Hydrocarbons - Complete Exercise Solution

Multiple Choice Questions (MCQs)

i. Dehydration of ethyl alcohol with conc. H_2SO_4 results in:

Answer: D) Ethene

Explanation: When ethyl alcohol (C_2H_5OH) is heated with conc. H_2SO_4 at 170°C, a water molecule is removed (dehydration), forming a double bond:

$CH_3CH_2OH \rightarrow CH_2=CH_2 + H_2O$

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ii. Which reagent distinguishes ethene from acetylene?

Answer: B) Bromine solution

Explanation: Both ethene and acetylene decolourise bromine solution, but acetylene requires **two moles** of Br_2 (two addition steps) while ethene requires only **one mole**. This quantitative difference distinguishes them. Alkaline $KMnO_4$ and CCl_4 do not differentiate between the two.

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iii. Final product X in: $HC\equiv CH + 2HBr \rightarrow X$

Answer: B) $CH_3–CHBr_2$

Explanation: The reaction occurs in two steps:

- Step 1: $HC\equiv CH + HBr \rightarrow CH_2=CHBr$ (vinyl bromide)
- Step 2: $CH_2=CHBr + HBr \rightarrow CH_3–CHBr_2$ (1,1-dibromoethane)

Final product X = $CH_3–CHBr_2$

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iv. Which decolourises Br_2 water?

Answer: B) Ethene

Explanation: Ethene ($CH_2=CH_2$) is an unsaturated hydrocarbon. It reacts with bromine water by addition across the double bond, decolourising the red-brown Br_2 water:

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v. Ethene reacts with HBr to form:

Answer: A) $CH_3–CH_2–Br$

Explanation: HBr adds across the double bond of ethene in an addition reaction:

$CH_2=CH_2 + HBr \rightarrow CH_3–CH_2–Br$ (bromoethane / ethyl bromide)

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vi. Which statement is NOT true for alkynes?

Answer: B) They burn to form CO_2

Explanation: This statement is **incomplete**, hence not fully true. Alkynes burn in excess oxygen to form **both CO_2 and H_2O**, not CO_2 alone:

$2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$

Options A, C, and D are all correct statements about alkynes.

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vii. General formula for alkenes is:

Answer: D) C_nH_{2n}

Explanation:

- Alkanes: C_nH_{2n+2}
- Alkenes: C_nH_{2n} ✓
- Alkynes: C_nH_{2n-2}

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viii. All members of alkane series have:

Answer: A) All single bonds

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ix. Baeyer's reagent is:

Answer: B) Alkaline $KMnO_4$

Explanation: Baeyer's reagent is cold, dilute, **alkaline potassium permanganate ($KMnO_4$)**. It is purple/violet in colour and is used to test for unsaturation. It must be alkaline and cold — acidic or hot $KMnO_4$ gives different products and is not Baeyer's reagent.

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x. Which gives carboxylic acid with alkaline $KMnO_4$?

Answer: C) Acetylene

Explanation: When acetylene (HC≡CH) is oxidised with alkaline $KMnO_4$, formic acid (HCOOH) is produced:

$HC{\equiv}CH + [O] + H_2O \rightarrow HCOOH$ (formic acid)

Ethane and methane (saturated) do not react. Ethene gives a diol (ethylene glycol), not a carboxylic acid, with cold alkaline $KMnO_4$.

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xi. Which gives a mixture of hydrocarbons on halogenation?

Answer: C) Ethane

Explanation: Alkanes undergo substitution reactions with halogens in sunlight. Since multiple H atoms can be replaced one by one, a mixture of mono-, di-, tri-substituted products is formed:

$C_2H_6 + Cl_2 \rightarrow C_2H_5Cl + C_2H_4Cl_2 + C_2H_3Cl_3 + \ldots$ (mixture)

Ethene and ethyne undergo clean addition reactions, producing a single defined product each step.

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xii. Baeyer's test shows the presence of:

Answer: B) A double bond

Explanation: Baeyer's test was originally designed to detect C=C double bonds (unsaturation) in alkenes. The alkaline $KMnO_4$ oxidises the double bond and is decolourised. In the Pakistani 10th grade curriculum, this test is specifically associated with the presence of a double bond.

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xiii. Which one is the least reactive?

Answer: D) Ethane

Explanation: Ethane is a saturated alkane with only strong C–C and C–H single bonds. It has no π bond and no reactive site. Among ethyne, ethene, propene (all unsaturated), and ethane, ethane is the least reactive as it only undergoes slow substitution reactions under special conditions (sunlight).

xiv. Ethane reacts with chlorine in the presence of:

Answer: C) Sunlight

Explanation: Alkanes undergo substitution (halogenation) only when energy is provided to break the Cl–Cl bond and generate chlorine free radicals. Sunlight (UV light) provides this energy. The reaction does not occur in the dark or with just water/ether.

$C_2H_6 + Cl_2 \rightarrow C_2H_5Cl + HCl$ (in sunlight)

Short Answer Questions

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i. Why is alkane inert in nature?

Alkanes contain only strong, non-polar C–C and C–H single bonds (sigma bonds). They have no π bonds and no reactive sites to attract electrophiles or nucleophiles. Because of the absence of any active functional group or multiple bond, alkanes do not readily participate in chemical reactions. This is why they are also called paraffins (Latin: parum affinis = little affinity).

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ii. What is Baeyer's Test?

Baeyer's test is a chemical test used to detect the presence of unsaturation (double or triple bonds) in organic compounds. The reagent is cold, dilute, alkaline $KMnO_4$ (purple/violet colour).

When an unsaturated compound is added, the purple colour is discharged (decolourised), confirming a double bond.

$CH_2=CH_2 + [O] + H_2O \rightarrow HOCH_2–CH_2OH$ (Purple $KMnO_4$ → Colourless)

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iii. What are Saturated Hydrocarbons?

Hydrocarbons in which all carbon atoms are joined by single covalent bonds (C–C) only are called saturated hydrocarbons. They cannot add any more hydrogen atoms (hence "saturated"). All remaining valencies are filled by hydrogen.

General formula: C_nH_{2n+2}

Examples: Methane (CH_4), Ethane (C_2H_6), Propane (C_3H_8)

iv. What are Addition Reactions?

Reactions in which atoms or groups of atoms add directly across a multiple bond (C=C or C≡C) without the loss of any atom are called addition reactions. A single product is formed with no byproduct.

Example: $CH_2=CH_2 + H_2 \rightarrow CH_3–CH_3$ (ethene + hydrogen → ethane, in presence of Ni at 200°C)

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v. What is Alkene? Give Examples.

Alkenes are **unsaturated hydrocarbons** containing at least one carbon-carbon **double bond (C=C)**. General formula: C_nH_{2n}. They are more reactive than alkanes due to the π bond.

Name	Molecular Formula
Ethene	C_2H_4
Propene	C_3H_6
Butene	C_4H_8

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vi. Why are alkenes more reactive than the corresponding alkanes?

Alkenes contain a C=C double bond, which consists of one σ (sigma) bond and one π (pi) bond. The π bond is weaker and has electrons available above and below the molecular plane, making it easily attacked by electrophiles. Alkanes have only strong, non-polar C–C single bonds and no π electrons, giving them no reactive site. Hence alkenes are far more reactive.

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vii. How can Ethane be produced from Ethene?

Ethane is produced from ethene by catalytic hydrogenation — addition of H_2 gas over a nickel catalyst at 200°C:

$CH_2=CH_2 + H_2 \rightarrow CH_3–CH_3$ (Ni catalyst, 200°C)

This is an additional reaction where H_2 adds across the C=C double bond to form the saturated alkane, ethane.

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viii. Why do additional reactions occur in ethene and ethyne but NOT in ethane?

Ethene and ethyne contain π bonds (double and triple bonds). These π bonds are weaker than σ bonds, and their electron clouds are accessible to attacking reagents. Reagents break these π bonds and add across them.

Ethane has only C–C and C–H single (σ) bonds — strong, non-polar, with no π bond and no reactive site. Therefore, ethane undergoes substitution, not addition reactions.

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ix. Two Methods of Preparation of Alkyne

Method 1 — From Calcium Carbide and Water:

$CaC_2 + 2H_2O \rightarrow HC\equiv CH + Ca(OH)_2$

(Calcium carbide reacts with water to produce acetylene gas)

Method 2 — Dehydrohalogenation of Dihalides:

$CH_3CHBr_2 + 2KOH(alc) \rightarrow HC\equiv CH + 2KBr + 2H_2O$

(Two molecules of KOH remove two molecules of HBr from a dihalide)

Long Answer Questions

i. Differentiate Between Alkanes and Alkenes + Methods of Preparation of Alkanes

Differences Between Alkanes and Alkenes

Property	Alkanes	Alkenes
Bond Type	Single bonds (C–C) only	At least one double bond (C=C)
General Formula	C_nH_{2n+2}	C_nH_{2n}
Saturation	Saturated	Unsaturated
Reactivity	Less reactive (inert)	More reactive
Type of Reaction	Substitution	Addition
Baeyer's Test	Negative (no change)	Positive (decolourises)
Bromine Water Test	Negative	Positive (decolourises)
Examples	CH_4, C_2H_6, C_3H_8	C_2H_4, C_3H_6, C_4H_8

Methods of Preparation of Alkanes

1. Hydrogenation of Alkenes

Alkenes react with H_2 gas over a Ni catalyst:

$CH_2=CH_2 + H_2 \rightarrow CH_3–CH_3$ (ethene → ethane, Ni, 200°C)

2. Reduction of Alkyl Halides

Alkyl halides are reduced using nascent hydrogen (Zn + HCl):

$C_2H_5Br + 2[H] \rightarrow C_2H_6 + HBr$

3. Wurtz Reaction

Two molecules of alkyl halide are coupled using sodium metal in dry ether:

$2CH_3Br + 2Na \rightarrow CH_3–CH_3 + 2NaBr$ (methyl bromide → ethane)

4. From Natural Gas / Petroleum

Alkanes are obtained industrially by fractional distillation of petroleum and from natural gas (which is mainly methane, CH_4).

ii. Important Reactions of Alkenes

1. Hydrogenation (Addition of H_2)

$CH_2=CH_2 + H_2 \rightarrow CH_3–CH_3$ (Ni catalyst, 200°C)

2. Halogenation (Addition of Br_2)

Decolourises bromine water — used as a test for alkenes:

$CH_2=CH_2 + Br_2 \rightarrow CH_2Br–CH_2Br$ (red-brown → colourless)

3. Hydrohalogenation (Addition of HBr)

$CH_2=CH_2 + HBr \rightarrow CH_3–CH_2Br$ (bromoethane / ethyl bromide)

4. Hydration (Addition of H_2O)

$CH_2=CH_2 + H_2O \rightarrow CH_3–CH_2OH$ (H_2SO_4 catalyst; product = ethanol)

5. Oxidation — Baeyer's Test

$CH_2=CH_2 + [O] + H_2O \rightarrow HOCH_2–CH_2OH$ (cold alk. $KMnO_4$; product = ethylene glycol; $KMnO_4$ decolourises)

6. Combustion

$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$

7. Polymerisation

$n(CH_2=CH_2) \rightarrow (–CH_2–CH_2–)_n$ (product = polyethylene / polythene)

iii. Oxidation Reactions of Ethene and Ethyne

Oxidation of Ethene (C_2H_4)

A. Baeyer's Test — Cold, Dilute, Alkaline $KMnO_4$

$CH_2=CH_2 + [O] + H_2O \rightarrow HOCH_2–CH_2OH$ (Product: Ethylene glycol; $KMnO_4$ decolourises — Positive test)

B. Complete Combustion

$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$

Oxidation of Ethyne (C_2H_2)

A. Baeyer's Test — Cold, Dilute, Alkaline $KMnO_4$

$HC\equiv CH + [O] + H_2O \rightarrow HCOOH$ (Product: Formic acid / methanoic acid; $KMnO_4$ decolourises — Positive test)

B. Complete Combustion

$2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$

Ethyne burns with a very **bright, luminous, sooty flame** due to its high carbon content.

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iv. Important Reactions of Ethyne (Acetylene)

1. Hydrogenation — Addition of H_2 (Two Steps)

Step 1: $HC\equiv CH + H_2 \rightarrow CH_2=CH_2$ (ethene) Step 2: $CH_2=CH_2 + H_2 \rightarrow CH_3–CH_3$ (ethane) (Ni catalyst, 200°C)

2. Halogenation — Addition of Br_2 (Two Steps)

Step 1: $HC\equiv CH + Br_2 \rightarrow CHBr=CHBr$ (1,2-dibromoethene) Step 2: $CHBr=CHBr + Br_2 \rightarrow CHBr_2–CHBr_2$ (1,1,2,2-tetrabromoethane)

3. Hydrohalogenation — Addition of HBr (Two Steps)

Step 1: $HC\equiv CH + HBr \rightarrow CH_2=CHBr$ (vinyl bromide) Step 2: $CH_2=CHBr + HBr \rightarrow CH_3–CHBr_2$ (1,1-dibromoethane)

4. Hydration — Addition of H_2O

$HC{\equiv}CH + H_2O \rightarrow CH_3CHO$ (H_2SO_4 / $HgSO_4$ catalyst; Product: Acetaldehyde / ethanal)

5. Combustion

$2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$

Burns with a very bright flame; used in **oxy-acetylene welding torches**.

6. Oxidation — Baeyer's Test

$HC{\equiv}CH + [O] + H_2O \rightarrow HCOOH$ (alk. $KMnO_4$; Product: Formic acid; Purple $KMnO_4$ decolourises — confirms unsaturation)