

Chem12 Entropy : Notes/W.S.-20

The **entropy** of a system (symbol S) is a measure of the degree of disorder or randomness of that system.

The change in entropy is given by ΔS . $\Delta S = S(\text{products}) - S(\text{reactants})$.

Important : A natural tendency in nature is for matter to achieve a high entropy and low enthalpy.

The following situations represent an increase ($\Delta S = +$) in **entropy** :

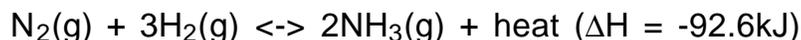
- an ionic solid is dissolved in water
- a liquid becomes a gas
- a solid becomes a liquid
- few molecules become more molecules
- there is an increase in the temperature

Exercise 1 : Predict whether ΔS is + or -.

- $\text{N}_2\text{O}_4(\text{g}) \rightarrow 2\text{NO}_2(\text{g})$
- water freezes
- $\text{NaCl}(\text{s}) \rightarrow \text{Na}^+(\text{aq}) + \text{Cl}^-(\text{aq})$
- $4\text{NH}_3(\text{g}) + 3\text{O}_2(\text{g}) \rightarrow 2\text{N}_2(\text{g}) + 6\text{H}_2\text{O}(\text{g})$
- $\text{Zn}(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{H}_2(\text{g}) + \text{Zn}^{2+}(\text{aq})$
- $\text{C}_{14}\text{H}_{28}(\text{s}) + \text{H}_2(\text{g}) \rightarrow \text{C}_{14}\text{H}_{30}(\text{s})$
- $6\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{l}) \rightarrow \text{C}_6\text{H}_{12}\text{O}_6(\text{s}) + 6\text{O}_2(\text{g})$
- $\text{PCl}_3(\text{l}) + \text{Cl}_2(\text{g}) \rightarrow \text{PCl}_5(\text{s})$
- $\text{H}_2\text{O}(\text{g}) \rightarrow \text{H}_2(\text{g}) + (1/2)\text{O}_2(\text{g})$
- $4\text{Fe}(\text{s}) + 3\text{O}_2(\text{g}) \rightarrow 2\text{Fe}_2\text{O}_3(\text{s})$
- $\text{C}_2\text{H}_2(\text{g}) + 2\text{Cl}_2(\text{g}) \rightarrow \text{C}_2\text{H}_2\text{Cl}_4(\text{l})$
- $\text{H}_2(\text{g}) + \text{Br}_2(\text{l}) \rightarrow 2\text{HBr}(\text{g})$
- $2\text{HgO}(\text{s}) \rightarrow 2\text{Hg}(\text{l}) + \text{O}_2(\text{g})$
- $2\text{Al}(\text{s}) + 3\text{Br}_2(\text{l}) \rightarrow \text{Al}_2\text{Br}_6(\text{s})$
- $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{SO}_3(\text{g})$
- $\text{PCl}_3(\text{l}) + \text{Cl}_2(\text{g}) \rightarrow \text{PCl}_5(\text{s})$
- A quantity of gas is heated.

Entropy (continued)

In the Haber process, ammonia is made from $\text{N}_2(\text{g})$ and $\text{H}_2(\text{g})$ according to the **reversible** reaction :



The double arrow means that the reaction is **reversible** and the system is said to be at **equilibrium**. Both the **forward** and **reverse** reactions occur at the same time. This reaction requires high temperature, high pressure and a **catalyst**.

This is an example of the two competing factors which drive a reaction. **S increases** (reverse reaction in this case) and **H decreases** (forward reaction in this case)

These two factors can be combined in the Gibbs equation :

$$G = H - TS \quad (\text{T is the Kelvin temperature})$$

We can also write :

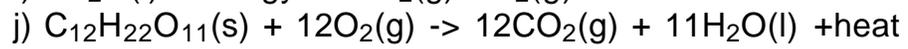
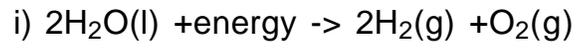
$$\Delta G = \Delta H - T\Delta S \quad (\text{T constant})$$

If ΔG is -, the forward reaction is favored (**spontaneous**). If ΔG is +, the reverse reaction is favored. If $\Delta G = 0$, the system is at equilibrium. G is the Gibbs free energy. It is the maximum amount of energy available to do work.

ΔH	ΔS	
-	+	products favored (spontaneous)
+	-	reactants favored (not spon)
-	-	equilibrium (depends on T)
+	+	equilibrium (depends on T)

Exercise 2 : Determine what happens in the following reactions. It will go to completion (products favored), or it will not occur (reactants favored), or, it will reach equilibrium)

- $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{O}(\text{g}) + 483\text{kJ}$
- $\text{C}(\text{s}) + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) \quad \Delta H = -394\text{kJ}$
- $\text{N}_2(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow 2\text{NO}_2(\text{g}) \quad \Delta H = +68\text{kJ}$
- $\text{N}_2\text{O}_4(\text{g}) + 52\text{kJ} \rightarrow 2\text{NO}_2(\text{g})$
- $\text{S}(\text{s}) + \text{O}_2(\text{g}) \rightarrow \text{SO}_2(\text{g}) \quad \Delta H = -297\text{kJ}$
- $\text{A}(\text{g}) + \text{B}(\text{g}) \rightarrow \text{C}(\text{s}) \quad \Delta H = -100\text{kJ}$
- $\text{XY}(\text{g}) \rightarrow \text{X}(\text{g}) + \text{Y}(\text{g}) + \text{heat}$
- $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g}) + \text{heat}$



Answers : 1)a) +, b) -, c) +, d) +, e) +, f) -, g) -, h) -, i) +, j) -, k) -, l) +, m) +, n) -, o) -, p) -, q) +. 2)a) eq, b) pf, c) rf, d) eq, e) pf, f) eq, g) pf, h) eq, i) eq, j) pf.