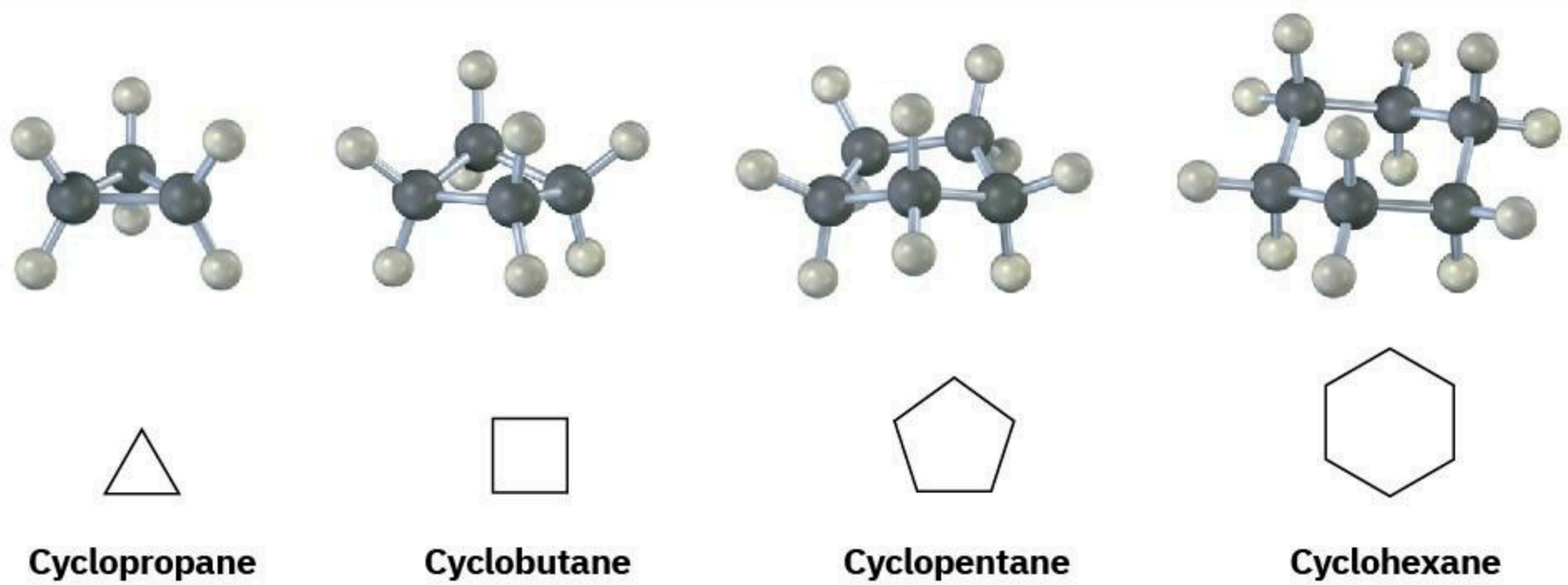
Lecture 11

Alicyclic compounds: structure, extraction and chemical properties

Lecture: PhD, acc. professor: Kudaibergenova B.M

Aim and Objectives

Aim: to study the classification, structure, preparation, properties and reactions of alicyclic compounds and their importance in industry.



- Define alicyclic compounds
- Classify by ring structure and saturation
- Explain structure and geometry
- Study ring strain and stability

- Investigate preparation methods
- Examine addition, substitution, oxidation, combustion
- Compare small and large rings
- Identify practical applications

Introduction

Non-aromatic cyclic compounds, saturated or unsaturated, with one or more rings. The simplest are cycloalkanes.

C_nH_{2n} ($n \geq 3$)

Compound	Formula
Cyclopropane	C_3H_6
Cyclobutane	C_4H_8
Cyclopentane	C_5H_{10}
Cyclohexane	C_6H_{12}

Classification

Saturated

Only C–C single bonds. Cyclopropane, cyclobutane, cyclohexane.

Unsaturated

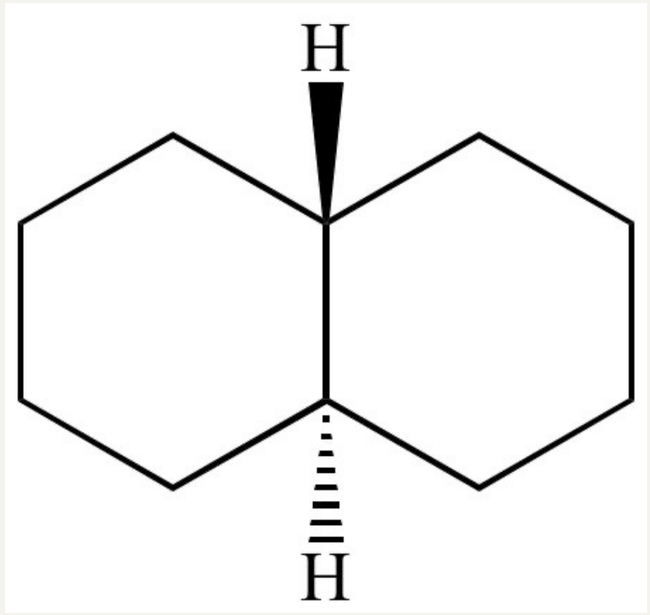
Double or triple bonds. Cyclopentene, cyclohexene, cyclooctyne.

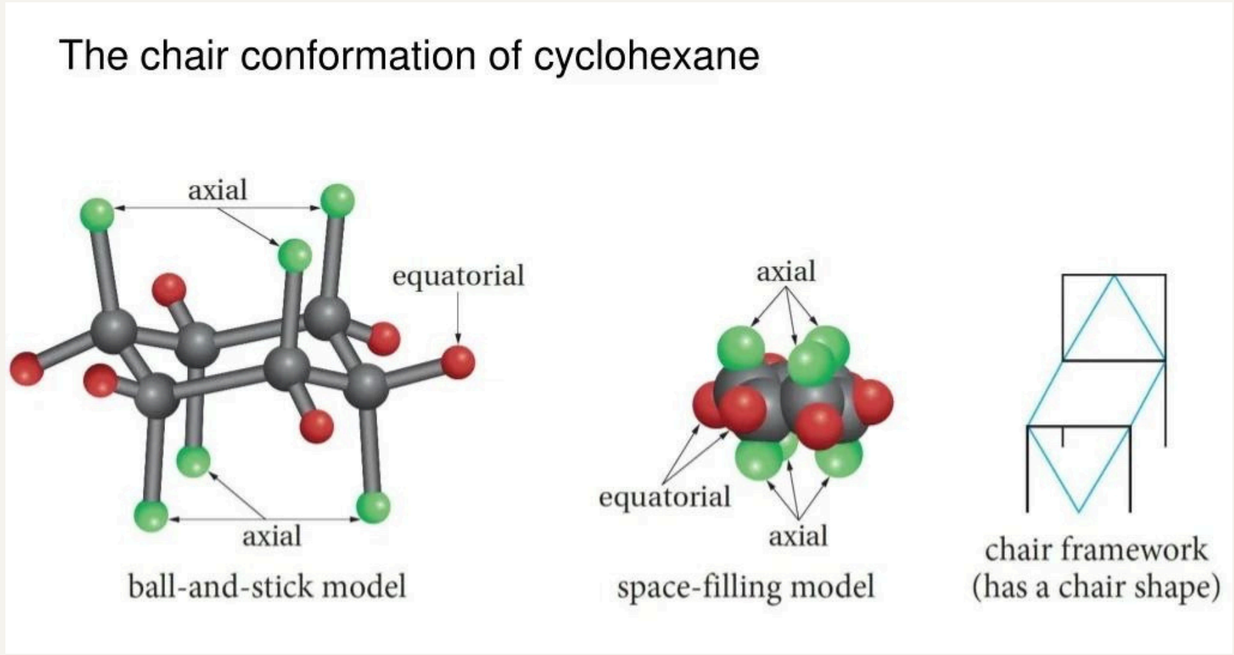
Monocyclic

One ring. Example: cyclohexane.

Polycyclic

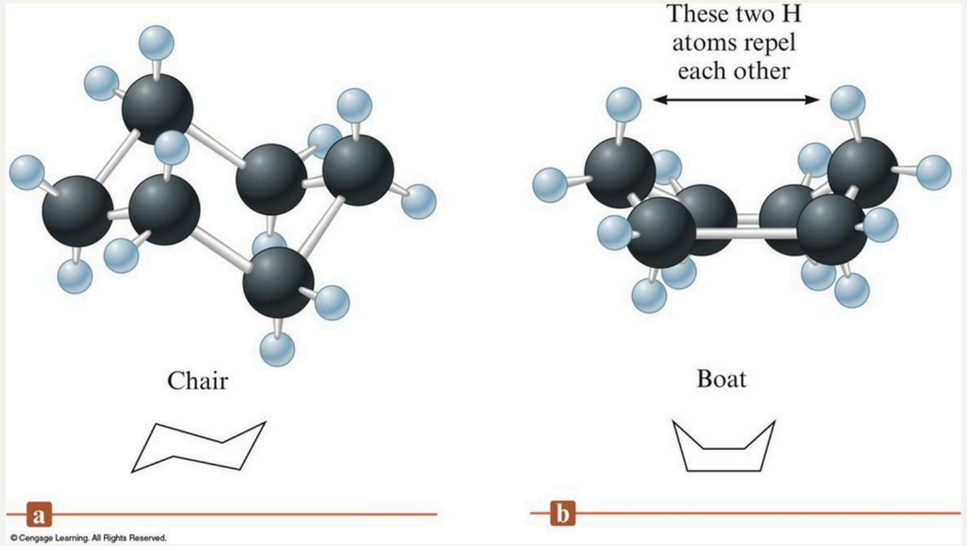
Two or more rings. Decalin, norbornane.





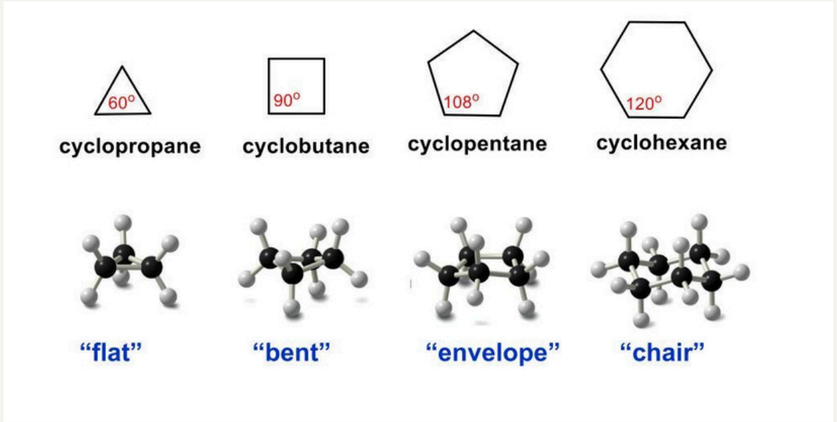
Structure and Geometry

sp^3 carbons prefer a tetrahedral angle of about 109.5°.
Ring size controls stability and reactivity.



Ring	Geometry
Cyclopropane	Three-membered, internal angles about 60°
Cyclobutane	Four-membered, nonplanar
Cyclopentane	Five-membered, commonly puckered
Cyclohexane	Six-membered, chair conformation

Ring Strain and Stability



Angle strain

Deviation from ideal bond angles.

Torsional strain

Repulsion between eclipsed bonds.

Steric strain

Atoms or groups too close together.

Compound	Main characteristic
Cyclopropane	High angle and torsional strain
Cyclobutane	Significant angle and torsional strain
Cyclopentane	Lower strain (puckering)
Cyclohexane	Very low strain (chair)

Isomerism and Nomenclature

Structural

Same formula, different connectivity: cyclobutane and methylcyclopropane (C_4H_8).

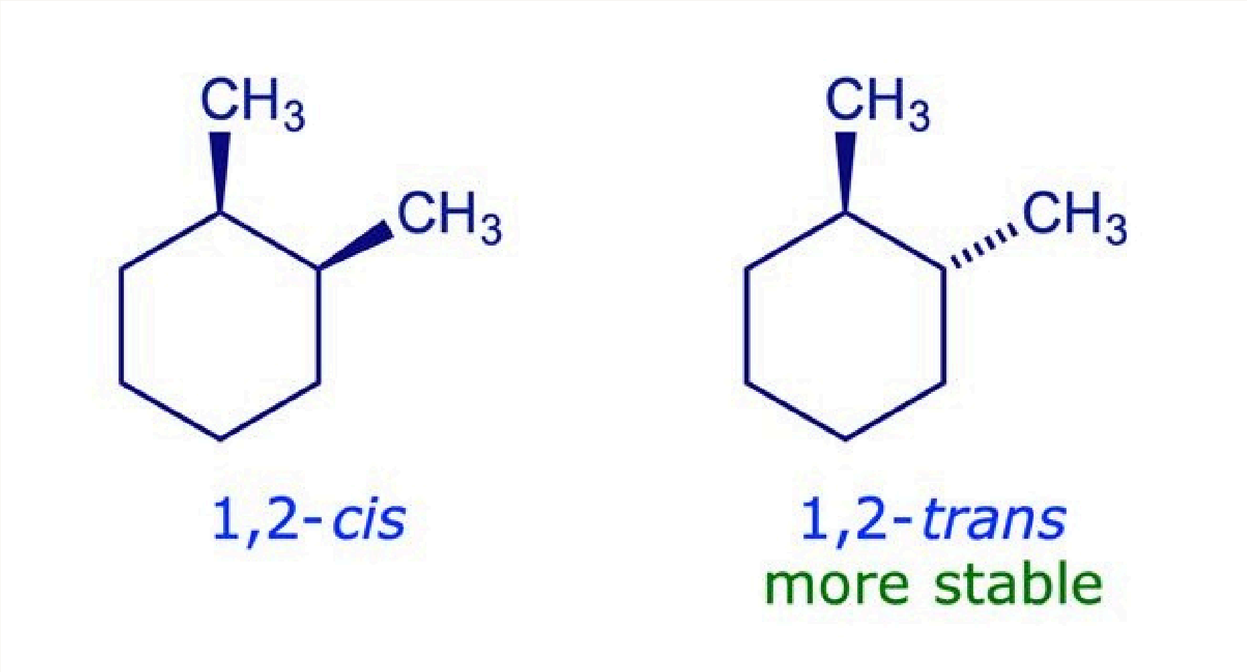
Geometrical

Cis: substituents on the same side. Trans: opposite sides.

Conformational

Different spatial arrangements from bond rotation and ring flexibility.

- Add the prefix cyclo- to the hydrocarbon name
- Number substituents for the lowest locants
- Indicate cis/trans where needed



Preparation

$BrCH_2CH_2CH_2Br + 2Na \rightarrow C_3H_6 + 2NaBr$

Intramolecular Wurtz reaction gives cyclopropane

$C_6H_6 + 3H_2 \rightarrow C_6H_{12}$ (Ni, heat, pressure)

Hydrogenation of benzene gives cyclohexane

$C_6H_{10} + H_2 \rightarrow C_6H_{12}$ (Ni)

Hydrogenation of cyclohexene

$CH_2{=}CH_2 + CH_2I_2 \rightarrow C_3H_6 + ZnI_2$ (Zn–Cu)

Cyclopropanation of alkenes

Physical and Chemical Properties

- Lower members: gases or volatile liquids
- Higher members: liquids or solids
- Insoluble in water, soluble in nonpolar solvents
- Boiling points rise with molecular mass
- Most are flammable

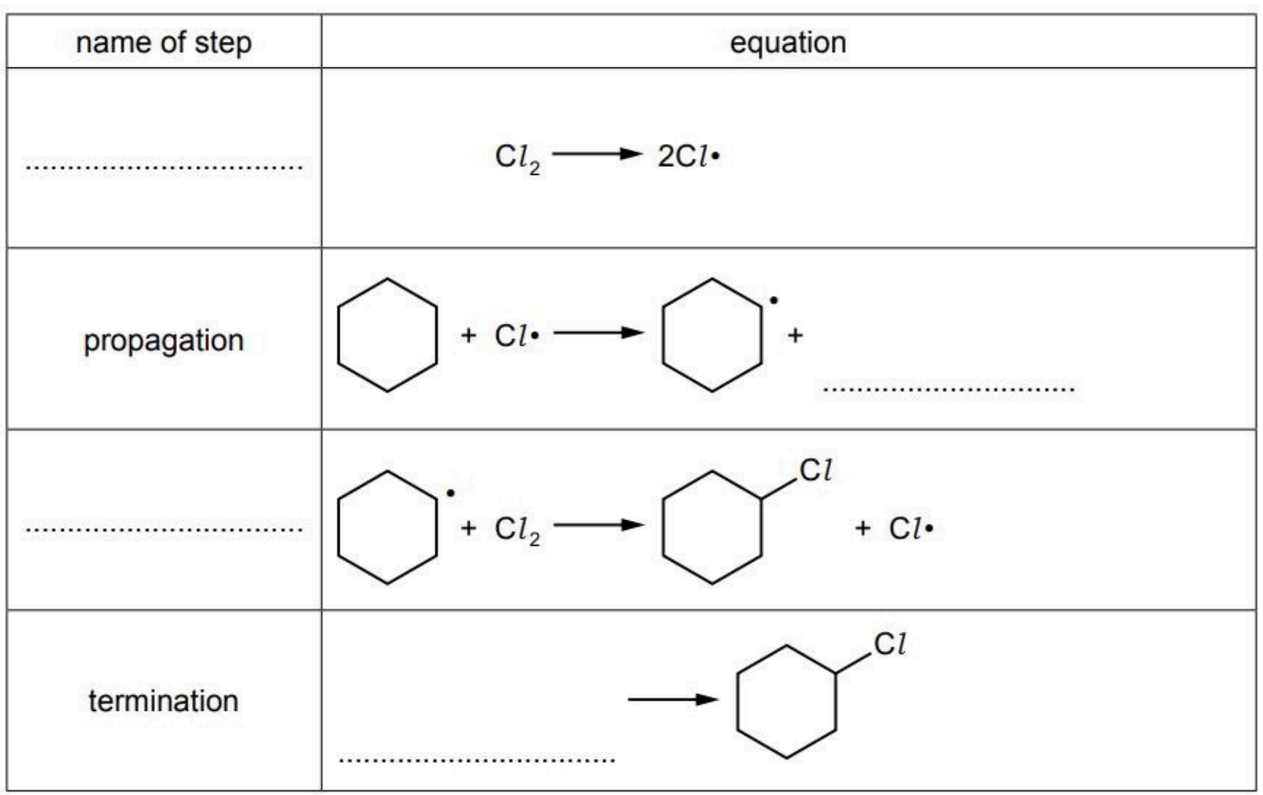
Reaction	Reagents	Products
Combustion	O_2	CO_2, H_2O
Radical substitution	Cl_2, UV	Chlorocycloalkanes
Small-ring hydrogenation	H_2, Ni	Alkanes
Ring opening	HBr	Haloalkanes
Oxidation	Oxidants	Alcohols, ketones, acids

Substitution Reactions

$C_6H_{12} + Cl_2 \rightarrow C_6H_{11}Cl + HCl$ (UV light)

Free-radical chlorination gives chlorocyclohexane

- Initiation: UV splits Cl_2 into chlorine radicals
- Propagation: Cl• removes H, giving a cyclohexyl radical
- The radical reacts with Cl_2 to form the product
- Termination: radicals combine



Ring-Opening Reactions

Cyclopropane opens easily because of high ring strain.

$C_3H_6 + H_2 \rightarrow CH_3CH_2CH_3$ (Ni, heat)

Propane

$C_3H_6 + HBr \rightarrow CH_3CH_2CH_2Br$

1-Bromopropane

$C_3H_6 + Br_2 \rightarrow BrCH_2CH_2CH_2Br$

1,3-Dibromopropane

Reactions of Cycloalkenes

Addition reactions at the C=C bond, as in open-chain alkenes.

$C_6H_{10} + H_2 \rightarrow C_6H_{12}$ (Ni)

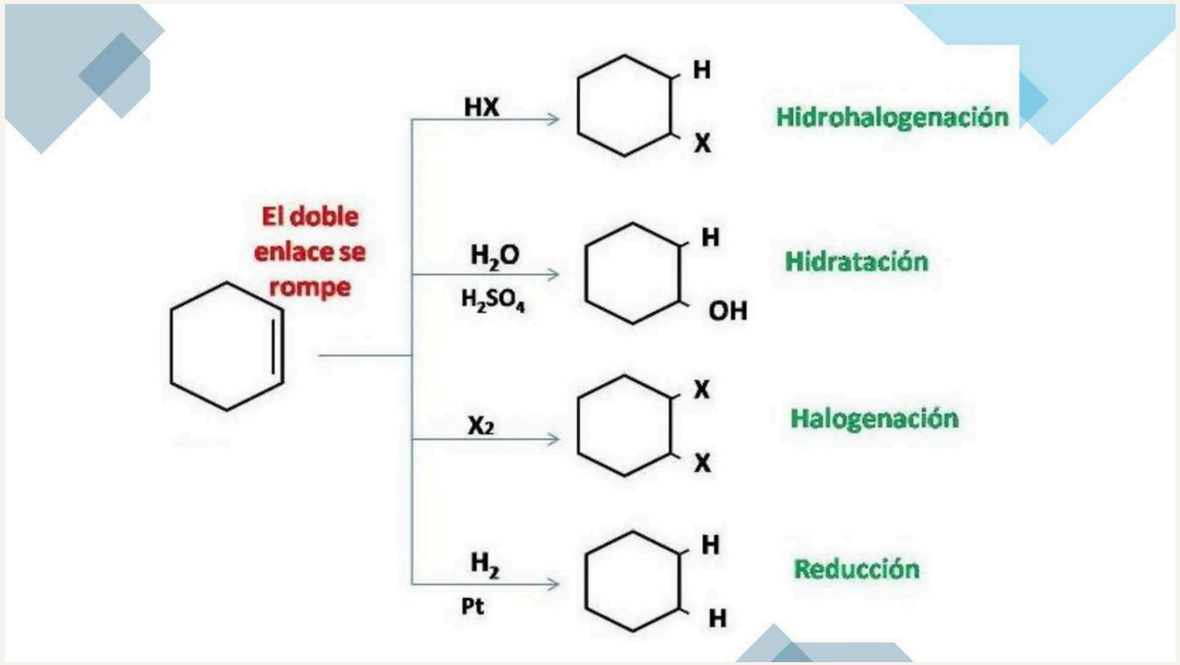
Hydrogenation: cyclohexane

$C_6H_{10} + Br_2 \rightarrow C_6H_{10}Br_2$

Halogenation: mainly trans-1,2-dibromocyclohexane (anti addition)

$C_6H_{10} + H_2O \rightarrow C_6H_{11}OH$ (H^+)

Hydration: cyclohexanol



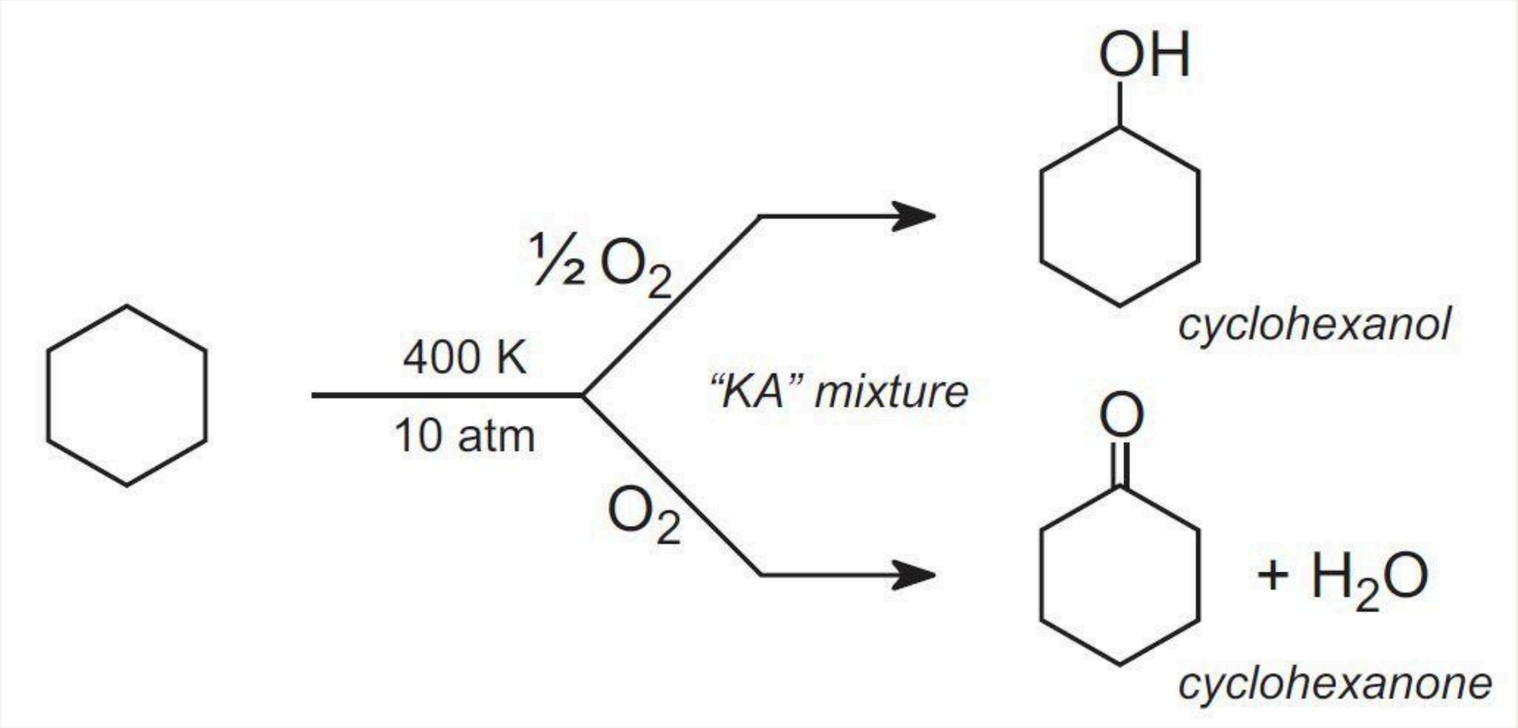
Oxidation and Combustion

Oxidation

Cyclohexane gives cyclohexanol and cyclohexanone, key nylon intermediates. $2C_6H_{12} + O_2 \rightarrow 2C_6H_{11}OH$ (simplified).

Complete combustion

$C_6H_{12} + 9O_2 \rightarrow 6CO_2 + 6H_2O$. Combustion releases energy; controlled oxidation makes valuable chemicals.



Industrial Applications

Also in fragrances, agrochemicals, advanced materials and polymers.

Nylon

Cyclohexane-derived intermediates, including cyclohexanone.

Pharmaceuticals

Cyclopentane and cyclohexane rings in drugs and intermediates.

Solvents and synthesis

Cyclohexane as a nonpolar solvent and feedstock.







Conclusion

- Rings may be saturated or unsaturated
- Ring size and geometry control stability and reactivity
- Cyclopropane and cyclobutane are strained
- Made by cyclization, hydrogenation and other reactions
- Cycloalkanes undergo radical substitution
- Small rings undergo ring-opening addition
- Cycloalkenes undergo addition at C=C
- Essential in industry, polymers and pharmaceuticals