IV) Predicting Whether a Reaction Will Go to Completion, to Equilibrium, or Not React

Enthalpy

Enthalpy is a term that describes the total potential energy content (the energy in the particles) involved in a system.

Example: N_2O_4 + energy ⇔ $2NO_2$

The forward reaction is → Endothermic.

The reverse reaction is Exothermic ←.

For an endothermic reaction, is the enthalpy increasing or decreasing? Why? Enthalpy is increasing because energy is required for the rxn to proceed ∴ energy is being absorbed into the particles

Endothermic reactions have **increasing** or MAXIMUM enthalpy because the particles are gaining energy.

Exothermic reactions have decreasing or minimum enthalpy because particles are releasing energy.

In nature, is it easier to gain energy, or lose energy? much easier to lose energy.

* **Therefore, reactions naturally tend toward energy loss, meaning they tend toward the EXOTHERMIC direction. In other words, they tend toward decreasing or minimum enthalpy.**

symbol

(S) Entropy – the amount of thermal energy in a closed space that is NOT available to do work.

Entropy is the measure of disorder or randomness in a system.

Think of your bedroom. If it easier for your bedroom to become messy or keep it clean? easier to let it be messy.

This comes down to probability. Out of all the possible states your room could be in (an infinite amount), many more of them are considered disordered states compared to ordered states.

So, nature tends toward disorder, or increasing entropy, for the simple reason that…

There are many more disordered states compared to ordered states entropy => unavailability of a systems thermal energy for conversion into mechanical work.

Rank the states of matter [(aq) included] from most entropic to least entropic: g > aq > l > s

more "degrees of freedom" → g; s ↳ few available variations

Reactions tend toward increasing or maximum entropy (the side with the most gas particles).

*as particles gain temperature/KE, their motion becomes chaotic ∴ ↑ Entropy

Examples: Determine which direction entropy is increasing

1) $A_{(g)} + 3B_{(g)} \Leftrightarrow 2C_{(g)} + 4D_{(g)}$ →

2) $A_{(s)} + B_{(g)} \Leftrightarrow 2C_{(l)} + D_{(l)}$ ← 1 mol(g)

*combining particles decreases entropy.

3) $A_{(aq)} + B_{(s)} \Leftrightarrow 2C_{(l)} + D_{(l)}$ ← (aq) > (l) >> (s) · no (g) particles

4) $A_{(g)} + B_{(g)} \Leftrightarrow C_{(g)} + D_{(g)}$ none, all equal.

Summary:

Reactions naturally tend towards minimum **enthalpy and** (energy loss/exothermic) MAXIMUM **entropy.** (most (g) particles)
In other words, reactions tend toward the exothermic **direction and the side with** most **gas particles.**

So, we can use the summary to make predictions on whether reactions go to completion, form an equilibrium, or don't occur at all.

Examples: Predict whether each reaction will go to completion ©, form equilibrium (E), or not react (NR)

1. $H_2SO_{4(l)} + H_2O_{(l)} \Rightarrow H_2SO_{4(aq)} + 150kJ$

→ exothermic
→ (aq) > (l)
⇒ rxn will go to completion.

2. $C_2H_{2(g)} + Ca(OH)_{2(aq)} \Rightarrow CaC_{2(s)} + 2H_2O_{(l)}$ $\Delta H = {}^{+}185kJ$

+ energy
← exothermic
← more (g)

NO reaction
both min enthalpy + max entropy oppose the rxn completing.

3. $C_2H_{6(g)} \Rightarrow C_2H_{2(g)} + 2H_{2(g)}$ $\Delta H = {}^{+}311kJ$

+energy

← exothermic

→ more (g) molec.

system will tend to favor equilibrium.

Assignment 5: Reaction Predictions

State whether each reaction will go to completion (C), equilibrium (E), or not react (NR)

1. $4NH_{3(g)} + 5O_{2(g)} \Rightarrow 4NO_{(g)} + 6H_2O_{(g)}$ $\Delta H = +115kJ$
2. $N_2O_{4(g)} + 58.9kJ \Rightarrow 2NO_{2(g)}$
3. $2Bi^{3+}_{(aq)} + 3H_2S_{(g)} \Rightarrow BiS_{3(s)} + 6H^{+}_{(aq)} + \text{energy}$
4. $2H_2O_{2(aq)} \Rightarrow O_{2(g)} + 2H_2O_{(l)}$ $\Delta H = -189kJ$
5. $H_2O_{(g)} + C_{(s)} \Rightarrow CO_{2(g)} + H_{2(g)}$ $\Delta H = +31.3kJ$
6. $3C_2H_{2(g)} \Rightarrow C_6H_{6(g)} + 143kJ$
7. $NaOH_{(aq)} + 2.4kJ \Rightarrow NaOH_{(s)}$
8. $CS_{2(g)} + 3O_{2(g)} \Rightarrow CO_{2(g)} + 2SO_{2(g)} + 66kJ$

9. A student predicts that the following reaction will go to completion. Do you agree or disagree? Support with an explanation.

$$CO_{(g)} + H_2O_{(l)} \Rightarrow CO_{2(g)} + H_{2(g)} \quad \Delta H = 42kJ$$

10. For the following reaction, in which direction is enthalpy increasing? In which direction is entropy maximized? Will the reaction reach equilibrium?

$$2C_4H_{10(g)} + 13O_{2(g)} \Rightarrow 8CO_{2(g)} + 10H_2O_{(g)} + 128kJ$$

V) The Equilibrium Constant

molar ratio of products over reactants at Equilibrium

The equilibrium constant is called "K_{eq}" and is found by multiplying product concentrations and dividing that by the result of multiplying reactant concentrations.

Do **not** include solids and liquids in K_{eq} expressions as the concentrations of these remain constant.

Example: Write the K_{eq} expression:

$$2HI_{(g)} \Leftrightarrow I_{2(g)} + H_{2(g)} \qquad K_{eq} = \frac{[H_2][I_2]}{[HI][HI]} = \frac{[H_2][I_2]}{[HI]^2}$$