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RATE OF REACTION AND EQUILIBRIUM

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INFO

This is a study sheet by Linus Metzler about Rate of Reaction and Equilibrium, which was mentioned in the 2nd Kanti at Mr. Uetz. There is no claim for completeness. All warranties are disclaimed.

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STUDY PART

- **RS** means, this learning aim is on the cheat sheet we are allowed to use in the test! → see attachment on page 6
- Some learning aims are not discussed, these are
 - You can find reasonable reaction pathways for any simple of a reaction example
 - You know how the rate of reaction can be increased with solid reactants **RS**
 - You can calculate the equilibrium constant (K) out of the concentrations of the reactants in the dynamic equilibrium of a reaction
 - You can calculate with the help of the equilibrium constant (K) the concentrations of all reactants in the dynamic equilibrium of a reaction
 - You can explain how the actual equilibrium is affected by adding of a reactant **RS**
 - You can explain all the rules about the effects on the actual equilibrium **RS**
 - You can describe for any chemical reaction how the actual equilibrium can be affected
 - You can distinguish between effects on the rate of reaction and effects on the actual equilibrium (**RS**)

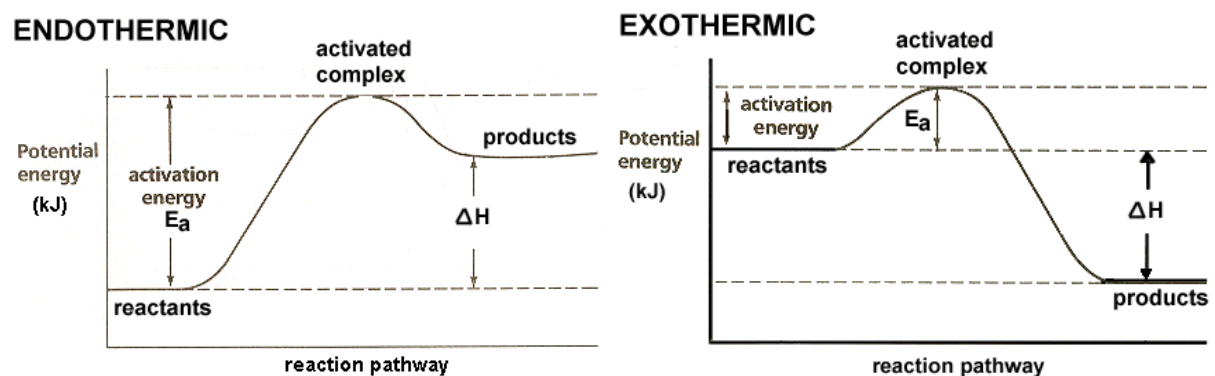
YOU CAN EXPLAIN THE EXPRESSIONS EXOTHERMIC, ENDOTHERMIC AND REACTION ENERGY

An **ENDOTHERMIC REACTION** is a reaction in which the system **absorbs** energy from the surroundings in the form of heat. In such a reaction the energy content of the products is **higher** than the one of the educts.

An **EXOTHERMIC REACTION** is a reaction that **releases** energy from the system, usually in the form of heat, but also in the form of light (e.g. a spark, flame, or explosion), electricity (e.g. a battery), or sound (e.g. burning hydrogen). In such a reaction the energy content of the products is **lower** than the one of the educts.

ENTHALPY or **REACTION ENERGY** is the difference in energy content of educts and products. **RS**

YOU ARE ABLE TO DRAW AND TO INTERPRET AN ENERGY DIAGRAM



YOU CAN EXPLAIN WHEN ENDOTHERMIC REACTIONS CAN BECOME SPONTANEOUS

Nature always tries to have more disorder, the so called **ENTROPY**. And if a reaction which can happen at room temperature creates more disorder, it may happen spontaneous.

Example: *Salt + Salt → Gas + Liquid + Solution*

EXTRA INFORMATION

$$\Delta G = \Delta H - T * \Delta S$$

The free energy ΔG is calculated by subtracting from a **positive** integer for **endothermic** resp. a **negative** integer for **exothermic** reactions ΔH from the product of the **absolute temperature** T and ΔS which is positive if the **entropy increases**. For spontaneous processes, ΔG has to be negative.

YOU KNOW THE TWO LAWS OF THERMODYNAMICS, WHICH RULE ALL PROCESSES IN NATURE **RS**

1. Nature favors energetically **stable bonds** and strong forces between atoms. Forming strong forces leads to a **production of heat**.
2. Nature favors processes in which the **disorder increases** (particles with a **lot of movement** and **maximum of mixing!**). This is the so called **ENTROPY**.

YOU CAN DECIDE FOR ANY REACTION WHETHER THE ENTROPY INCREASES OR DECREASES

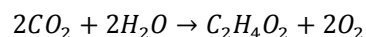
Entropy increases when...

- ... solids are dissolved
- ... solids or liquids become gases
- ... solids or liquid become solutions
- ... gases are released from solutions
- ... temperature rises → particles move faster
- ... more products are formed than educts are used
- ... a reaction is **endothermic**

Attention in an exothermic reaction, entropy can decrease **or** increase!

YOU ARE ABLE TO EXPLAIN THE EXPRESSION "PATHWAY OF REACTION" WITH THE FORMATION OF GLUCOSE

Attention the formulas are heavily simplified!



A reaction pathway basically describes which intermediates are formed "along the way".

YOU ARE ABLE TO EXPLAIN, WHY SOME REACTIONS RUN VERY SLOWLY

- Too cold
- Too less educts
- ...

YOU ARE ABLE TO EXPLAIN WHY ALL REACTIONS NEED ACTIVATION ENERGY

- **ACTIVATION ENERGY** is defined as the energy that must be overcome in order for a chemical reaction to occur. Activation energy may also be defined as the minimum energy required to start a chemical reaction.
- A **CATALYST** **reduces the activation energy** of a chemical reaction without being used up. **RS**

YOU CAN FIND OUT WHETHER A REACTION IS EXOTHERMIC OR ENDOTHERMIC

- **Polar bindings** are energetically **more favorable** than unpolar bindings. Ionic bindings are even more favorable. **RS**

➔ A reaction is exothermic if polar bonds are formed from unpolar bonds.

YOU CAN EXPLAIN WHY A CHEMICAL REACTION TAKES PLACE MORE EASILY, IF THE TEMPERATURE IS HIGH

If the **activation energy** is risen, the **speed** of the molecules **increases** and hereby they are fast enough to **break binding when colliding**.

YOU ARE ABLE TO EXPLAIN THE EXPRESSION "RATE OF REACTION"

- The **REACTION RATE** for a reactant or product in a particular reaction is defined as how fast or slow a reaction takes place.
- [...] The **change of concentration** of the reactant divided by the time is called the **RATE OF REACTION** [...] **RS**
-

YOU CAN EXPLAIN WHY REACTIONS RUN FASTER WHEN THE CONCENTRATION OF THE REACTANTS IS INCREASED

Like this, the chance of a collision of two particles is much higher.

YOU KNOW THE INFLUENCE OF THE TEMPERATURE ON THE RATE OF REACTION

- According to the **RGT-RULE** which is true for about **10-20%** of all reactions. The reaction rate doubles, when temperature is increased by 10°C.

YOU ARE ABLE TO EXPLAIN WHY REACTION RATES ARE SOMETIMES INCREASED BY THE PRESSURE

By increasing pressure, particles collide more often. **RS**

YOU CAN EXPLAIN HOW A CATALYST CAN REDUCE THE ACTIVATION ENERGY

A catalyst reacts with the other educts to form **energetically more favorable** intermediates, but **recovers** after the reaction and is therefore "unchanged".

YOU CAN EXPLAIN WHY WITH SOME REACTIONS THE FORWARD REACTION AND THE BACKWARD REACTION CAN TAKE PLACE AT THE SAME TIME

WILL FOLLOW SOON!

YOU CAN EXPLAIN THE DYNAMIC EQUILIBRIUM AND THE EQUILIBRIUM CONSTANT (K)

$$K = \frac{[C] \cdot [D]}{[A] \cdot [B]} \rightarrow \text{Equilibrium constant} = \frac{[\text{concentration of product C}] \cdot [\text{concentration of product D}]}{[\text{concentration of educt A}] \cdot [\text{concentration of educt B}]}$$

$K > 1$: forward reaction is faster → more C and D than A and B; equilibrium on the right
 $K < 1$: backward reaction is faster → more A and B than C and D; equilibrium on the left

The **DYNAMIC EQUILIBRIUM** is the state in which the concentrations of the reactants and products have not yet changed with time. It occurs only in **reversible reactions**, and not in irreversible reactions.

ATTACHMENTS

Rules to be used in the tests:

Rule: Polar bindings are energetically more favourable than unpolar bindings. Ionic bindings are even more favourable!

Definition: The difference between the energy content of the products and the energy content of the educts equals the released **reaction energy = enthalpy**.

Definition: The **Activation Energy** is closely related to the intermediates built during the reaction. That means, the higher the energy to break the bindings to build intermediates, the bigger is the **Activation Energy**.

Definition: A catalyst reduces the activation energy of a chemical reaction without being used up. It increases the rate of reaction but has no influence on the dynamic equilibrium!

Definitions: The more collisions between particles in a given time, the faster the reaction (**collision theory**). The change of the concentration of the reactant divided by the time is called the **rate of reaction** (Reaktionsgeschwindigkeit). The unit is mol per litre and seconds.

Rule 1: The rate of reaction increases with increasing temperature. This makes particles collide more often and collide more violently.

Rule 2: The rate of reaction increases, when the concentration of the reactants is increased. This makes particles collide more often.

Rule 3: The rate of reaction of solid reactants increases, when the surface area of the reactants is increased. This makes particles collide more often.

Rule 4: The rate of reaction of gaseous reactants increases, when the pressure is increased. This makes particles collide more often.

Rule 1a: Addition of a reactant to a reaction in the dynamic equilibrium leads to the formation of **more products**. The actual equilibrium lies further to the right.

Rule 1b: Removal of products from a reaction in the dynamic equilibrium leads to the **new formation of products**. The actual equilibrium lies further to the right.

Rule 2a: By heating of a reaction mixture in the dynamic equilibrium the **endothermic reaction** becomes faster.

Rule 2b: By cooling of a reaction mixture in the dynamic equilibrium the **exothermic reaction** becomes faster.

Rule 3a: By increasing the pressure on reaction mixture in the dynamic equilibrium the reaction becomes faster, which produces **less gaseous particles** (need less space).

Rule 3b: By decreasing the pressure on reaction mixture in the dynamic equilibrium the reaction becomes faster, which produces **more gaseous particles** (need more space).

Law 1: Nature favours energetically stable bonds and forces between particles = The forces between the particles should be strong! = Enthalpy must be big = exothermic processes are favoured.

Law 2: Nature favours processes in which the disorder increases (particles with a lot of movement and maximum of mixing!) = Entropy increases.