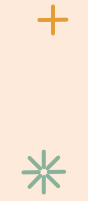


University Chemistry Review



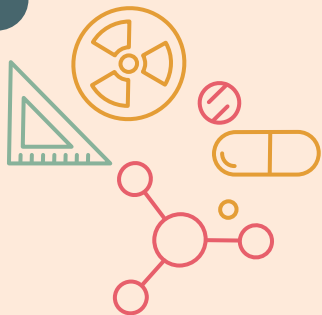


Table of Contents



01

Topic 11

Organic chemistry

03

Topic 13

Kinetics

02

Topic 12

Spontaneity

04

Topic 14

Chemical equilibrium





1

Topic 11

Organic chemistry





Organic reactions



→ Important reactions in organic chemistry

◆ Substitution

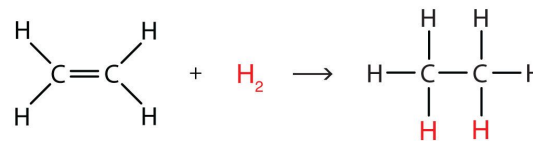
- One functional group is replaced with another



 substitutes for -H

◆ Addition

- Addition of one or more atoms to a molecule



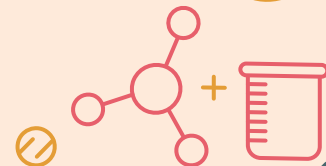
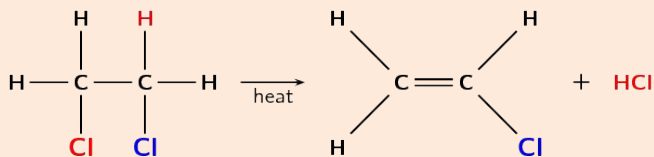
Ethylene

Hydrogen

Ethane

◆ Elimination

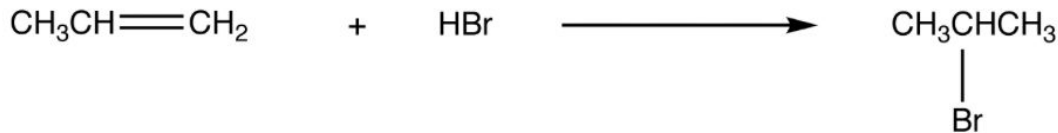
- Removal of one or more atoms from adjacent carbons in a given molecule



Markovnikov's rule

◆ Markovnikov's rule

- Describes how an addition reaction may proceed to form the most potentially stable organic molecule
- The least electronegative atom in a reaction will bond to the carbon with the highest number of alkyl groups



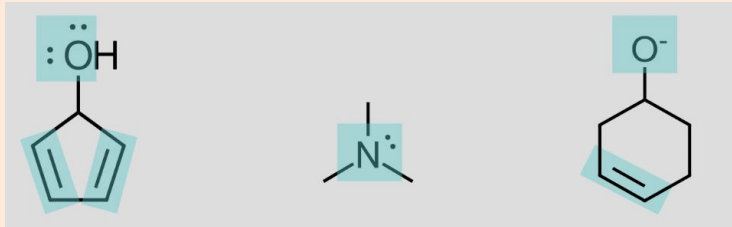


Nucleophiles and Electrophiles



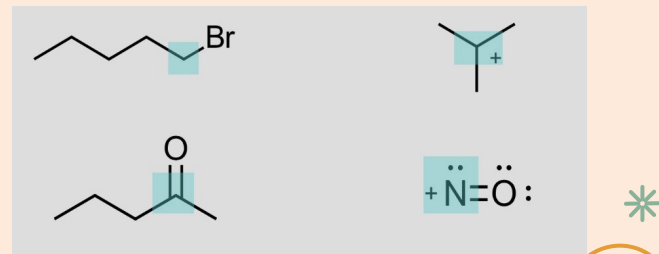
→ Nucleophiles

- ◆ Attracted to positive charges
- ◆ Includes:
 - Lone pairs
 - Multiple (i.e., double/triple) bonds
 - Negative charges

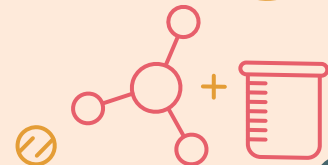


→ Electrophiles

- ◆ Attracted to e⁻
- ◆ Includes:
 - Positive charges
 - Positively polarized atoms



→ Basis of most chemical reactions is the interaction between nucleophiles and electrophiles





2

Topic 12

Spontaneity

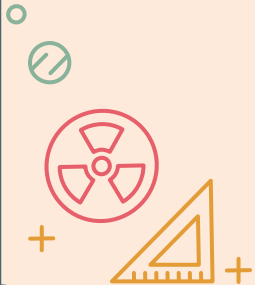




Making sense of it all



- Why does there seem to be a natural progression of events?
- ◆ Change can be reasonably predicted based on a natural direction of change
 - I.e., Based on natural laws, an object will always fall toward another object with a stronger force of gravity (e.g., a waterfall)
 - ◆ The universe favours spontaneity
 - The universe being a system and its surroundings
 - I.e., Entropy (S)!!!





Entropy

→ What the heck is entropy?

- ◆ A thermodynamic principle
- ◆ Empirical measurement of the disorder or randomness as it relates to a given closed system
 - In this sense, it represents the amount of thermal energy in a closed system that is unavailable to perform work
 - If energy is not put into a system, the closed system will move closer to entropy, or true randomness, as time passes

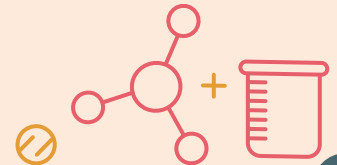
→ $S = (kb)(\ln)(W)$



+



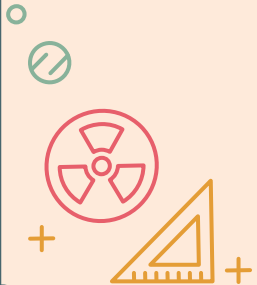
+





Entropy

- $S = (k_b)(\ln)(W)$
- ◆ S = entropy (SI unit measurement = J/K)
 - ◆ k_b = Boltzmann's constant
 - $1.38E-23$ J/K
 - ◆ \ln = a natural logarithm
 - ◆ W = number of possible configurations of a state



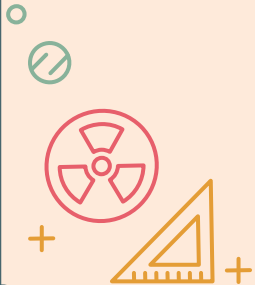
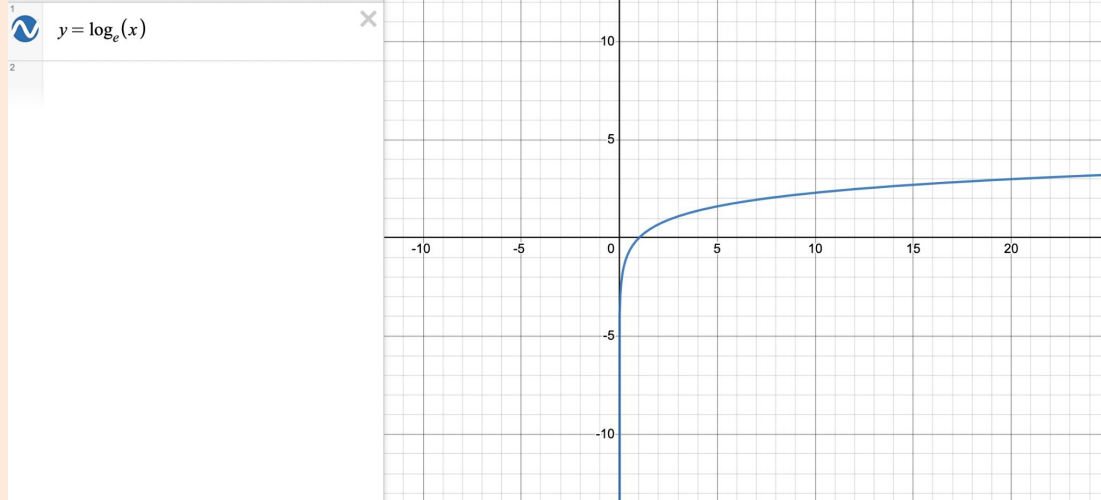


Entropy

→ ln
◆

Wait...what's ln?

- ln =
 - a logarithm to the base of e
- e = is an irrational number that is used in mathematics
- ∴ $\ln(x) = \log_e(x) = y$
- The ln of a negative number is 'undefined' and therefore there is a vertical asymptote at (0,0)



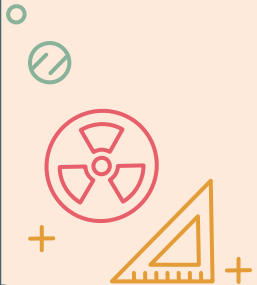


What is spontaneity?



- Spontaneous change
 - ◆ Occurs when change happens in a system without any influence or input from the surroundings

- Spontaneous processes release energy and are favourable
 - ◆ Doesn't mean that heat is always released when a reaction takes place
 - Heat = the transfer of thermal energy from one object to another

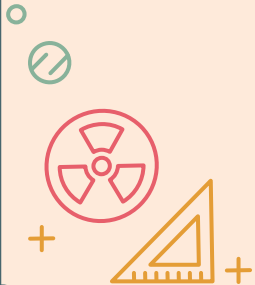




Ok, back to entropy

→ Entropy

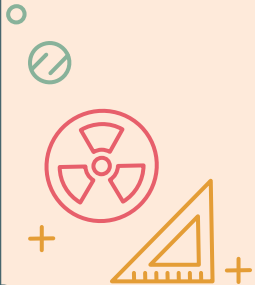
- ◆ Recognized as a state function
 - The path and rate of a reaction are negligible here
 - This is thermodynamics, after all!
 - We're not concerned with how quickly a reaction proceeds, just that it has taken place at all!
- ◆ $\therefore \Delta S = S(\text{final}) - S(\text{initial})$
 - $\Delta S > 0 \rightarrow$ melting, vaporization, creating a solution, the outcome of a solution that increases the number of moles, and heating a substance
 - $\therefore \Delta S > 0$ is favourable





Entropy change?

- Entropy decrease of a system
 - ◆ Can only occur if the entropy of a system's surroundings increases
- $\Delta S(\text{universe}) = \Delta S(\text{system}) + \Delta S(\text{surroundings})$
 - ◆ Considered spontaneous if $\Delta S(\text{universe}) > 0$
 - ◆ Considered non-spontaneous if $\Delta S(\text{universe}) < 0$
 - “Non-spontaneous” refers to the fact that a process or reaction in a system will not occur without influence from its surroundings
- By this logic...
 - ◆ A spontaneous rxn ($\Delta S > 0$) carried out in a forward direction will, in turn, be non-spontaneous ($\Delta S < 0$) in the opposite direction





Energy Review

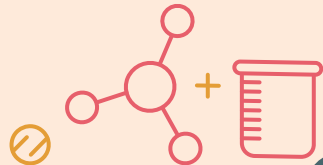
- Enthalpy → State function that describes the properties of a thermodynamic system
 - ◆ The path taken from reactants to products is irrelevant
 - ◆ The rate of a rxn is irrelevant
 - More concerned with whether the rxn will happen or not
- Hess's law
 - ◆ For any multi-step rxn, the net enthalpy is equal to the sum of all of the enthalpies from each step of the rxn



+



+





Gibbs free energy (ΔG)



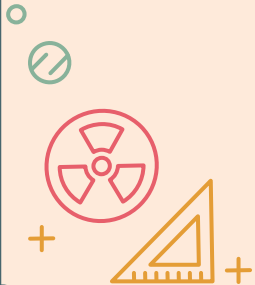
- A thermodynamic concept that empirically describes the maximum amount of work that can be carried out by a closed system with no external influence
 - ◆ Basically demonstrates the energy of a chemical reaction after taking into account entropy
 - ◆ Determines the spontaneity of a reaction
- $\Delta G = \Delta H - T\Delta S$
 - ◆ ΔG = Gibbs free energy (expressed in: J, kJ, kJ/mol, etc...)
 - ◆ ΔH = enthalpy of a reaction
 - ◆ T = temperature in Kelvin
 - ◆ ΔS = entropy
- A reaction is said to be spontaneous if $\Delta G < 0$
 - ◆ Non-spontaneous if $\Delta G > 0$
 - ◆ At equilibrium if $\Delta G = 0$





What happens if a reaction is nonspontaneous?

- Nonspontaneous reactions are said to be unfavourable as they do not favour the formation of products from reactants
- This obviously isn't ideal as this would prevent a ton of reactions from being carried forward. So, what gives??
 - ◆ Reaction coupling!! (a.k.a meet Biochemistry)
 - When an unfavourable, or nonspontaneous reaction, is paired with the energy produced from a favourable/spontaneous reaction
 - E.g., Most biological processes are unfavourable!
 - ◆ Solution: use a universal energy source to couple unfavourable reactions
 - ◆ ATP to the rescue!
 - The third inorganic phosphate of ATP is cleaved off and the energy released from ATP hydrolysis is used to drive unfavourable reactions forward





3

Topic 13

Kinetics

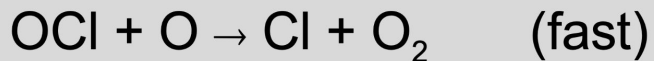




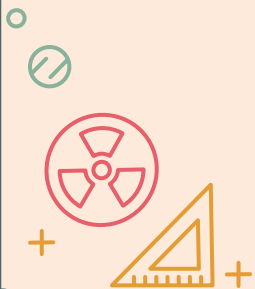
Rate of reaction

→ Rate determining step

- ◆ The slowest reaction in a multi-step reaction
 - Therefore, the overall rate of a multi-step reaction = the rate determining step
- ◆ E.g.,



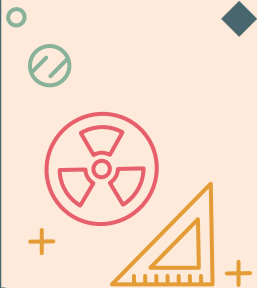
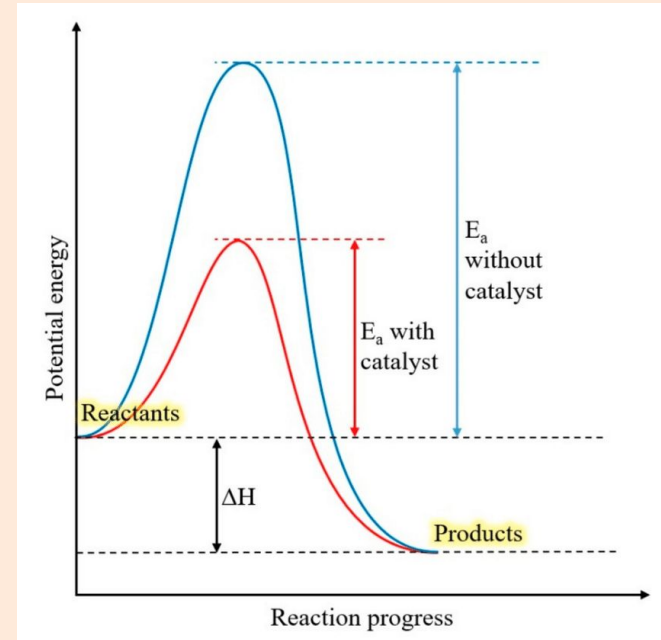
rate of overall reaction = rate of first step





Catalysts

- Most reactions (especially biological reactions) are too slow to effectively proceed on their own and require an extra boost!
 - ◆ A catalyst lowers the activation energy of a reaction by stabilizing the transition state, therefore making the reaction more favourable
- Catalysts serve only a kinetic role, and therefore do not affect ΔG
 - ◆ Therefore, they speed up the reaction, but don't directly affect the thermodynamic properties of the reaction





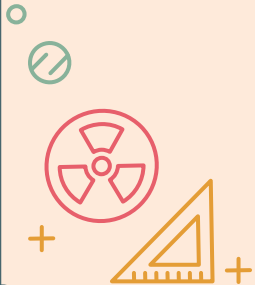
Chemical kinetics



→ What affects the rate of a reaction?

◆ E.g., $A + B \rightarrow C$

- The rate at which reactants A and B collide with each other
- The fraction of molecules A and B having the correct orientation when they collide
- The fraction of collisions between molecules A and B resulting in enough energy to cause a reaction to move forward





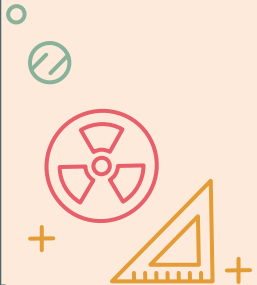
Chemical kinetics



→ What affects the rate of a reaction?

◆ E.g., $A + B \rightarrow C$

- The rate at which reactants A and B collide with each other
 - Collision rate = $Z [A][B]$
 - Therefore, if you increase the [] of reactants, there will be a higher collision rate





Chemical kinetics



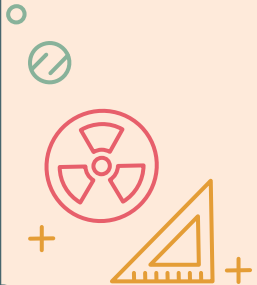
→ What affects the rate of a reaction?

◆ E.g., $A + B \rightarrow C$

- The fraction of molecules A and B having the correct orientation when they collide

- p = fraction of collisions with the correct orientation

- ◆ $0 < p < 1$





Chemical kinetics



→ What affects the rate of a reaction?

◆ E.g., $A + B \rightarrow C$

- The fraction of collisions between molecules A and B resulting in enough energy to cause a reaction to move forward

- $f = e^{-E_a/RT}$

- ◆ E_a = activation energy

- If energy of collisions $> E_a$, then there is a chance products may be formed from reactants



+



+





Chemical kinetics



→ Put it all together!

- ◆ Collision rate = $Z [A][B]$
- ◆ $0 < p < 1$
- ◆ $f = e^{-E_a/RT}$

→ Therefore...

- ◆ rate = $(p)(f)(Z[A][B])$
- ◆ rate = $(p)(Z)(e^{-E_a/RT})$

→ And finally Arrhenius stepped in and gave us:

- ◆ Rate = $Ae^{-E_a/RT}$



+



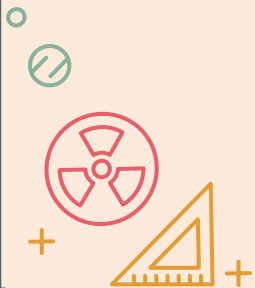
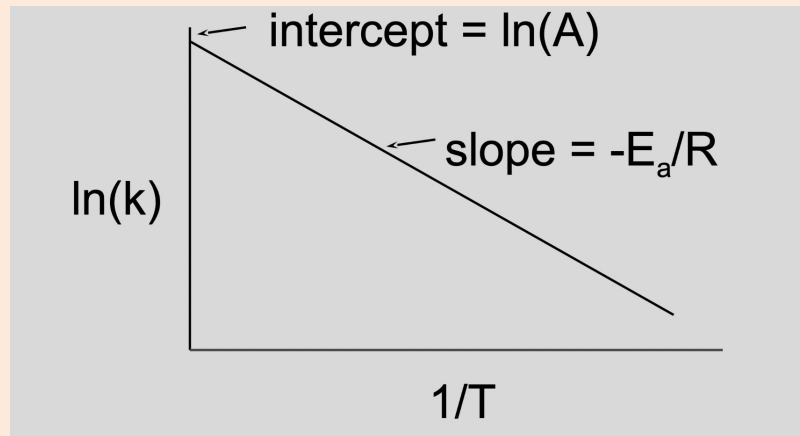
+





Return of ln

- When values are unknown, you can rearrange Arrhenius' equation to solve for A or E_a
 - ◆ $\therefore \ln(k) = [-E_a/R][1/T] + \ln(A)$
- Subsequent return of the linear equation!!
 - ◆ $y = mx + b$





4

Topic 14

Chemical equilibrium





What is equilibrium?

→ Equilibrium, by definition

◆ When:

- 1. The [] of reactants and products are not changing
- 2. The forward rate = the reverse rate

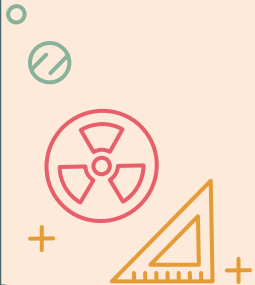
◆ $[C][D]/[A][B] = k_f/k_r$

→ K_{eq} , the equilibrium constant

◆ A function of temperature

◆ $K_{eq} = [C]^c[D]^d/[A]^a[B]^b$

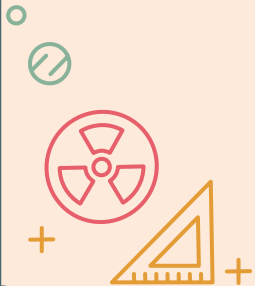
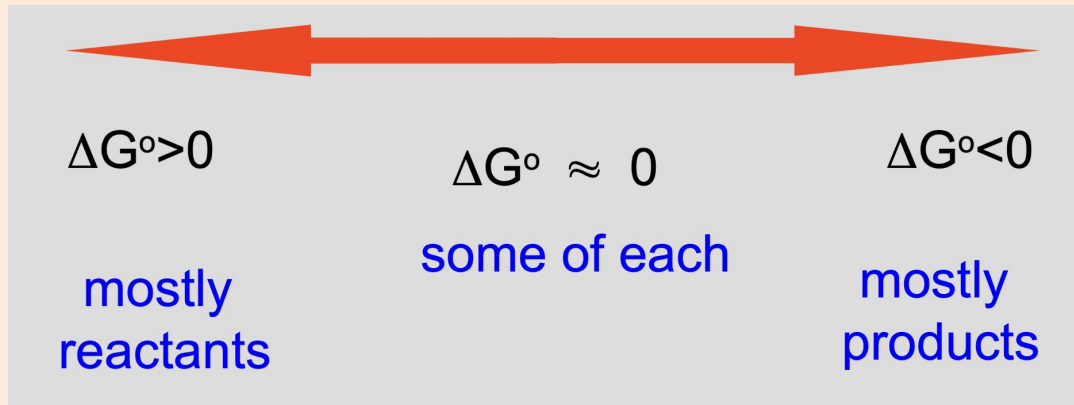
- The exponents are directly related to the stoichiometry of the equation!!
 - A.k.a make sure the equation is properly balanced!
- Does not include pure liquids (e.g., H₂O or solids)
- For gases, use a partial pressure variation of the equation
 - $K_{eq} = (pC^c)(pD^d)/(pA^a)(pB^b)$





What is equilibrium?



- K and ΔG are related → K is a function of ΔG°
- ◆ As a system gets closer to equilibrium, gibbs free energy decreases
 - Recall: $\Delta G = 0$ means that a reaction is at equilibrium!
 - Therefore, if you know the value of ΔG° , then you can determine the point of equilibrium for a given reaction





Thanks!

Please email me if you need anything!



CREDITS: This presentation template was created by **Slidesgo**, including icons by **Flaticon**, and infographics & images by **Freepik**

Please keep this slide for attribution

