

**Chemistry 12: Equilibrium****Lesson 3 – Predicting if a reaction is spontaneous or not****Enthalpy**

In an exothermic Reaction ( $\Delta H$  is negative), the enthalpy is decreasing.  
The heat term is on the products side.

In an endothermic Reaction ( $\Delta H$  is positive), the enthalpy is increasing.  
The heat term is on the reactant side.

Look at the following examples:

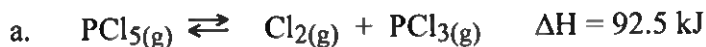
1.  $A + B \rightleftharpoons C + D$   $\Delta H = -24 \text{ kJ}$  is exo so enthalpy is decreasing
2.  $X + Y \rightleftharpoons Z$   $\Delta H = 87 \text{ kJ}$  is endo so enthalpy is increasing
- 3.  $E + D \rightleftharpoons F + 45 \text{ kJ}$  is exo so enthalpy is decreasing
- 4.  $G + J + 36 \text{ kJ} \rightleftharpoons L + M$  is endo so enthalpy is increasing

In an exothermic reaction. The products *will be favoured* because the products have minimum enthalpy. In other words, there is a natural tendency here for reactants to spontaneously form products.

See if you can predict what would happen in an *endothermic reaction*.

In an *endothermic reaction*, the reactants have minimum enthalpy, so the reactants will be favoured. In other words, if the reactants are mixed they will tend to remain as reactants (spontaneously form products)

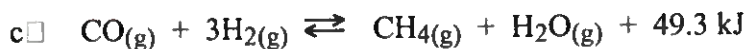
1. Tell whether each of the following is *endothermic* or *exothermic* and state which has *minimum enthalpy*, the *reactants* or the *products*:



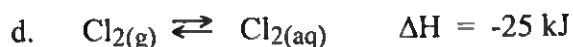
endo thermic and the reactants have *minimum enthalpy*.



endo thermic and the reactants have *minimum enthalpy*.

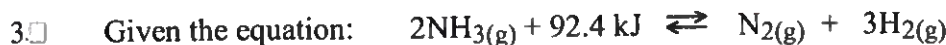


exo thermic and the products have *minimum enthalpy*.



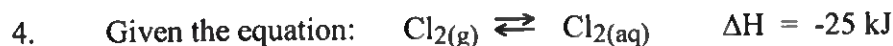
exo thermic and the products have *minimum enthalpy*.

2. When no other factors are considered, a reaction will move in such a way (left or right) in order to achieve a state of minimum enthalpy.



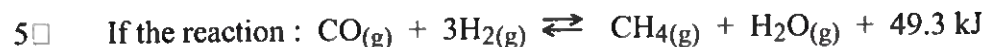
If only the *enthalpy* is considered, the (reactant / products) will be favoured at equilibrium.

~~Products~~ reactants



If only the *enthalpy* is considered, the (reactant / products) will be favoured at equilibrium.

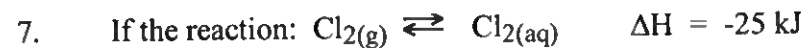
products



was proceeding to the *right*, the enthalpy would be decreasing ing. Is this a favourable change? yes.



was proceeding to the *right*, the enthalpy would be increasing ing. Is this a favourable change? no.



was proceeding to the *right*, the enthalpy would be decrease ing. Is this a favourable change? yes.

8□ If the reaction:  $2\text{NH}_3(\text{g}) + 92.4 \text{ kJ} \rightleftharpoons \text{N}_2(\text{g}) + 3\text{H}_2(\text{g})$

was proceeding to the *right*, the enthalpy would be increasing ing. Is this a favourable change? no.

As you can see by looking at the exercises above, there are two ways of looking at what happens to the *enthalpy*:

If the reaction is exothermic, the products have minimum enthalpy and the formation of products (move toward the right) is favourable.

If the reaction is endo, the reactants have minimum enthalpy and the formation of products (move toward the right) is unfavourable. In this case the formation of reactants (move toward the left) is favourable.

## Entropy

Entropy simply means disorder, or lack of order.

randomness

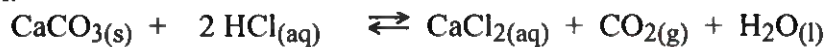
**Entropy of a Solid < Entropy of a Liquid < Entropy of aqueous < Entropy of a Gas**

Chemists and successful Chemistry Students (THAT'S YOU!) can look at a chemical equation with subscripts showing the phases and tell which has maximum entropy, the *reactants* or the *products*.

In other words, they can look at an equation and tell whether *entropy* is increasing or decreasing as the reaction *proceeds to the right*.

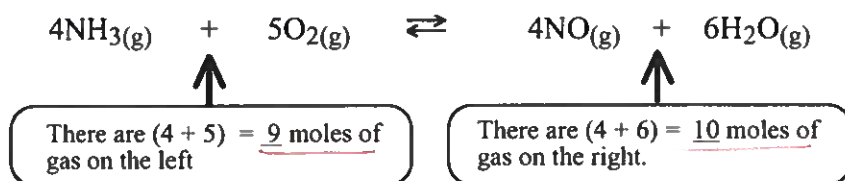
In the following examples, the entropy is increasing (or the *products* have greater entropy):

1. There is a *gas* (or gases) on the *right*, when there are *no gases* on the *left* of the equation:



2. When there are *gases on both sides*, the *products* have greater entropy when there

are **more moles of gas on the right** (add up coefficients of gases on left and right.):



Another way to look at the last example is to say that:

**"The side with the greater number of moles of gas has the greatest entropy."**

3. When a **solid dissolves in water**, the **products** ( the aqueous solution of ions ) have **greater entropy**. This makes sense because:

SOLID = lots of order = low entropy  
 AQUEOUS = solid dissolves = less order increase in entropy

Here are few exercises for you:

9. For each of the following, decide whether the **reactants** or the **products** have **greater entropy**:

- a)  $\text{I}_2(\text{s}) \rightleftharpoons \text{I}_2(\text{aq})$  The products have greater entropy.
- b)  $2\text{NH}_3(\text{g}) \rightleftharpoons \text{N}_2(\text{g}) + 3\text{H}_2(\text{g})$  The products have greater entropy.
- c)  $\text{NH}_3(\text{g}) \rightleftharpoons \text{NH}_3(\text{aq})$  The reactants have greater entropy.
- d)  $\text{CO}(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons \text{COCl}_2(\text{g})$  The reactants have greater entropy.
- e)  $\text{MgCO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightleftharpoons \text{MgCl}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
- The products have greater entropy.

There is a natural tendency in nature toward *maximum disorder* or *maximum entropy*!

**Chemical systems will tend toward a state of maximum entropy if no other factors are considered.**

To summarize both trends:

In nature, there is a tendency toward minimum enthalpy and maximum entropy.

We say that:

When the two tendencies oppose each other (one favours reactants, the other favours products), the reaction will reach a state of equilibrium

*That is, there will be some reactants and some products present. The relative amounts of each depends on conditions like temperature, pressure, concentration etc.*

Processes in which both the tendency toward *minimum enthalpy* and toward *maximum entropy* favour the reactants, will not react at all

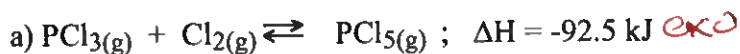
(ie. None of the reactants will be converted into products. There will be no products formed!)

Processes in which both the tendency toward *minimum enthalpy* and toward *maximum entropy* favour the products, will go to completion

(ie. All reactants will be converted into products. There will be no reactants left once the process is finished!)

Here's something for you to do:

10. For each of the following reactions decide which has **minimum enthalpy** (reactants or products), which has **maximum entropy** (reactants or products), and if the reactants are mixed, what will happen? (go to completion/ reach a state of equilibrium/not occur at all).



The products has/have  <sup>$\Delta H$</sup>  minimum enthalpy.

The reactants has/have maximum entropy.

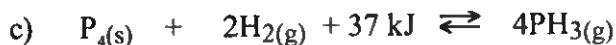
If  $\text{PCl}_3$  and  $\text{Cl}_2$  are put together, what should happen? (go to completion/ reach a state of equilibrium/not occur at all) eq.



The reactant products has/have minimum enthalpy.

The reactants has/have maximum entropy.

If  $\text{NO}_2$  was put in a flask, what should happen? (go to completion/ reach a state of equilibrium/not occur at all) eq.



The reactants has/have minimum enthalpy.

The products has/have maximum entropy.

If  $\text{P}_4(\text{s})$  and  $6\text{H}_2(\text{g})$  was put in a flask, what should happen? (go to completion/ reach a state of equilibrium/not occur at all) eq.



Enthalpy: Prod.

Entro.: Prod.

rxn will go to completion

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