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Organic Chemistry Reactions (Quick Study Academic)

Quick Study
ACADEMIC

ORGANIC CHEMISTRY

REACTIONS

Features of an Organic Reaction

- **Mechanism:** Describes the overall reaction using a series of simple steps.
- **Stoichiometry:** Calculate reactants 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 = $\frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$ (product mass / chemical yield)
- **Equilibrium:** Reaction does not proceed to completion. Instead, it reaches a balanced state of forward and reverse reactions.

Major Reaction Types

- Acid
- Elimination (E1, E2)
- Base
- Cyclization
- Oxidation-reduction
- Hydrolysis
- Condensation
- Addition
- Substitution (S_N1, S_N2)
- Radical reaction
- Free-radical reaction

Important Reaction

- Diels-Alder: Two cyclic alkenes
- Grignard-Crabbe: Add acid or alkyl group
- Friedel-Crafts: Add alkyl or acyl group
- Wolff-Kishner, Clemmensen: Reduce ketone to alkane
- Wittig: Convert aldehydes/ketones to alkenes
- Wurtz-Fittig: Coupling aldehydes/ketones to alkenes

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 (HA)

- Weaker H-A bond
- Greater electronegativity of "A"
- Inductive effect of substituent on "A" (electron withdrawing enhances trend)
- 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, electronic effects which shift electron density to the atom with the lone pair increases base strength

Alkane

Properties

- Hydrocarbon
- Weak intermolecular forces
- Non-Cyclic: General formula C_nH_{2n+2}
- Tetrahedral: C-C (109°)

Nomenclature

- Add "ane" to prefix
- Locate substituent by position #
- **Haloalkane:** 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 (flat strain)

Chair Conformation: Stable conformer

- Bond Conformation: Less stable
- Axial Position: Perpendicular to ring
- Equatorial Position: In ring plane
- See H₁ and H₂ in their diagram below
- **Cis:** Two substituents in the up position
- **Trans:** One substituent up and one down

Isotomers

- Hydrogenation: alkene or alkyne (H₂, Pt catalyst)
- Free-radical reaction of alkane
- Radical halohalide (Zn, H₂)
- Friedel-Crafts alkylation

Reactive

- Combustion: Alkane + O₂ → CO₂ + H₂O
- Halogenation: to haloalkane (Cl₂/hν, light or heat)

Alkene

Properties

- No free rotation of C=C
- E/Z, geometric: groups by steric volume (Z - higher priority groups on the same side)

Nomenclature

- **Alkene:** C=C in most stable
- **Hofmann Rule:** from the least substituted alkene
- **Markovnikov Addition:** H adds to C with most H's
- **Zaitsev Elimination:** Favors alkene with most substitution

Synthesis

- Dehydration: alcohol (H⁺, heat) (elimination)
- Dehydrohalogenation: haloalkane (base, heat)
- Dehalogenation: vicinal dihalide (Zn, acetic acid)
- Hydrogenation: alkene
- **Wittig:** Aldehyde/ketone + phosphorus ylide

Reaction

- Combustion (O₂)
- Hydrohalide: to 2°/3° alcohol (H⁺, H₂O), 1° from alkene; can be reversible (Markovnikov)
- Halohalide: to dihalide, hydrohalogenation (HBr: D, H, D, D, HBr) (anti, anti-Markovnikov)
- Oxidation: can be reversible to alcohol
- Hydrohalogenation (HX) (Markovnikov)
- Halohydrin: (Br₂, H₂O) (vic dihalide) (X₂, CCl₄, anti addition)
- Halohydrin: (X₂, H₂O) (anti addition)
- Hydrohalide: to form a 1,2-diol (KMnO₄, acid, OH⁻, syn addition)
- Oxidize to carboxylic acid (KMnO₄, hot OH⁻)
- Oxidation to ketone (D, Zn, H₂O)
- Hydrogenation to alkane (Pt, H₂, syn addition)
- Free radical polymerization
- Alkene reaction
 - Alkylic halogenation (Cl₂, heat)
 - Diels-Alder: Cycloalkene from diene + alkene/alkyne

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 + for endothermic reactions

Hess's Law/Leffler Postulate: The TS is the same for the reactant or product that is closer to energy. The endothermic TS is like the product and the exothermic TS is like the reactant

Kinetic vs. Thermodynamic Control: K₁ and K₂ describe thermodynamic stability

- If K₁ is large and negative (exothermic), the product formation is likely controlled by "thermodynamics". A large K₂ 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's thermodynamic characteristics

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



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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