Foundations of Organic Chemistry.

Organic chemistry is based off the study of carbon-based compounds. focusing on structure, bonds, reactivity, & functional groups.
it's all about Carbons ability to form four stable covalent bonds leading to huge diversity.

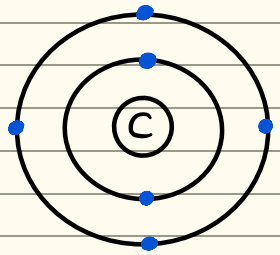
6
C
Carbon
[He] $2s^2 2p^2$

Basic Terminology:

- Hydrocarbon : Compound containing only C + H (alkanes, alkenes...)
- functional group : A group of atoms that impact specific chemical behaviour
- Homologous series : A series of compounds with the same functional group, successive members differing by CH_2
- Isomers : Same molecular formula but different structures
- Saturated / Unsaturated : Saturated = ONLY single bonds; Unsaturated = Has double + triple bond

Bonding, Hyberdization & Structure

- Carbon has 4 valence electrons → forms 4 covalent bonds



Why is Carbon so special?
→ Think of carbon as a "molecular lego block": it can link itself in chains, branches, rings, and connect to many functional groups.

- Hyberdization : the mixing of atomic orbitals to form new hybird orbitals that are used to make covalent bonds. It explains molecular geometry, bond angles, & bond strength in organic molecules.

Hyberdization table:

Hyberdization	Orbital mix	Geometry	Bond Angle	Example	Common in
sp^3	1s + 3p	Tetrahedral	~ 109.5°	CH_4	Alkanes, Alchohol
sp^2	1s + 2p	Trigonal planar	~ 120°	C_2H_4	Alkenes, Carbonyls
sp	1s + 1p	linear	~ 180°	C_2H_2	Alkynes, nitriles

Common Organic Examples:

- Methane (CH_4) → sp^3 → Tetrahedral, all single bonds
- Ethene (C_2H_4) → sp^2 → Double bond
- Ethyne (C_2H_2) → sp → Triple Bond
- Benzene (C_6H_6) → sp^2 → Delocalized e- (planar structure)

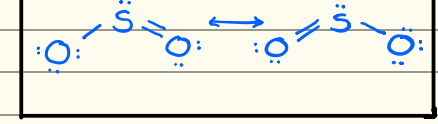
A little tip:

- In Benzene (C_6H_6), each carbon is sp^2 hyberdized, and the leftover p orbitals combine into a delocalized π system (aromatic stability)

What is Resonance?

Resonance structures are different ways of drawing the same molecules

eg (SO_2):



we use resonance structures to explain stability!

Functional groups (Summary)

A functional group is the reactive part of a molecule that determines its chemical properties & type of reactions.

Functional group	Example Compound	Formula / Structure	Suffix	General Reactions
Alkane	Ethane	C – C	-ane	Substitution
Alkene	Ethene	C = C	-ene	Addition
Alkyne	Ethyne	C ≡ C	-yne	Addition
Alcohol	Ethanol	– OH	- ol	Oxidation, Elimination
Aldehyde	Ethanal	– CHO	- al	Oxidation
Ketone	Propanone	– CO –	- one	Reduction
Carboxylic acid	Ethanoic acid	– COOH	- oic acid	Condensation
Ester	Ethyl ethanoate	– COO	- oate	Hydrolysis
Amine	Ethylamine	– NH_2	-amine	Substitution
Amide	Ethanamide	– $CONH_2$	- amide	Hydrolysis
Halogenoalkane	Bromoethane	– X (X = Cl, Br, I)	-	Nucleophilic Substitution

TIPS:

- functional groups act like a "signature" for reactions
- Similar functional groups = Similar reactivity
- When naming, always number the carbon closest to the functional group.

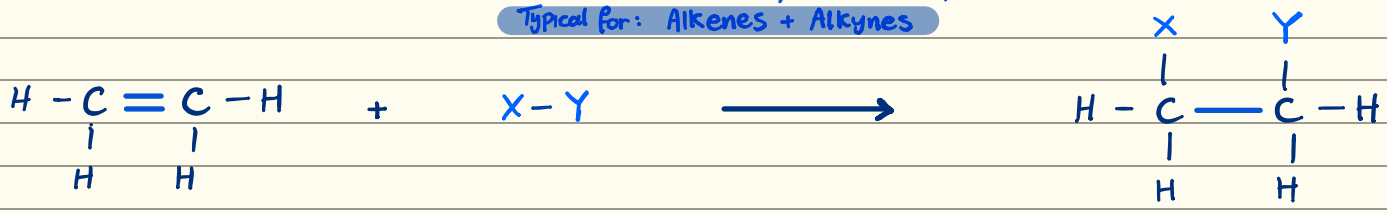
Key Reaction Types & Mechanisms

Overview: Reaction Types:

1- Addition Reactions

Two reactants combine to form one product.

Typical for: Alkenes + Alkynes



Mechanism:

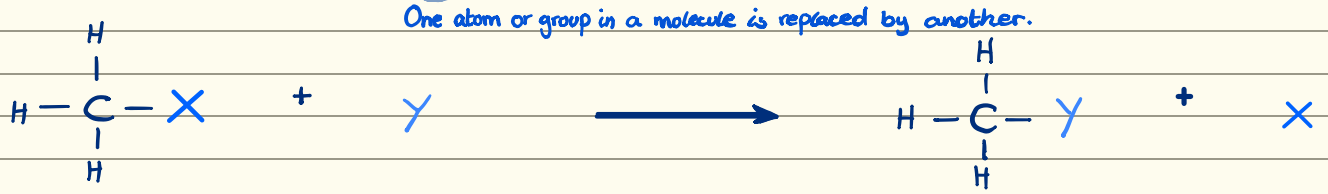
- Electrophilic addition: the double bond (rich in electrons) attracts an electrophile like Br_2 or HBr.
- The π bond breaks and two new σ bonds form.

Tip: addition reduces the number of multiple bonds

Think: "adding atoms, breaking double bonds"

2- Substitution Reactions

One atom or group in a molecule is replaced by another.



Main Types:

- Free radical: Steps:

① Initiation:
UV light breaks a halogen molecule
e.g. $Cl_2 \rightarrow 2Cl\cdot$
- Free radicals are formed

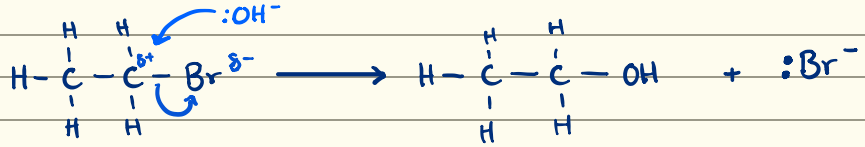
② Propagation:
Chain reaction keeps going
e.g. 1. $CH_4 + Cl\cdot \rightarrow CH_3\cdot + HCl$
2. $CH_3\cdot + Cl_2 \rightarrow CH_3Cl + Cl\cdot$
- Radicals are used and regenerated

③ Termination:
Two radicals combine to end the reaction
e.g. $Cl\cdot + CH_3\cdot \rightarrow CH_3Cl$
- No more radicals → reaction stops

- Nucleophilic

A nucleophile (electron-rich) replaces a leaving group (like a halogen) in a molecule

e.g.: CH_3Br + OH^- → CH_3OH + Br^-
haloalkane, nucleophile, leaving group



KEY POINTS
- Happens in haloalkanes
- Needs warm aqueous conditions
- Produces an alcohol, amine or nitrile (depending on nucleophile)

- Electrophilic

An electrophile (electron-poor species) replaces a hydrogen atom in an aromatic ring such as benzene.

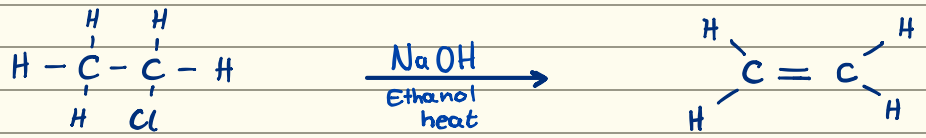
e.g.: $C_6H_6 + Br_2 \rightarrow C_6H_5Br + HBr$ → Bromination of Benzene

Conditions:
$FeBr_3$ or $AlBr_3$ Catalyst

KEY POINTS
- Electrophile = electron seeking
eg: Br^+, NO_2^+
- Reaction keeps the stability of the ring

3 - Elimination Reactions

A small molecule (like H_2O) is removed, forming a double bond



Alkyl halide → Alkene

e.g: $C_2H_5OH \rightarrow C_2H_4 + H_2O$

Ethanol → Ethene + water

3 Conditions:
- Concentrated H_2SO_4 (acid catalyst)
- Heat

KEY Idea : Remove water or hydrogen halide → get an alkene.

There are three fundamental events of Elimination reactions:
1. Proton Removal
2. Formation of C-C pi bond
3. Removal of the leaving group

affecting factors:
- → The stability of the carbocation
- → The form of the leaving group
- → Solvent type

4 - Oxidation & Reduction

Otherwise known as Redox Reactions

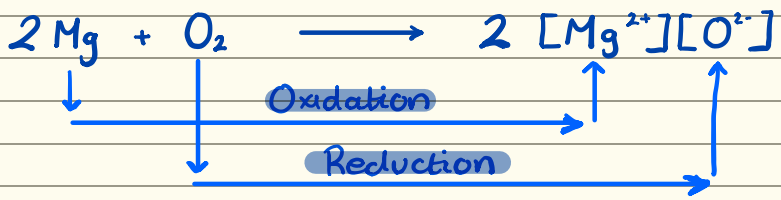
OIL Oxidation Is Loss , **RIG** Reduction Is Gain

→ Gain of Oxygen or loss of hydrogen

e.g: Ethanol → Ethanoic acid

→ Gain of hydrogen or loss of Oxygen

e.g: $C_2H_4 + H_2 \rightarrow C_2H_6$



Redox

Reflux = How you make "what happens" happen safely

→ used to heat safely without losing reactants

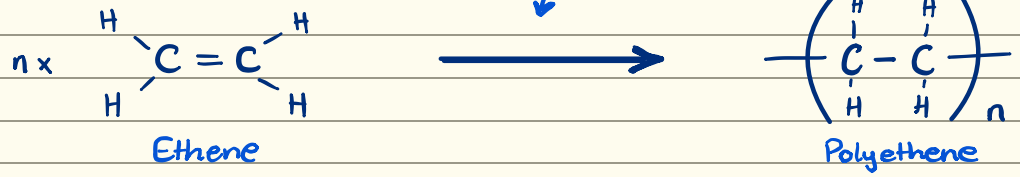
e.g: full oxidation of ethanol under reflux

5 - Polymerisation

Many small molecules (monomers) join together to form one large molecule (polymer)

1. Addition Polymerisation

double bonds open and link together

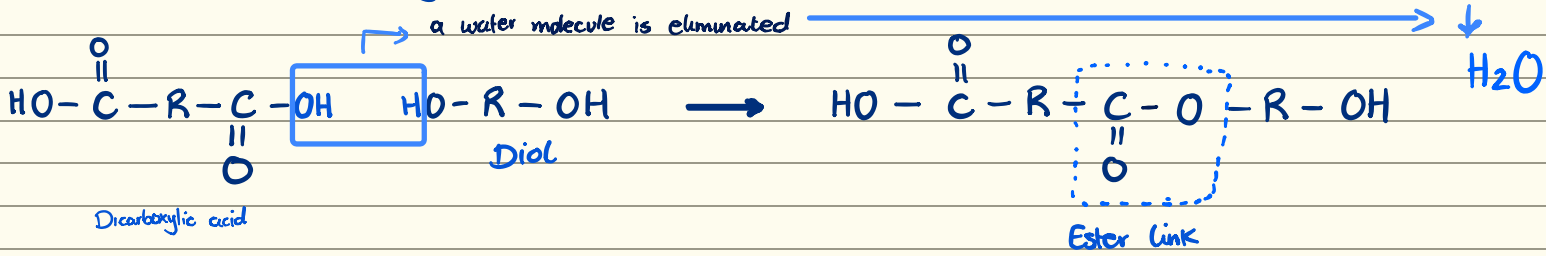


Ethene → Polyethene

Monomers : alkenes (have C=C double bonds)

2. Condensation Polymerisation

a water molecule is eliminated



Dicarboxylic acid

Diol

Ester link

The example above shows a Condensation Reaction between a Dicarboxylic acid & a Diol to form a polyester

Monomers : with two functional groups each (e.g. diol + dicarboxylic acid)
↳ they join together and lose a small molecule (like H_2O)

Q: So what ACTUALLY is different between the two polymerisations?

Feature	Addition Polymerization	Condensation Polymerization
Monomers	Alkenes (C=C)	Molecules with 2 functional groups
By-product	None	Small molecule (H_2O or HCl)
Bond formed	C-C single bonds	Ester or amide bonds
Example	Ethene - Polyethene	Diol + Dicarboxylic acid → Polyester
Atoms lost?	None	Yes (water or acid)

Addition : no loss
Condensation : joins + loses water