

Hydrocarbons

Phase 1: Alkanes & Conformations (The Foundation)

Focus: Understanding 3D structure and basic substitution.

1. Concepts to Master:

- **Conformations of Ethane:** You must learn to draw **Newman Projections**.
 - *Rule:* "Staggered" is stable (low energy). "Eclipsed" is unstable (high torsional strain).
 - *Refer to PDF:* Page 2 (diagrams) and Page 93 (Case Study on Torsional strain).
- **Preparation Methods:**
 - **Wurtz Reaction:** Doubles the carbon chain (e.g., Methyl chloride → Ethane).
Note: Doesn't work well for odd carbons.
 - **Decarboxylation (Soda-lime):** Reduces carbon chain by one.
- **Chemical Properties:**
 - **Free Radical Halogenation:** You **must** memorize the 3 steps: Initiation, Propagation, Termination. (Refer to PDF Page 1 Section i).

2. Critical Questions from your PDF to Solve:

- **Page 91, Q10:** Intermediate radicals (Tertiary > Secondary > Primary stability).
 - **Page 92, Q3:** Drawing Newman projections.
 - **Page 93, Case Based Q1:** Understanding Torsional strain.
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Phase 2: Alkenes (The Reaction Hub)

Focus: Addition reactions. This is where most students lose marks.

1. Concepts to Master:

- **Geometrical Isomerism:** Cis (same side) vs. Trans (opposite side).
 - *Fact:* Trans has higher melting point (better packing). Cis has higher boiling point (more polar).
- **Markovnikov vs. Anti-Markovnikov (Peroxide Effect):**
 - *Rule:* "Rich get richer." The H goes to the carbon with more H's already.
 - *Exception:* **HBr + Peroxide** (Only HBr!) does the opposite.
- **Ozonolysis:** This is the **most frequent question** in your PDF.
 - *Trick:* Break the double bond and put an 'O' on both broken ends.
 - *Reverse Trick:* Remove the O's from the products and join them with a double bond to find the reactant.

2. Critical Questions from your PDF to Solve:

- **Page 86:** Mechanism of Markovnikov addition (Practice drawing the carbocation).
 - **Page 92, Q1:** Cis/Trans boiling point logic.
 - **Page 92, Q4:** Reverse Ozonolysis (Finding Alkene 'A').
 - **Page 94, Q1 (ii):** Distinguishing using Bromine water (Test for unsaturation).
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Phase 3: Alkynes (Acidity & Cycles)

Focus: Distinguishing tests.

1. Concepts to Master:

- **Acidity:** Terminal alkynes (triple bond at the end, like $CH \equiv CH$) are acidic because of **sp hybridization**.
 - *Test:* They react with Sodium metal or Ammoniacal Silver Nitrate (Tollen's reagent) to give a precipitate. Alkenes/Alkanes do not do this.
- **Cyclic Polymerization:**
 - Red hot iron tube + Ethyne \rightarrow **Benzene**. (Crucial conversion).

2. Critical Questions from your PDF to Solve:

- **Page 91, Q11 (Assertion/Reason):** Hybridization and acidity.
 - **Page 94, Q2 (iii):** Chemical test to distinguish Ethene and Ethyne.
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Phase 4: Aromatic Hydrocarbons (Benzene)

Focus: Resonance and "The Rules".

1. Concepts to Master:

- **Huckel's Rule:** To be aromatic, a ring must be: Cyclic, Planar, Conjugated, and have $(4n + 2)\pi$ **electrons** (e.g., 2, 6, 10, 14 electrons).
- **Electrophilic Substitution:** Benzene does *not* like addition (it breaks stability). It likes substitution.
 - *Mechanism:* Generation of Electrophile \rightarrow Carbocation formation \rightarrow Proton removal.
- **Directing Groups:**
 - **Ortho/Para directors (Activators):** $-CH_3$, $-OH$, $-Cl$ (push electrons in).
 - **Meta directors (Deactivators):** $-NO_2$, $-COOH$ (pull electrons out).

2. Critical Questions from your PDF to Solve:

- **Page 88:** Conditions of Aromaticity.
 - **Page 92, Q1 (a):** Rate of nitration (Toluene > Benzene > Nitrobenzene).
 - **Page 94, Q1 (iii):** Conversions (Ethyne \rightarrow Benzene \rightarrow Acetophenone).
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Phase 1: ALKANES.

Part 1: Preparation of Alkanes (How to make them)

There are two main reactions you **must** memorize from Page 84 of your PDF.

1. Wurtz Reaction (The "Doubler")

- **Concept:** If you have an alkyl halide (like Methyl Bromide, 1 carbon), and you react it with Sodium (Na) in dry ether, it doubles the chain.
- **Reaction:** $CH_3Br + 2Na + BrCH_3 \rightarrow CH_3 - CH_3$ (Ethane) $+ 2NaBr$
- **Important Note:** This is great for making alkanes with **even** numbers of carbons (2, 4, 6). It is **bad** for odd numbers (3, 5) because you get a messy mixture of products.

→ PDF Application:

- **Page 92, Q4(b):** asks about Wurtz Reaction.
 - *Answer:* It is used to prepare higher alkanes (doubling the number of carbons).
- **Page 91, Q1:** "Which hydrocarbon has highest boiling point?" (Indirectly related to size, which Wurtz increases).
- **Page 3 (2nd PDF section), Q8:** "Why is Wurtz reaction not preferred for odd number of carbon atoms?"
 - *Answer:* Because if you use two different alkyl halides (e.g., to make 3 carbons), you will get a mixture of 2-carbon, 3-carbon, and 4-carbon alkanes, which are hard to separate.

2. Decarboxylation (The "Step Down")

- **Concept:** You start with a Sodium salt of a carboxylic acid (like Sodium Acetate). You heat it with **Soda-lime** ($NaOH$ and CaO).
- **Result:** CO_2 is removed, and you get an alkane with **one less carbon** than you started with.
- **Reaction:** $CH_3COONa + NaOH \xrightarrow{CaO, \Delta} CH_4$ (Methane) $+ Na_2CO_3$

→ PDF Application:

- **Page 92, Q5:** "Sodium salt of which acid is needed for the preparation of methane?"
 - *Answer:* Sodium Acetate (CH_3COONa). (Since Acetate has 2 carbons, removing one gives Methane with 1 carbon).
 - **Page 92, Q2(a):** "Benzoic acid to benzene" (This is also decarboxylation).
 - *Answer:* React Benzoic acid with $NaOH$ to get Sodium Benzoate, then heat with Soda-lime to remove the COO group and get Benzene.
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Part 2: Physical Properties (Boiling Point)

- **Concept 1 (Size):** Bigger molecule = Higher Boiling Point (more Van der Waals forces).
- **Concept 2 (Shape):**
 - **Straight chain** (like a long spaghetti) = High Boiling Point (lots of surface area to stick to neighbors).
 - **Branched chain** (like a ball) = Low Boiling Point (less surface area, they roll off each other).

→ PDF Application:

- **Page 90, Q1:** "Which... has highest boiling point?"
 - Options: Isobutane, Butane, Neopentane, n-Hexane.
 - **Answer: (d) n-Hexane.**
 - **Reasoning:** Hexane has 6 carbons (biggest mass). Butane/Isobutane have 4. Neopentane has 5. Bigger mass wins first.
 - **Page 91, Q12 (Assertion/Reason):**
 - Assertion: BP increases with molecular mass.
 - Reason: Van der Waals forces increase with molecular mass.
 - **Answer: (a) Both true and correct explanation.**
 - **Page 3 (2nd PDF), Q2:** "Arrange n-pentane, iso-pentane and neo-pentane in decreasing order of boiling points."
 - **Answer:** n-pentane > iso-pentane > neo-pentane.
 - **Reasoning:** All are C_5H_{12} . n-pentane is straight (most surface area). Neo-pentane is a ball (least surface area).
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Part 3: Conformations (The 3D Shape of Ethane)

This is the most technical part of Phase 1. Refer to **Page 85** and **Page 93** of your PDF.

- **The Concept:** Single bonds ($C - C$) can rotate like a wheel. This creates different shapes called **Conformations**.
- **The Two Main Shapes (Newman Projections):**
 1. **Staggered:** The Hydrogens on the front carbon are *between* the Hydrogens of the back carbon. (Looks like a star).
 - **Status: Stable.** Low Energy. The electrons are far apart (Minimum repulsion).
 2. **Eclipsed:** The front Hydrogens cover the back Hydrogens directly.
 - **Status: Unstable.** High Energy. The electrons repel each other.
- **Torsional Strain:** The repulsion felt in the "Eclipsed" form.

→ PDF Application:

- **Page 92, Q3:** "Draw Newman projections... Which is more stable and why?"

- *Answer:* You must draw the circle diagrams from Page 85. **Staggered** is more stable because the electron clouds of C-H bonds are far apart, causing minimum repulsion (least torsional strain).
 - **Page 93, Case Based Q1 (c):** "Which conformation of ethane has less torsional strain and why?"
 - *Answer:* Staggered conformation has the least torsional strain because the Hydrogen atoms are at the maximum distance apart (dihedral angle 60°).
 - **Page 1 (2nd PDF), Q1:** "Which conformation of n-butane is most stable?"
 - *Answer:* **(c) Staggered** (specifically called "Anti" in butane, where the big groups are furthest apart).
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Part 4: Chemical Properties (Free Radical Halogenation)

- **Concept:** Alkanes are lazy (inert). But with UV light ($h\nu$) and Chlorine (Cl_2), they react.
- **Mechanism (Free Radical Substitution):**
 1. **Initiation:** Sunlight breaks $Cl - Cl$ into two Cl^\bullet dots (radicals).
 2. **Propagation:** The Cl^\bullet steals an H from the alkane, making an alkyl radical. This chain reaction continues.
 3. **Termination:** Two radicals hit each other and stop the chain.
- **Stability of Radicals:** Tertiary (3°) > Secondary (2°) > Primary (1°).

→ PDF Application:

- **Page 91, Q9:** "Chlorination of alkanes in diffused sunlight is an example of..."
 - *Answer:* **(b) Free radical substitution reaction.**
 - **Page 91, Q15 (Assertion/Reason):** "Addition of HBr to propene in presence of peroxide..." (This links Alkane radical stability to Alkenes).
 - *Answer:* **(a).** It follows free radical mechanism.
 - **Page 4 (2nd PDF), Q9:** "Relative reactivity of 1° , 2° , 3° hydrogens..."
 - *Teacher Note:* This asks you to calculate percentages.
 - *Formula:* (Number of H atoms \times Reactivity) / Total Reactivity.
 - *Example:* 2-methylbutane has different types of Hydrogens. 3° hydrogens are the most reactive (Reactivity rate 5.0).
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Summary Checklist for Phase 1 (Alkanes)

If you can answer these 4 questions, you have mastered Phase 1:

1. **How do you turn Methyl Bromide into Ethane?** (Ans: Wurtz Reaction with Na).
2. **Why does n-Pentane boil at a higher temperature than Neo-pentane?** (Ans: Surface area/Van der Waals forces).
3. **Draw Staggered Ethane.** (Ans: The "Star" Newman projection).
4. **What is the first step of Chlorination?** (Ans: Initiation/Homolysis of Cl_2).

Phase 2: ALKENES is the most important part of Hydrocarbons because it has the most reaction rules. If you master this, you master 50% of the chapter.

Let's break it down into **4 Key Concepts**.

Concept 1: Geometrical Isomerism (Cis vs. Trans)

Alkenes have a double bond ($C = C$). Unlike single bonds, double bonds **cannot rotate**. They are locked in place. This creates two shapes:

1. **Cis-isomer**: The identical groups are on the **same side**.
 - *Property*: It is **Polar** (unsymmetrical pulling of electrons).
 - *Result*: Higher **Boiling Point** (molecules stick together like magnets).
2. **Trans-isomer**: The identical groups are on **opposite sides**.
 - *Property*: It is **Symmetrical**.
 - *Result*: Higher **Melting Point** (molecules pack neatly into a solid crystal, like stacking bricks).

→ **PDF Application**:

- **Page 92, Q1**: "Draw cis and trans... Which has higher boiling point and why?"
 - *Answer*: **Cis-isomer** has higher boiling point because it has a higher dipole moment (it is more polar).
 - **Page 93, Case Based Q1 (OR part)**: "Why is trans but-2-ene has higher melting point...?"
 - *Answer*: **Trans-isomer** is symmetrical and packs better in the crystal lattice. (Think: Tetris blocks fitting perfectly).
 - **Page 91, Q14 (Assertion/Reason)**: Boiling point of Cis > Trans?
 - *Answer*: **(c) A is correct, R is incorrect**. (Wait, looking at the answer key in your PDF, it says (c). Let's check. Assertion: BP of Cis > Trans (True). Reason: Trans is polar (False, Trans is non-polar). So yes, Assertion is True, Reason is False).
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Concept 2: Preparation (The "Elimination")

To make a double bond, you have to **remove** things from a single bond. This is called β -**Elimination**.

- **From Alcohols (Dehydration)**: Use Concentrated H_2SO_4 and heat. It removes water ($H - OH$).
 - *Reaction*: $C_2H_5OH \xrightarrow{Conc.H_2SO_4, 443K} CH_2 = CH_2 + H_2O$
- **From Alkyl Halides (Dehydrohalogenation)**: Use **Alcoholic KOH** (not aqueous!). It removes acid ($H - X$).

- **Saytzeff Rule (The "Poor get Poorer" Rule):** When removing Hydrogen to make a double bond, remove the H from the carbon that *already has fewer Hydrogens*. This makes the most substituted (stable) alkene.

→ PDF Application:

- **Page 94, Q1(i):** "Write chemical equation for lab preparation of ethene."
 - *Answer:* Ethanol + Conc H_2SO_4 at 443K → Ethene.
- **Page 94, Q2(ii):** "Complete the equation: $CH_3CH(Cl) - CH_2 - CH_3 \xrightarrow{Alc.KOH}$ "
 - *Answer:* This is elimination. You have two choices for removing H.
 - Option A: Remove from the right (gives But-2-ene). **Major Product** (Saytzeff rule).
 - Option B: Remove from the left (gives But-1-ene). Minor Product.
 - *Final Equation:* → $CH_3 - CH = CH - CH_3$ (Major).

Concept 3: Markovnikov vs. Anti-Markovnikov (The "Addition" Rules)

This is the **#1 most asked concept**. When you add something like $H - Br$ to a double bond, the bond opens up. But where does the H go?

- **Rule A: Markovnikov's Rule (The Default):** "Rich get Richer."
 - The H goes to the carbon that already has **more** Hydrogens.
 - The Br goes to the carbon with **fewer** Hydrogens.
 - *Mechanism:* Forms a stable **Carbocation** intermediate.
- **Rule B: Anti-Markovnikov / Peroxide Effect (The Exception):**
 - **Condition:** Only works with **HBr + Organic Peroxide**.
 - *Result:* Opposite. H goes to the carbon with fewer H's.
 - *Mechanism:* Forms a **Free Radical** intermediate.

→ PDF Application:

- **Page 86:** "Mechanism of Addition according to Markovnikov Rule".
 - *Study Tip:* Memorize that 3° Carbocation > 2° > 1° . The reaction goes through the most stable path.
- **Page 93, Q5:** "Addition of HBr to propene yields 2-bromopropane, while in presence of benzoyl peroxide... yields 1-bromopropane."
 - *Answer:* Explain both rules.
 - Case 1: Markovnikov addition (Electrophilic addition) → 2-bromopropane.
 - Case 2: Peroxide Effect (Free Radical addition) → 1-bromopropane.
- **Page 91, Q15:** Assertion/Reason regarding Peroxide effect.
 - *Answer:* (a) Both true. Peroxide follows free radical mechanism.
- **Second PDF, Q34:** "Why is peroxide effect not seen with HCl or HI?"

- **Answer:** The $H - Cl$ bond is too strong to break by radicals. The $H - I$ bond is too weak (Iodine radicals combine with themselves to form I_2 instead of reacting). Only $H - Br$ is "just right".

Concept 4: Ozonolysis (The "Scissors")

This is a specific reaction used to locate double bonds.

- **Reagents:** O_3 (Ozone) followed by Zn/H_2O .
- **The Trick:** Take an eraser, erase the double bond ($=$), and draw an $=O$ on both cut ends.
 - Example: $CH_2 = CH_2 \rightarrow CH_2 = O + O = CH_2$ (Methanal + Methanal).
- **The Reverse Trick:** If the question gives you the products and asks for the alkene, remove the oxygen atoms and double-bond the carbons together.

→ **PDF Application:**

- **Page 92, Q4:** "Alkene 'A' on ozonolysis gives ethanal and pentan-3-one."
 - **Logic:**
 - Product 1: Ethanal ($CH_3 - CH = O$)
 - Product 2: Pentan-3-one ($CH_3 - CH_2 - C(=O) - CH_2 - CH_3$)
 - **Action:** Remove the O's and connect them.
 - **Answer:** $CH_3 - CH = C(CH_2CH_3)_2$. Name: **3-Ethylpent-2-ene**.
- **Page 90, Q3:** "Ozonolysis of benzene... gives?"
 - **Answer:** Benzene has 3 double bonds. Breaking them all gives 3 molecules of **Glyoxal** ($CHO - CHO$).

Concept 5: Distinguishing Tests

How do you prove something is an Alkene (Unsaturated) vs. an Alkane (Saturated)?

1. **Bromine Water Test:**
 - Add reddish-brown Bromine water (Br_2/CCl_4).
 - **Alkene:** Decolorizes it (Brown \rightarrow Colorless).
 - **Alkane:** No change.
2. **Baeyer's Reagent:**
 - Add Cold Dilute Alkaline $KMnO_4$ (Purple).
 - **Alkene:** Decolorizes it (Purple \rightarrow Brown ppt of MnO_2).
 - **Alkane:** No change.

→ **PDF Application:**

- **Page 94, Q1 (ii)(a):** "When ethene is passed through Br_2 water."

- *Answer:* The reddish-brown colour is discharged (decolorized). 1,2-Dibromoethane is formed.
 - **Page 94, Q2 (iii)(a):** "Distinguish Ethene and Ethyne."
 - *Correction:* This question asks Ethene vs Ethyne. Both decolorise Bromine water. To distinguish them, use Ammoniacal $AgNO_3$ (Tollen's). Ethyne gives white ppt, Ethene does not.
 - **Page 94, Q2 (iii)(b):** "Distinguish Ethene and Ethane."
 - *Answer:* Add Bromine water. Ethene decolorizes it; Ethane does not.
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Summary Checklist for Phase 2 (Alkenes)

Can you answer these in your head?

1. **Which has a higher melting point: Cis-2-butene or Trans-2-butene?** (Ans: Trans).
2. **Propene + HBr \rightarrow ?** (Ans: 2-Bromopropane via Markovnikov).
3. **Propene + HBr + Peroxide \rightarrow ?** (Ans: 1-Bromopropane via Anti-Markovnikov).
4. **Reaction to convert Ethanol to Ethene?** (Ans: Conc. H_2SO_4 , 443K).
5. **What does Ozonolysis do?** (Ans: Cuts the double bond, adds Oxygen).

Phase 3: ALKYNES ($C \equiv C$) is shorter than Alkenes, but it contains **two specific concepts** that examiners love because students often get them confused.

Here is the breakdown.

Concept 1: Acidity of Alkynes (The "s-Character" Rule)

This is the most likely question to appear in reasoning (Assertion/Reason) or 1-mark sections.

- **The Rule:** A Hydrogen atom attached to a **Triple Bonded Carbon** is **Acidic**. It can pop off as H^+ .
 - *Why?* Hybridization.
 - Alkane ($C - C$): sp^3 (25% s-character). Big and fluffy. Holds electrons loosely.
 - Alkene ($C = C$): sp^2 (33% s-character).
 - Alkyne ($C \equiv C$): sp (**50% s-character**). Small and tight. The carbon loves electrons (electronegative) so much it pulls them away from Hydrogen, leaving the H "loose" and acidic.
- **The Order:** Ethyne ($CH \equiv CH$) > Ethene ($CH_2 = CH_2$) > Ethane ($CH_3 - CH_3$).
- **Crucial Condition:** This only works for **Terminal Alkynes** (where the triple bond is at the end of the chain, e.g., Propyne). Internal alkynes (e.g., But-2-yne) have no H on the triple bond, so they are **not** acidic.

→ **PDF Application:**

- **Page 91, Q11 (Assertion/Reason):** "Acetylene is acidic in nature." / "In Acetylene carbon is sp hybridised."
 - *Answer:* **(a) Both true and correct explanation.** High s-character = High electronegativity = Acidic proton.
 - **Page 94, Q2(i)(a):** "Ethyne is more acidic than ethene."
 - *Answer:* Ethyne carbon is sp hybridized (50% s-character), making it more electronegative than Ethene's sp^2 carbon (33% s-character).
 - **Page 94, Q2(iii)(a):** "Chemical test to distinguish Ethene and Ethyne."
 - *Answer:* **Ammoniacal Silver Nitrate ($AgNO_3$) Test.**
 - Ethyne (Acidic H) + $AgNO_3 \rightarrow$ **White Precipitate** (Silver Acetylide).
 - Ethene (No Acidic H) \rightarrow **No Reaction.**
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Concept 2: Hydration (Adding Water / Tautomerism)

This is the "trickiest" reaction mechanism in this chapter.

- **Reagents:** Water (H_2O) + Dilute H_2SO_4 + $HgSO_4$ (Mercuric Sulphate).

- **The Mechanism (The "Switch"):**
 1. Water adds to the triple bond (Markovnikov rule applies).
 2. You get an intermediate called an **Enol** (Vinyl Alcohol: $CH_2 = CH - OH$). **This is unstable.**
 3. **Tautomerism:** The H jumps from the O to the CH_2 , and the double bond moves to the O .
 4. **Result:** You get a **Carbonyl compound** (Aldehyde or Ketone).
- **Specific Reactions to Memorize:**
 - Ethyne \rightarrow **Ethanal** (Acetaldehyde).
 - Propyne \rightarrow **Propanone** (Acetone).

\rightarrow **PDF Application:**

- **Page 92, Q2(c):** "Convert Ethyne to Acetaldehyde."
 - *Answer:* React Ethyne with H_2O , $HgSO_4/H_2SO_4$ at 333K.
 - **Page 88, Section iv:** Review the diagram showing "Isomerisation" (Tautomerism).
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Concept 3: Cyclic Polymerization (The "Iron Tube")

This is the bridge between Aliphatic (straight chain) and Aromatic (ring) chemistry.

- **The Reaction:** Pass Ethyne through a **Red Hot Iron Tube** at 873K.
- **Result:** Three Ethyne molecules join hands to form a ring.
 - $3 \times C_2H_2 \rightarrow C_6H_6$ (**Benzene**).

\rightarrow **PDF Application:**

- **Page 94, Q1(iii)(a):** "Convert Ethyne to Benzene."
 - *Answer:* Red hot iron tube at 873K.
 - **Page 88:** Section "Preparation of Benzene".
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Concept 4: Preparation from Calcium Carbide

NCERT explicitly mentions this industrial method.

- **Steps:**
 1. Limestone ($CaCO_3$) \rightarrow Lime (CaO).
 2. Lime + Coke (C) \rightarrow Calcium Carbide (CaC_2).
 3. **Calcium Carbide + Water \rightarrow Ethyne (C_2H_2) + Slaked Lime.**
- **Reaction:** $CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2$.

\rightarrow **PDF Application:**

- **Page 87, Preparation i:** "From calcium carbide".
 - *Note:* Questions often ask "What happens when Calcium Carbide is hydrolyzed?" The answer is "Ethyne gas is evolved."
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Phase 3 Summary Checklist

Can you answer these?

2. **Which is acidic: But-1-yne or But-2-yne?** (Ans: But-1-yne, because it has a terminal H).
3. **What reagent distinguishes Ethyne from Ethene?** (Ans: Ammoniacal $AgNO_3$ or Ammoniacal Cu_2Cl_2).
4. **Ethyne + Red Hot Iron Tube = ?** (Ans: Benzene).
5. **Ethyne + Water + $HgSO_4/H_2SO_4$ = ?** (Ans: Ethanal/Acetaldehyde).
6. **Ethyne + 2 Br_2 (in CCl_4) = ?** (Ans: 1,1,2,2-Tetrabromoethane. Note: It consumes *two* molecules of bromine).

Final Boss: Aromatic Hydrocarbons (Benzene).

This section usually carries the most marks in long-answer questions. The good news? It follows a very strict set of rules. Unlike Alkenes where you have to look for "Markovnikov," here you just have to follow the "Traffic Police" (Directive Influence).

Here are the **4 Pillars of Benzene**.

Pillar 1: Aromaticity (The "VIP Club" Rules)

Not every ring is Aromatic. To be in the "Benzene Club," a molecule must pass **Huckel's Rule**.

- **The 3 Conditions:**
 1. **Cyclic:** Must be a ring.
 2. **Planar:** Must be flat (sp^2 hybridized).
 3. **Huckel's Rule:** Must have $(4n + 2)\pi$ **electrons**.
 - If $n = 0 \rightarrow 2$ electrons.
 - If $n = 1 \rightarrow 6$ electrons (Benzene).
 - If $n = 2 \rightarrow 10$ electrons (Naphthalene).
- **Why care?** Aromatic compounds are super stable. They **do not** like Addition reactions (because addition breaks the ring's stability). They only like **Substitution**.

→ **PDF Application:**

- **Page 92, Q3 (a) & (c):** "How Huckel's rule is applied? / Conditions for aromaticity."
 - *Answer:* Write the 3 conditions above.
 - **Page 92, Q3 (b):** "Cyclopentadienyl anion vs Cyclopentadiene."
 - *Answer:* The Anion has 6π electrons (4 from double bonds + 2 from the negative charge) = **Aromatic**. The neutral diene has 4π electrons (only double bonds) and an sp^3 carbon = **Not Aromatic**.
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Pillar 2: Preparation of Benzene

There are 3 ways to make Benzene in the lab.

1. **Cyclic Polymerization:** (We did this in Phase 3). Red hot iron tube + Ethyne.
2. **Decarboxylation:** Sodium Benzoate + Soda-lime ($NaOH/CaO$) \rightarrow Benzene.
3. **Reduction of Phenol: (Memorize this!)**
 - Phenol (C_6H_5OH) + **Zinc Dust** (Zn) \rightarrow Benzene (C_6H_6) + ZnO .
 - *Concept:* Zinc steals the Oxygen.

→ **PDF Application:**

- **Page 91, Q4:** "Phenol when distilled with zinc dust gives:"
 - **Answer: (b) Benzene.**
 - **Page 92, Q2 (a):** "Convert Benzoic acid to benzene."
 - **Answer:** Step 1: NaOH (make salt). Step 2: Soda-lime/Heat (Decarboxylation).
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Pillar 3: Electrophilic Substitution (The "Big 5" Reactions)

Benzene is rich in electrons (negative cloud). It invites **Electrophiles** (positive charge lovers, E^+) to swap places with a Hydrogen.

You **must** know the Reagent and the Electrophile for these 5 reactions:

1. **Halogenation:** $Cl_2 + \text{Anhydrous } AlCl_3 \rightarrow \text{Chlorobenzene}$.
 - **Electrophile:** Cl^+ (Chloronium ion).
2. **Nitration:** $\text{Conc. } HNO_3 + \text{Conc. } H_2SO_4 \rightarrow \text{Nitrobenzene}$.
 - **Electrophile:** NO_2^+ (Nitronium ion).
3. **Sulphonation:** Fuming Sulphuric Acid ($H_2SO_4 + SO_3$) \rightarrow **Benzenesulphonic acid**.
 - **Electrophile:** SO_3 (Neutral electrophile).
4. **Friedel-Crafts Alkylation:** $CH_3Cl + \text{Anhydrous } AlCl_3 \rightarrow \text{Toluene}$ (Methylbenzene).
 - **Electrophile:** CH_3^+ (Methyl carbocation).
5. **Friedel-Crafts Acylation:** $CH_3COCl + \text{Anhydrous } AlCl_3 \rightarrow \text{Acetophenone}$.
 - **Electrophile:** CH_3CO^+ (Acylium ion).

Note: Anhydrous $AlCl_3$ is the catalyst. It generates the electrophile.

→ **PDF Application:**

- **Page 91, Q6:** "The catalyst used in Friedel-Crafts reaction is..."
 - **Answer: (b) Anhydrous Aluminium Chloride.**
 - **Page 93, Case Based Q2 (c):** "Describe the mechanism of nitration of benzene."
 - **Answer:** You must write 3 steps:
 1. Generation of NO_2^+ .
 2. Attack of NO_2^+ on benzene (forming sigma complex).
 3. Removal of Proton (H^+) to restore aromaticity.
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Pillar 4: Directive Influence (The "Traffic Police")

If Benzene already has a group attached (like $-CH_3$ or $-NO_2$), where does the *next* group go? The existing group acts as a Traffic Policeman.

- **Type A: Ortho/Para Directors (The "Givers"):**
 - They push electrons *into* the ring (+R effect or Hyperconjugation).
 - *Examples:* $-CH_3$, $-OH$, $-NH_2$, $-Cl$, $-Br$.
 - *Result:* Incoming group goes to position 2 (Ortho) or 4 (Para).
- **Type B: Meta Directors (The "Takers"):**
 - They pull electrons *out* of the ring (-R effect).
 - *Examples:* $-NO_2$, $-COOH$, $-CHO$, $-CN$.
 - *Result:* Incoming group goes to position 3 (Meta).

→ PDF Application:

- **Page 91, Q8:** "Which... is an example of meta directing group?"
 - *Answer: (a) -CHO* (Aldehyde pulls electrons).
 - **Page 92, Q1 (a):** "Out of benzene, m-dinitrobenzene and toluene which will undergo nitration most easily?"
 - *Answer: Toluene.*
 - *Reason:* The Methyl group (CH_3) is an electron donor. It activates the ring, making it richer in electrons. Nitro groups (in dinitrobenzene) withdraw electrons, making the ring poor and unreactive.
 - **Page 94, Q2 (i)(b):** "Nitration of Toluene give ortho and para nitro toluene but not m-Nitro toluene."
 - *Reason:* Because the $-CH_3$ group is an Ortho/Para director due to Hyperconjugation (+I effect).
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Final Summary Checklist for Phase 4

Can you answer these?

1. **What catalyst is needed for Friedel-Crafts?** (Ans: Anhydrous $AlCl_3$).
 2. **Does Nitrobenzene direct the next group to Ortho, Para, or Meta?** (Ans: Meta, because NO_2 is a "Taker").
 3. **Does Phenol direct the next group to Ortho, Para, or Meta?** (Ans: Ortho/Para, because OH is a "Giver").
 4. **Convert Phenol to Benzene.** (Ans: Heat with Zinc dust).
 5. **Benzene + CH_3Cl + Anhyd. $AlCl_3$ = ?** (Ans: Toluene/Methylbenzene).
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Master Strategy for Your Exam

You have now covered all 4 Phases. Since you want full marks, here is your plan for the remaining days:

1. **Hour 1 (Mechanisms):** Write down the "Free Radical Halogenation" (Alkanes) and "Nitration of Benzene" (Arenes) mechanisms 5 times each. These are the most common 3-mark questions.
2. **Hour 2 (Conversions):** Go through **Page 94, Q1 (iii)**. Practice converting Ethyne \rightarrow Benzene \rightarrow Acetophenone.
3. **Hour 3 (Reasoning):** Read all the **Assertion/Reason** questions on **Page 91**. These are tricky but we have covered the logic for all of them.

If you get stuck on any specific question in the PDF, type the Question Number here, and I will explain the logic instantly. You are ready!