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Organic Chemistry Reactions (Quick Study Academic)

ORGANIC CHEMISTRY REACTIONS

Features of an Organic Reaction

- Mechanism:** Describes the overall reaction using a series of single steps.
- Stoichiometry:** Calculate reactant and product masses using the balanced equation and molar masses.
- Kinetics:** Study of the reaction rate and mechanism.
- Theoretical Yield:** Mass of product given by a complete reaction, % yield = $\frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$.
- Equilibrium:** Reaction does not proceed to completion. Instead, it reaches a balanced state of forward and reverse reactions.

Major Reaction Types

- Acid
- Base
- Oxidation-reduction
- Coordination
- Substitution (S_N1 , S_N2)
- Radical reaction
- Isomerization
- Elimination ($E1$, $E2$)
- Cyclization
- Hydrolysis
- Addition
- Radical reaction

Important Named Reactions

- Diels-Alder:** Forms cyclic alkenes.
- Friedel-Crafts:** Add aryl or alkyl group.
- Grignard:** Add alkyl or aryl group.
- Wittig:** Convert aldehydes/ketones to alkenes.

Kinetics & Reaction Mechanism

- Transition State (TS):** Maximum on the reaction coordinate curve, the least stable intermediate.
- Activation Energy (E_a):** Energy of the TS relative to the reactants. The change in enthalpy (ΔH) is ≈ 0 for exothermic reactions and $\approx +$ for endothermic reactions.
- Hammett-Lauritzen Plot:** The TS is more like the reactant or product that is closer in energy. The endothermic TS is like the product and the exothermic TS is like the reactant.
- Kinetic vs. Thermodynamic Control:** ΔG and ΔH describe thermodynamic stability. If ΔG is large and negative (exergonic), the product formation is likely controlled by "thermodynamics." A large E_a corresponds to a large amount of product relative to reactant. A large E_a may give rise to "kinetic" control, the energy of the TS controls the reaction, instead of the product-reaction thermodynamics.
- Solvent Effects:** A solvent may stabilize an intermediate, decreasing the E_a and increasing the rate of the reaction. Charged complexes are stabilized by polar solvents.

Organic Acid & Base

Acid

- Electron-pair acceptor (Lewis acid)
- Proton donor (Brønsted-Lowry acid)
- EX: Carboxylic acid

Base

- Electron-pair donor (Lewis base)
- Proton acceptor (Brønsted-Lowry base)
- EX: Amine

Factors Enhancing Acid Strength (H_A)

- Weaker H-A bond
- Greater electronegativity of "A"
- Inductive effect of substituent on "A" (electron withdrawing enhances transfer)
- More "s" character in hybrid orbital (s-orbital is lower in energy than p-orbital)
- Resonance-stabilized conjugate base (A⁻)

Factors Enhancing Base Strength

- Reverse of acid strength guidelines
- A base is a nucleophile, electron effects which shift electron density to the atom with the lone pair increases base strength

Alkane

Properties

- Hydrocarbon
- Weak intermolecular forces
- New Cyclic: General Formula C_nH_{2n}
- Tetrahedral: $C-C-C$ (109°)

Isomerism

- Add "and" to prefix
- Locate substituent by position #
- Halohalane: Substituted halide for H

Cycloalkane (C_nH_{2n})

- Bicyclic: Two fused or bridged rings
- Cyclopropane: $n = 3$ (highly strained)
- Cyclobutane: $n = 4$ (some flexibility)
- Cyclopentane: $n = 5$ (slight puckering)
- Cyclohexane: $n = 6$ (no strain)

Chair Conformation: Stable conformation

- Most Conformation: Least stable
- Axial Position: Perpendicular to ring
- Equatorial Position: In ring plane
- See H_a and H_e in chair diagram below

Cis: Two substituents in the up position

Trans: One substituent up and one down

Synthesis

- Hydrogenate alkene or alkyne (H_2 , Pt catalyst)
- Free-radical reaction of alkane
- Radical halohalane (Zn , HX)
- Friedel-Crafts alkylation

Reactions

- Combustion: $Alkane + O_2 \rightarrow CO_2 + H_2O$
- Halogenation to halohalane (Cl_2 , Br_2 , light or heat)

Alkene $>C=C<$

Properties

- Similar to alkane, non-polar, flammable

Nomenclature

- Add "ene" to prefix, use 1 to denote C=C position
- Isotactic: $C-C=C-C$
- Cumulative: $C=C=C$
- Polymersaturated Fatty Acid: 2 or more C=C
- Alkene: Adjacent C=C
- Vinyl Group: $H_2C=CH-$
- Methylene Group: H_2C-
- Allyl Group: $H_2C=CH-CH_2-$
- Vinyl Halide: Halide replaces H on $>C=C<$
- Conjugated: Alternate C=C and C-C (monomers)
- Alkadiene: 2 conjugated C=C (e.g., butadiene), cis and trans isomers about C=C bond
- Alkatriene: 3 conjugated C=C
- Aromatic: Conjugated monocyclic compound
- EX: (E) aniline = benzene
- Aromatic Cyclic base: Cyclopentadiene anion, cycloheptatriene cation (6 electrons)

Isomers

- No free rotation of C=C
- E/Z: prioritize groups by atomic weight
- Z: Higher priority groups on the same side

Nomenclature

- Cis is less stable (steric hindrance)
- Cis is more stable
- Markovnikov Rule: Form the least substituted alkene
- Markovnikov Addition: H adds to C with more H's
- Zaitsev Elimination: Form alkene with most substitution

Synthesis

- Dehydrohalogenation (HX , heat) (elimination)
- Dehydrohalogenation halohalide (heat, heat)
- Dehydrohalogenation via alkoxide (OH^- , water, acid)
- Hydrogenation: alkene
- Reagents: H_2 , Pt catalyst
- Reagents: H_2 , Pd catalyst
- Reagents: H_2 , Ni catalyst
- Wittig: Aldehyde/ketone + phosphorus ylide

Reaction

- Combustion (O_2)
- Hydration to 2°/3° alcohol (H_2O , H^+ from alkene, acid, rearrange (Markovnikov))
- Hydration to alcohol: hydroboration-oxidation (THF, BH_3 , H_2O_2 , $NaOH$, anti-Markovnikov)
- Oxymercuration-demercuration to alcohol
- Hydrohalogenation (HX) (Markovnikov)
- Hydrogenation (H_2 , Cl_2 , via dihalohalide (X_2 , CCl_4 , anti-addition)
- Hydrolysis (X_2 , H_2O , anti-addition)
- Hydrohalogenation to form a 1,2-diol (OsO_4 , cold OH^- , syn-addition)
- Oxidation to carboxylic acid ($KMnO_4$, hot OH^-)
- Oxidation to ketone (O_3 , Zn , H_2O)
- Hydrogenation to alkane (H_2 , syn-addition)
- Free radical polymerization
- Alkylation reaction
- Allylic halogenation (Cl_2 , heat)
- Diels-Alder: Cycloalkene from diene + alkene/alkyne



Synopsis

Quick Reference for the core essentials of a subject and class that is challenging at best and that many students struggle with. In 6 laminated pages our experienced chemistry author and professor gathered key elements organized and designed to use along with your text and lectures, as a review before testing, or as a memory companion that keeps key answers always at your fingertips. As many students have said "a must have" • study tool. Suggested uses:

- o Quick Reference " instead of digging into the textbook to find a core answer you need while studying, use the guide to reinforce quickly and repeatedly
- o Memory " refreshing your memory repeatedly is a foundation of studying, have the core answers handy so you can focus on understanding the concepts
- o Test Prep " no student should be cramming, but if you are, there is no better tool for that final review

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