (where the ΔH for condensation, $\Delta H_r' = -44 \text{ kJ mol}^{-1}$), then ΔH_f of $\text{H}_2\text{O}(\text{l}) = (-242 - 44) = -286 \text{ kJ mol}^{-1}$.

Please note that these three ΔH s are negative, i.e. these are all net exothermic processes!

Let me do another example for you. *[NB Both ΔH_f of $\text{CO}_2(\text{g})$ and ΔH_c of $\text{CO}(\text{g})$ are exothermic Reactions, therefore ΔH is negative in each case!]*

- When you burn or combust Carbon (which is a solid under standard conditions) in excess Oxygen then you get Carbon Dioxide



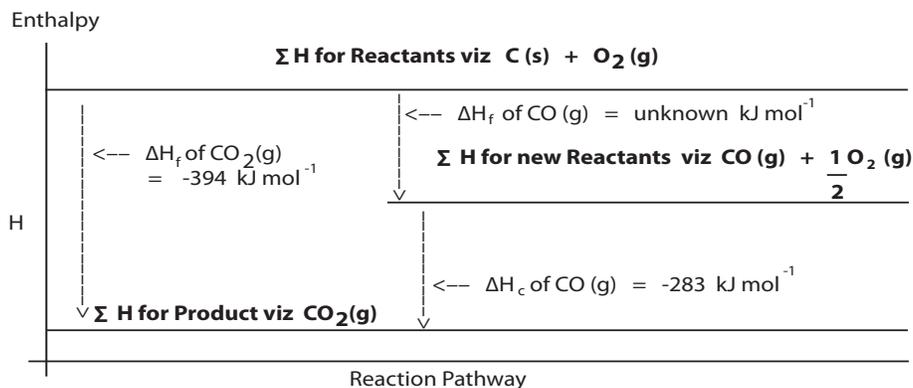
and when you burn Carbon Monoxide (which is a gas under standard conditions) in excess Oxygen, then you also get Carbon Dioxide



- I hope that you have been sufficiently alert to notice that in the second equation I have NOT said that it will also give you the ΔH_f of $\text{CO}_2(\text{g})$ – and the reason for this is because **Carbon Monoxide is NOT one of the constituent ELEMENTS of CO_2 !** Carbon and Oxygen **ARE** the constituent **ELEMENTS** of CO_2 therefore it was correct in the first equation to say that ΔH_f of $\text{CO}_2(\text{g}) = \Delta H_c$ of $\text{C}(\text{s})$, but it would NOT have been correct to say that in the second equation.

¹ Please do remember this identity viz. ΔH_f of Water = ΔH_c of $\text{H}_2(\text{g})$. It is a very useful one. Please also note that one mole of gaseous H_2 molecules is being combusted, and not one mole of gaseous H atoms. The ΔH s for the two are not the same.

Enthalpy Profile Diagram for the formation of Gaseous Carbon Monoxide and Carbon Dioxide



- In each case you end up with 1 mole of Carbon Dioxide (so you finish up with the same amount of Enthalpy) therefore you draw both **END** products at exactly the same point on the y-axis.
- Now let me ask you a very important question : **“Can you use this diagram to work out the Change in Enthalpy for the Formation of Carbon Monoxide?”**
- Could you please think VERY CAREFULLY about the answer to this question before you read on – and I will give you a hint : *write down the Reaction Equation for the Formation of 1 mole of Carbon Monoxide!* [I will answer my question very soon!]

E) Enthalpy Changes and Chemical Reactions

- A Chemical reaction occurs when reactant species collide with sufficient energy for existing bonds to be broken and new bonds to be formed. *[If no existing bonds are broken and no new bonds are formed, then the two species will merely collide with and bounce off each other and no reaction will have occurred!* It is exactly the same as bumping into a girl/boy on the school bus without falling in love with her/him.]
- As a corollary to the above, it will also be true to say that when a reaction occurs, then either (a) a net amount of energy will be consumed or (b) a net amount of energy will be released.

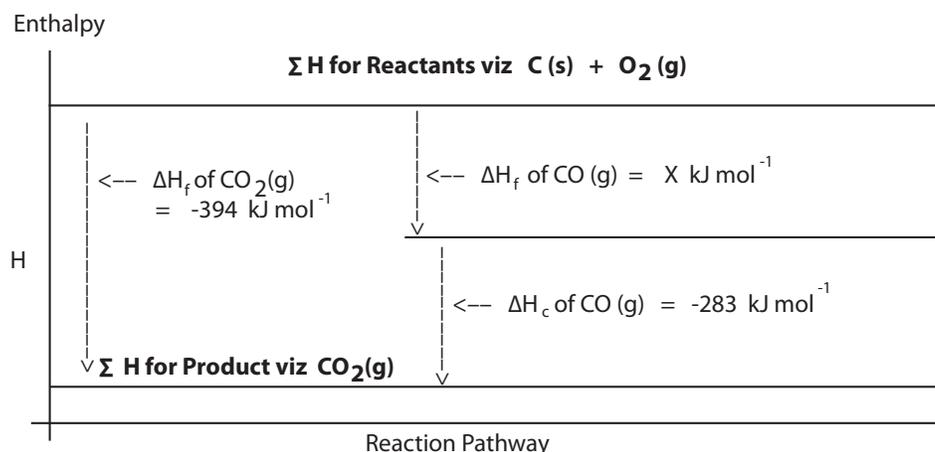
NB Some of the signs that a reaction has occurred are

- *heat is given off or heat is consumed (cf. above), therefore*
- *the reactants / products undergo a change in temperature e.g. $Zn(s)$ reacting with $AgNO_3(aq)$*
- *a change might occur in the colour of the reactants e.g. the classic orange \rightarrow green in the oxidation of some Alcohols (primary and secondary alcohols, but **not** tertiary alcohols)*
- *a precipitate might form as with $AgI/AgBr/AgCl$, or*
- *in certain reactions a gas (such as H_2 or CO_2) might be generated. When some acids attack a metal $H_2(g)$ is generated, and when an Acid attacks Calcium Carbonate, then $CO_2(g)$ is generated.*

E2 The use of Enthalpy Profile diagrams in calculations

- It is very difficult to measure the ΔH of Formation of Carbon Monoxide (because it is difficult to make sure that no Carbon Dioxide at all is formed during the reaction); but, let us say that
 - a) you know the value of the ΔH of Combustion of Carbon Monoxide, and that
 - b) you know the value of the ΔH of Formation of Carbon Dioxide– **then, it becomes a very simple matter to deduce the ΔH of Formation of Carbon Monoxide.**

Let me show you how to solve the problem by using an Enthalpy Profile diagram where “X” is the unknown amount of energy in kJ mol^{-1} .



and since equal vertical distances represent equal amounts of Enthalpy, then you can now see that

$$\begin{aligned} \Delta H_f \text{ of CO (g)} + \Delta H_c \text{ of CO (g)} &= \Delta H_f \text{ of CO}_2 \text{(g)}, \text{ therefore} \\ \Delta H_f \text{ of CO (g)} &= \Delta H_f \text{ of CO}_2 \text{(g)} - \Delta H_c \text{ of CO (g)} \\ &= [-394 - (-283)] \text{ kJ mol}^{-1} \\ \Delta H_f \text{ of CO (g)} &= -111 \text{ kJ mol}^{-1} \end{aligned}$$

- *Isn't it beautifully simple – and isn't it simply beautiful!
Isn't that easy (but only if you were careful with your signs)!*
 - We have talked fairly extensively about ΔH , and could you note that ΔH can be called the “**Change in Enthalpy in a Reaction**” or the “**Enthalpy Change of a Reaction**” (and I prefer the former to the latter).
 - You are required to know about the Standard Conditions for the measurement of ΔH , therefore let me remind you of them.
 - Ironically “Standard Conditions” are for **Room Temperature** ($20\text{-}25^\circ\text{C}$) and Pressure $101,325 \text{ Pa}$ (and **not** for Standard Temperature (0°C and Pressure $100,000 \text{ Pa}$)).
- STP is for 0°C and $100,000 \text{ Pa}$.²**
- Unless otherwise stated, Standard Conditions are always assumed to be the case, therefore people often write just “ ΔH ” as a shorthand for “ ΔH° ”, therefore for ΔH or ΔH° , the four Standard Conditions are
 - All solutions must have a **CONCENTRATION** of 1 mole dm^{-3}
 - The **TEMPERATURE** of the reaction must be $273\text{-}298\text{K}$ (i.e. $20\text{-}25^\circ\text{C}$)
 - The **PRESSURE** must be $100,000\text{-}101,325 \text{ Pa}$, and
 - All Reactants/Products must be in their **STANDARD STATES** for the above.

NB *In the exam you must use whatever figures that you are given in the exam data booklet.
 $1 \text{ Pa} = 1 \text{ Nm}^{-2}$ i.e. $1 \text{ Newton per square metre}$.*

Chemistry is so lovely when you know what you are doing – but that can be said for every field of endeavour.

² This is the definition that IUPAC has adopted since 1982. NIST gives a different definition, but since we are learning Chemistry, just stick to what the **International Union of Pure and Applied Chemistry** (IUPAC) says.