CHAPTER 8

Organic Chemistry

SYLLABUS – SCOPE OF SYLLABUS – in and after MARCH 2021

I] INTRODUCTION TO – ORGANIC COMPOUNDS.

- **Unique nature of Carbon atom** - *tetra valency, catenation.*
- **Formation of single, double & triple bonds, straight chain, branched chain, cyclic compounds [only benzene].**

II] STRUCTURE & ISOMERISM.

- **Structure of compounds –**
  with single, double & triple bonds.
- **Structural formulae of hydrocarbons –**
  Structural formula must be given for: alkanes, alkenes, alkynes up to 5 carbon atoms.
- **Isomerism –**
  Structural [chain, position]

III] HOMOLOGOUS SERIES – CHARACTERISTICS WITH EXAMPLES.

- **Alkane, alkene, alkyne series and their gradation in properties and the relationship with the molecular mass or molecular formula.**

IV] SIMPLE NOMENCLATURE

- **Simple nomenclature –**
  – of the hydrocarbons with simple functional groups – [double bond, triple bond, alcoholic, aldehydic, carboxylic group] longest chain rule & smallest number for functional groups rule - trivial & IUPAC names [compounds with only one functional group]

V] HYDROCARBONS: ALKANES, ALKENES, ALKYNES.

- **Alkanes –**
  - **General formula** – *Methane [greenhouse gas] & Ethane*
  - **Methods of Preparation** *from • Sodium ethanoate [sodium acetate] • Sodium propanoate [sodium propionate] • Iodomethane [methyl iodide] • Bromoethane [ethyl bromide].*
  - **Properties** – *Complete combustion of methane & ethane, Reaction of methane & ethane with chlorine through substitution.*
- **Alkenes –**
  [unsaturated hydrocarbons with a double bond]; Ethene as an example.
  - **Methods of preparation of** – *ethene by • Dehydro halogenation reaction • Dehydration reactions.*
- **Alkynes –**
  [unsaturated hydrocarbons with a triple bond]; Ethyne as an example of alkyne.
  - **Methods of preparation** *from — Calcium carbide • 1,2 dibromoethane [ethylene dibromide].*
  - **Only main properties** – particularly addition products with hydrogen & halogen namely Cl_2, Br_2, & I_2, pertaining to alkenes & alkynes.
- **Uses – of methane • ethane • ethene • ethyne.**

VI] ALCOHOLS: ETHANOL — PREPARATION, PROPERTIES & USES.

- **Preparation of** – *ethanol by • Hydrolysis of alkyl halide.*
- **Properties –**
  - **Physical :** *Nature • Solubility • Density • Boiling Points.*
  - **Chemical :** *Combustion • Action with sodium • Ester formation with acetic acid • Dehydration with conc. sulphuric acid to prepare ethene.*
- **Denatured & spurious alcohol.**
- **Important uses** – *of ethanol.*

VII] CARBOXYLIC ACIDS [aliphatic mono carboxylic acid]:
ACETIC ACID – PROPERTIES & USES OF ACETIC ACID.

- **Structure of** – *acetic acid.*
- **Properties of** – *acetic acid:*
  - **Physical :** *Odour [vinegar] • Glacial acetic acid [effect of sufficient cooling to produce ice like crystals].*
  - **Chemical :** *Action with litmus • Alkalis • Alcohol [idea of esterification].*
- **Uses of** – *acetic acid.*

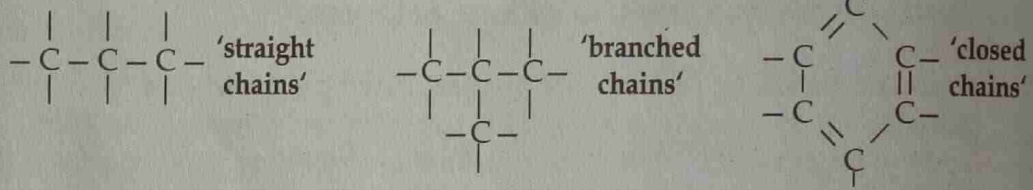
A. INTRODUCTION – Organic Chemistry

1. TERMS, SOURCES & IMPORTANCE – Of organic compounds

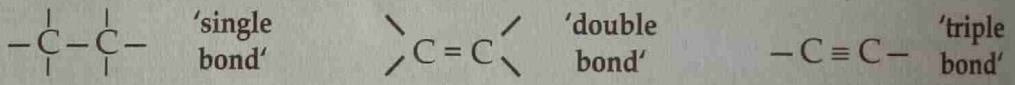
- *Lavoisier* [1785] – classified substances into *organic* [vegetable, animal origin] & *inorganic*.
- *Berzelius* [1800] – stated that a *'vital force'* was necessary for producing organic compounds.
- *Wohler* [1828] – first proved the natural ***'vital force theory'*** wrong by synthesising *'urea'*.
- **Organic Chemistry** – It is the ***'Chemistry of specific carbon compounds'*** [*except* – oxides, carbonates, carbides – most carbon compounds grouped into – *Organic Chemistry*.]
- **Hydrocarbons** – Organic compounds, composed of ***'Carbon & hydrogen only'*** [e.g. Methane – CH_4; Ethane – C_2H_6, Ethene – C_2H_4 & Ethyne – C_2H_2.]
- **Natural sources of organic compounds –** [**Plants** – Carbohydrates, acids • **Animals** – Proteins & urea • **Coal** – Dyes, drugs]
- **Importance of organic compounds** [Compounds of organic origin] – [**Food** – carbohydrates • **Dyes** - azodyes • **Clothing** – cotton • **Fuels** - petrol • **Medicines** - penicillin]

2. UNIQUE NATURE – Of carbon atom

- **TETRAVALENCY OF CARBON ATOM** – Carbon has – Four valence electrons.
  - Carbon forms – 4 covalent bonds by mutually sharing its 4 electrons with other atoms.
  - Carbon is – ***hence tetravalent*** or exhibits ***tetravalency***. [*At. no. of C=6; Elec. Config.* = 2,4]
- **CATENATION** – Tendency of an element to form – chains of identical atoms. [Catenation is thus the property of elements by virtue of which atoms of the element can link to each other in the form of chains of identical atoms e.g. a long chain or ring structure.]
- Catenation is ***maximum in carbon*** – since the value of C–C *bond energy* is maximum.
- Thus carbon undergoes self-linking – forming ***straight, branched & closed chains.***



- Catenation & tetravalency also results in formation of – ***single, double & triple bonds.***



- **FORMS ISOMERS** – organic compounds – *same molecular formula* but *different structural formula*.

Justification for separate branch for Organic Chemistry – Due to unique nature of 'C' atoms – which includes *tetravalency, catenation & leading to formation of isomers* – millions of organic compounds are known or synthesized [*almost 90% of all known compounds are organic*].

3. ORGANIC & INORGANIC COMPOUNDS

	ORGANIC COMPOUNDS	*INORGANIC COMPOUNDS*
COMPOSITION – contains	Few elements. [C, H, O, N, S, P, Cl, Br]	All elements.
NATURE OF COMPOUNDS	*Covalent*	*Electrovalent* [ionic]
• **Melting & Boiling point**	*Low*	*High*
• **Solubility** – in water	*Insoluble in water*	*Soluble*
– in organic solvents	*Soluble*	*Insoluble*
• **Conduction of electricity**	*Non-conductors*	*Good conductors*
• **Combustibility, Volatility**	*Combustible, Volatile*	*Non-combustible, Non-volatile*
CATENATION & ISOMERISM	Exhibited	Not exhibited

4. CLASSIFICATION – Of organic compounds

ALIPHATIC – OPEN CHAIN COMPOUNDS	*CYCLIC – CLOSED CHAIN COMPOUNDS*
HYDROCARBONS [Compounds containing C & H only]	• HOMOCYCLIC – *[only C atoms]*
a] SATURATED – ***Alkanes*** *e.g.* Ethane [C_2H_6]	e.g. ***Aromatic compound*** – Benzene  [C_6H_6]
b] UNSATURATED – ***Alkenes*** e.g. Ethene [C_2H_4]	• HETEROCYCLIC – *[C, O, N, S atoms]*
Alkynes e.g. Ethyne [C_2H_2]	e.g. ***Aromatic compound*** – Pyridine  [C_6H_5N]

B. HOMOLOGOUS SERIES – Organic Compounds

- **TERM – Homologous Series**
  Series *of organic compounds*, where the successive members follow a – ***regular structural pattern,*** successive compounds differing by a **'CH_2'** group.

- **GENERAL CHARACTERISTICS – of members of homologous series**

	ALL MEMBERS HAVE OR SHOW
COMPOSITION	**Same** – ***elements & functional group.***
GENERAL FORMULA	**Same** – ***general molecular formula.***
CHEMICAL PROP.	**Similar** – ***chemical properties*** [same *functional group* in each member]
MOLECULAR WT.	**Increase**– ***in molecular weight – down a series.*** [*mol. wt. of two adjacent members differs by* **'14'** $CH_2 = 12+2 = 14$].
PHYSICAL PROP.	**Increase**– ***in physical properties – down a series*** [gradual gradation seen with increase in mol. wt. e.g. *b.p., solubility*]

- **SIGNIFICANCE – of homologous series**
  - Helps in systematic study of organic compounds.
  - Predicts the properties & nature of other members of the series – if the same is known of the first few members.

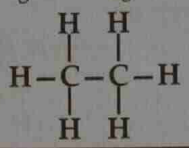
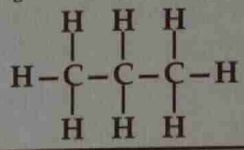
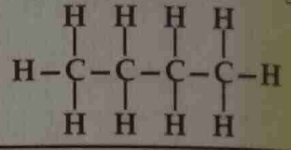
- **HOMOLOGOUS SERIES – of hydrocarbons**
  - **TERM:** ***Hydrocarbons*** – *Aliphatic, open chain, organic compounds* containing **'*C*'** & **'*H*'** only.
  - **MOLECULAR FORMULA:** C_xH_y where x & y are whole numbers.
  - **TWO MAIN GROUPS OF HYDROCARBONS:**
    a] ***Saturated hydrocarbons*** – containing C atoms joined by ***single covalent bond***
    e.g. **Alkanes**: C_2H_6 [ethane]
    b] ***Unsaturated hydrocarbons*** – containing C atoms joined by ***double or triple covalent bonds***
    e.g. **Alkenes**: C_2H_4 [ethene] & **Alkynes**: C_2H_2 [ethyne]

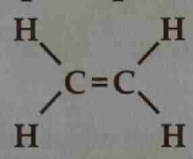
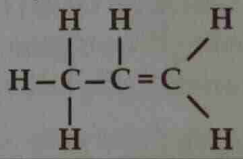
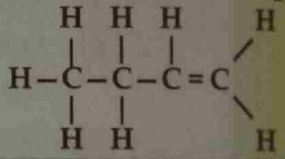
Homologous Series	General, Mol. Formula Name *[I.U.P.A.C.]*	Molecular Weight	B.P. [°C]	M.P. [°C]	[n = 6 to n = 10]
ALKANES	C_nH_{2n+2}				
	n=1 CH_4 Methane	16	–162	–183	C_6H_{14} *Hexane*
	n=2 C_2H_6 Ethane	30	–89	–172	C_7H_{16} *Heptane*
	n=3 C_3H_8 Propane	44	–42	–147	C_8H_{18} *Octane*
	n=4 C_4H_{10} Butane	58	–1	–135	C_9H_{20} *Nonane*
	n=5 C_5H_{12} Pentane	72	36	–130	$C_{10}H_{22}$ *Decane*

	General Formula	Molecular Formula	Name *[I.U.P.A.C.]*
ALKENES	C_nH_{2n}	–	–
[functional group]	n=1	C_2H_4 [mol. wt. = 28]	Ethene
	n=2	C_3H_6	Propene
	n=3	C_4H_8	Butene
	n=4	C_5H_{10}	Pentene
	n=5		
ALKYNES	C_nH_{2n-2}	–	–
[functional group]	n=1	C_2H_2 [mol. wt. = 26]	Ethyne
	n=2	C_3H_4	Propyne
	n=3	C_4H_6	Butyne
	n=4	C_5H_8	Pentyne
	n=5	[C=12, H=1]	

C. STRUCTURE – Organic Compounds

REPRESENTATION	**Organic compounds** – are represented by – a] Molecular formula b] Structural formula
a] MOLECULAR FORMULA	• Indicates – ***actual number of each kind of atoms*** – in a molecule of the organic compound. *e.g. Ethane – C_2H_6; Ethene – C_2H_4; Ethyne – C_2H_2.*
b] STRUCTURAL FORMULA	• Indicates – ***arrangement of various atoms*** – in a molecule of the organic compound. – *It is a more informative formula represented as* – i] **Condensed structural** ii] **Branched structural** – formula

1. ALKANES	*ETHANE*	*PROPANE*	*BUTANE*
Molecular formula	C_2H_6	C_3H_8	C_4H_{10}
Structural formula			
• Condensed	H_3C-CH_3	$H_3C-CH_2-CH_3$	$H_3C-CH_2-CH_2-CH_3$
• Branched			

2. ALKENES	*ETHENE* [ethylene]	*PROPENE* [propylene]	*1-BUTENE* [1-butylene]
Molecular formula	C_2H_4	C_3H_6	C_4H_8
Structural formula			
• Condensed	$H_2C=CH_2$	$H_3C-CH=CH_2$	$H_3C-CH_2-CH=CH_2$
• Branched			

3. ALKYNES	*ETHYNE* [acetylene]	*PROPYNE* [methyl acetylene]	*1-BUTYNE* [ethyl acetylene]
Molecular formula	C_2H_2	C_3H_4	C_4H_6
Structural formula			
• Condensed	$HC\equiv CH$	$H_3C-C\equiv CH$	$H_3C-CH_2-C\equiv CH$

CONDENSED STRUCTURAL FORMULA – also shows – **Alkyl group & Functional group**

• *ALKYL GROUP*	**All groups** - ***derived from parent alkane – by loss of 'H' atom.***			
– Parent alkane	Methane CH_4	Ethane C_2H_6	Propane C_3H_8	Butane C_4H_{10}
– Alkyl group - 'R'	***Methyl*** CH_3 –	***Ethyl*** C_2H_5 –	***Propyl*** C_3H_7 –	***Butyl*** C_4H_9 –
• *FUNCTIONAL GROUP*	**An atom, radical or bond – which *defines the structure of organic compounds & confers characteristic properties to it.***			

Functional group	*Organic compounds*	
Hydroxyl – OH	CH_3 – OH Methanol [methyl *alcohol*]	C_2H_5 – OH Ethanol [ethyl *alcohol*]
Aldehydic – CHO	H – CHO Methanal [form*aldehyde*]	CH_3 – CHO Ethanal [acet*aldehyde*]
Carboxylic – COOH	H – COOH Methanoic acid [formic *acid*]	CH_3 – COOH Ethanoic acid [acetic *acid*]
Halide – F, Cl, Br, I, [x]	CH_3 – Cl Chloro methane [methyl *chloride*]	C_2H_5 – Br Bromo ethane [ethyl *bromide*]

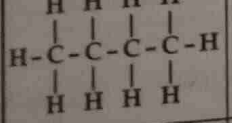
D. ISOMERISM – Organic Compounds

- **TERM** – **Isomers** are organic compounds having the – ***same molecular formula*** but ***differing*** in ***molecular arrangement*** or in ***structural formula.***
- **CHARACTERISTICS – Of Isomers –** phenomenon called – ***isomerism.***

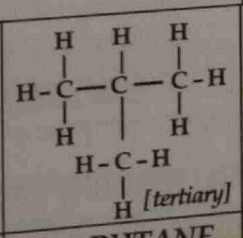
PROPERTIES –	**Similar** – *chemical properties* **Differ** – in *physical properties* [properties are of – isomers of the same homologous series]
NO. OF ISOMERS –	**Increases –** with *increase in number of carbon atoms.* [e.g. C_4H_{10} has two isomers, C_5H_{12} has three isomers...]
TYPES OF ISOMERISM–	
STRUCTURAL –	*e.g. Chain, Position,* Functional, Metamerism & Tautomerism • It is due to – difference in manner of linking of atoms
• *Chain Isomerism*	Due to difference in – *arrangement of C atoms* in the chain
• *Position Isomerism*	Due to difference in – *position of functional group e.g. '=' bond.*
Stereo isomerism – [reference]	*e.g. Geometrical isomerism* Due to difference in – *arrangement of atoms around the double bond*

- *ISOMERS OF ALKANES* – exhibit mainly – ***chain isomerism***

ALKANES	COMMON NAME	IUPAC NAME
ISOMERS OF BUTANE – C_4H_{10}	n–butane iso–butane *[branched chain isomer]*	*Butane* *2-methyl propane*
ISOMERS OF PENTANE – C_5H_{12}	n–pentane iso-pentane neo–pentane	*Pentane* *2-methyl butane* *2-2-dimethyl propane*



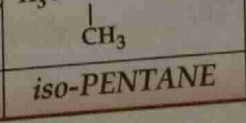
n-BUTANE



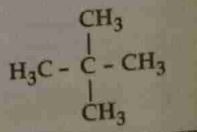
iso-BUTANE

$H_3C-CH_2-CH_2-CH_2-CH_3$

n-PENTANE



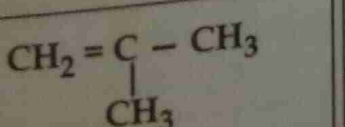
iso-PENTANE



neo-PENTANE

- *ISOMERS OF ALKENES* – exhibit mainly – ***chain & position*** [& geometrical] ***isomerism.***

$CH_3-CH_2-CH=CH_2$
1-butene



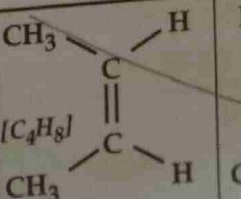
2-methyl propene

CHAIN ISOMERS

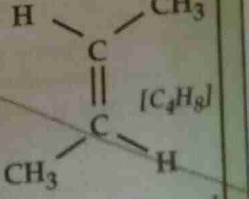
$CH_3-CH_2-CH=CH_2$
1-butene

$CH_3-CH=CH-CH_3$
2-butene

POSITION ISOMERS



2-butene [cis]



2-butene [trans]

Geometrical isomers

- *ISOMERS OF ALKYNES* – exhibit mainly – ***position isomerism.***

$CH_3-CH_2-C\equiv CH$ *1-butyne*
$CH_3-C\equiv C-CH_3$ *2-butyne*

POSITION ISOMERS

$CH_3-CH_2-CH_2-C\equiv CH$ *1-pentyne*
$CH_3-CH_2-C\equiv C-CH_3$ *2-pentyne*

E. NOMENCLATURE – Organic Compounds

- **TERM** – Nomenclature – is the system of *assignment of names to organic compounds.*
- **NEED** – for nomenclature
  Large number of organic compounds present need – *systematic naming.*
  - *Varying molecular structures* of organic compounds
  - *Isomerism* in organic compounds –
    increases need for – *correct, methodical & different naming* of each compound.
- **SYSTEMS** – of nomenclature a] ***Trivial system*** b] ***IUPAC system***

A. *TRIVIAL SYSTEM – Common names* – oldest system with no well defined basis

- **BASIC RULES OF NOMENCLATURE – BY THE TRIVIAL SYSTEM**
  - *The basis of naming organic compounds by the trivial system is its –*
    a] *Source* b] *Properties* c] *Latin or Greek origin – of compound*
    e.g. **Methane** – named *'marsh gas'* – from its source *'marshes'*.
    Acetic acid – name derived – from its source *'vinegar'*. [Latin: *acetum*].
- **NAMING OF ORGANIC COMPOUNDS – BY THE TRIVIAL SYSTEM**

Compounds	*METHOD OF NAMING*	*COMMON NAME*
ALKANES	• On basis of **source** or **property**:	Methane, Ethane, Propane, Butane
	• By prefixing **Greek numericals** –	*Pent*ane [5 C atoms], *Hex*ane [6]
ALKENES	• By substituting – suffix – *– ane* of alkane by – *ylene*	Eth*ylene* [alkane - eth*ane*] Prop*ylene* [alkane - prop*ane*]
ALKYNES	• As alkyl derivatives – of *acetylene*	Acetylene – *Methyl* acetylene
ALCOHOL	• By attaching *alcohol* – to corresponding *alkyl*	*Methyl* alcohol [*alkane* - methane, *alkyl* - methyl]

B. *IUPAC SYSTEM – systematic name* – most modern, largely used system

- **INTERNATIONAL UNION OF PURE & APPLIED CHEMISTRY [IUPAC]** –
  - IUPAC name takes up only –
    One molecular structure of the compound – Assigns only one name to the compound.
- **RULES OF NOMENCLATURE BY IUPAC SYSTEM** –
  Every name may consist of – *Root word • Primary suffix • Secondary suffix • Prefix*

Root word	– Indicates *number of carbon atoms* in linear chain. i.e. Meth-, Eth- etc. C_1 – *Meth-* C_2 – *Eth-* C_3 – *Prop-* C_4 – *But-* C_5 – *Pent-*
Primary suffix	– Indicates *nature of carbon chain* i.e. -ane, -ene, -yne. C-C [single bond] *-ane* C=C [double bond] *-ene* C≡C [triple bond] *-yne*
Secondary suffix	– Indicates the *particular functional group.* i.e. -ol, -al, -oic etc. Functional group: -OH -CHO -COOH -X [F, Cl, Br] Secondary suffix: *-ol* *-al* *-oic acid* *-chloro, bromo*
Prefix	– Indicates additional *substituent alkyl* or *functional group.* e.g. di- tri-tetra; bromo, chloro; ethyl, methyl [in alphabetical order].

NOMENCLATURE – Organic Compounds [Contd.]

NOMENCLATURE — IUPAC SYSTEM – Naming an Organic Compound

1. LONGEST CHAIN RULE – The longest continuous chain of 'C' atoms is selected.

$CH_3-CH_2-\underset{\displaystyle CH_3}{\underset{\vert}{CH}}-CH_2-CH_3$	*The longest chain is of 5 carbon atoms* – **Root word** C_5 – *Pent-* [The nature of carbon chain is C – C *[single bond]* – *Suffix* **-ane** & the substituent is an (alkyl) methyl – CH_3 group].

2. NUMBERING OF CARBON ATOMS

- ***Starts with*** – End **nearer to branch chain** [C atom with *first substituent* gets the *lowest no.*].
- ***Alkyl group*** – [substituent] – Gets the **smallest number** e.g. methyl group – CH_3.

$\overset{4}{CH_3}-\overset{3}{CH_2}-\underset{\displaystyle CH_3}{\overset{2}{\underset{\vert}{CH}}}-\overset{1}{CH_3}$ ✓ X	*Principal chain has 4 carbon atoms* – *Compound is an alkane* > C – C < – *The alkyl group is at C – 2* –		*-But-*	*-ane-*
		2-METHYL BUTANE		

- ***Functional group*** – [if also present] – Gets the **still smallest number** e.g. – OH.

$\overset{5}{CH_3}-\underset{\displaystyle CH_3}{\overset{4}{\underset{\vert}{CH}}}-\overset{3}{CH_2}-\underset{\displaystyle OH}{\overset{2}{\underset{\vert}{CH}}}-\overset{1}{CH_3}$ ✓ X	*Principal chain has 5 carbon atoms* – *Functional group is – OH* – *Functional group is at C– 2* – *Alkyl group at C– 4* –		*-Pent-*	*-ol* *2-ol*
		4-METHYL PENTAN-2-OL		

- ***Different functional groups*** – as substituents – **arranged – named alphabetically.**

$\overset{1}{CH_3}-\underset{\displaystyle Br}{\overset{2}{\underset{\vert}{CH}}}-\overset{3}{CH_2}-\underset{\displaystyle Cl}{\overset{4}{\underset{\vert}{CH}}}-\overset{5}{CH_3}$ ✓ X	*Correct name* – 2-bromo-4-chloro pentane *Wrong name* – 2-chloro-4-bromo pentane
	2-BROMO-4-CHLORO PENTANE

- ***Different alkyl groups*** – as substituents – **smaller alkyl gets minimum number.**

$\overset{1}{CH_3}-\overset{2}{CH_2}-\underset{\displaystyle CH_3}{\overset{3}{\underset{\vert}{CH}}}-\overset{4}{CH}-\underset{\displaystyle C_2H_5}{\overset{5}{\underset{\vert}{CH}}}-\overset{6}{CH_2}-\overset{7}{CH_3}$ ✓ X	*Correct numbering* *Incorrect numbering*	*Substituents named alphabetically – irrespective of their positions*
	4-ETHYL 3-METHYL HEPTANE	

- ***Halo substituents*** [e.g. -Cl] given smaller no. with preference to – **alkyl group.**
- ***Position & name of alkyl group*** – is written just before – **parent hydrocarbon.**
- ***Multiple no. of same alkyl groups*** – are written as **'di'** [for 2] **'tri'** [for 3] **'tetra'** [for 4] etc. [If *two alkyl groups* are on *same C atom* – *numeral repeated* e.g. 2,2 dimethyl butane]

ORGANIC COMPOUND	$H-\overset{1}{\underset{\displaystyle Cl}{\underset{\vert}{C}}}=\overset{2}{\underset{\displaystyle Cl}{\underset{\vert}{C}}}-H$	$H-\overset{1}{\underset{\displaystyle Br}{\underset{\vert}{C}}}-\overset{2}{\underset{\displaystyle Br}{\underset{\vert}{C}}}-H$ (Br, Br)	$\overset{1}{CH_3}-\overset{2}{CH}=\underset{\displaystyle CH_3}{\overset{3}{\underset{\vert}{C}}}-\overset{4}{CH_2}-\overset{5}{CH_3}$	$CH_3-\underset{\displaystyle CH_3}{\overset{2}{\underset{\vert}{C}}}-I$ ($^1CH_3$, $^3CH_3$)
Root word	*Eth* – [C_2]	*Eth* – [C_2]	*Pent* – [C_5]	*Prop* – [C_3]
Suffix	*-ene* [>C=C<]	*-ane* [>C–C<]	*-ene* [>C=C<]	*-ane* [>C–C<]
Prefix	*1,2-dichloro*	*1,1,2,2,tetrabromo*	*3-methyl*	*2-iodo-2-methyl*
IUPAC name	1,2 dichloro ethene	1,1,2,2,tetrabromo ethane	3-methyl pent-2-ene	2-iodo-2-methyl propane

WRITING STRUCTURAL FORMULA – From IUPAC name– *2-chloro-3-methyl-but-2-ene*

$\overset{1}{C}-\overset{2}{C}-\overset{3}{C}-\overset{4}{C}$	$\overset{1}{C}-\overset{2}{C}=\overset{3}{C}-\overset{4}{C}$	$\overset{1}{C}-\overset{2}{C}=\overset{3}{C}-\overset{4}{C}$ (Cl, CH_3)	$\overset{1}{CH_3}-\overset{2}{C}=\overset{3}{C}-\overset{4}{CH_3}$ (Cl, CH_3)
-But- [C_4] Write 4 *Carbon atoms* Number the C atoms	*-ene-* [>C=C<] Position the *double bond in the chain*	Position the *substituent* and *functional group*	Complete the *formula* by *satisfying valencies*

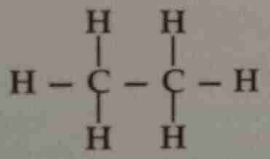
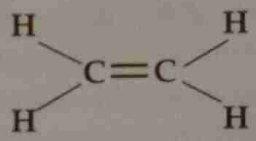
NOMENCLATURE – Reference Chart – IUPAC & Common Names

Homologous Series	Condensed Structural Formula	Functional Group	Root Word	Primary Suffix	Secondary Suffix	IUPAC NAME	TRIVIAL OR COMMON NAME
ALKANES	$C_n H_{2n+2}$ [Paraffins]						
CH_4 n=1	CH_4		METH	*-ANE*	-	**METHANE**	Methane
C_2H_6 n=2	H_3C-CH_3		ETH	*-ANE*	-	**ETHANE**	Ethane
C_3H_8 n=3	$H_3C-CH_2-CH_3$		PROP	*-ANE*	-	**PROPANE**	Propane
C_4H_{10} n=4	$H_3C-CH_2-CH_2-CH_3$		BUT	*-ANE*	-	**BUTANE**	Butane
ALKENES	$C_n H_{2n}$ [Olefins]						
n=1	-		-	-	-	-	-
C_2H_4 n=2	$H_2C=CH_2$	$>C=C<$	ETH	*-ENE*	-	**ETHENE**	Ethylene
C_3H_6 n=3	$H_3C\cdot CH=CH_2$	**Double**	PROP	*-ENE*	-	**PROPENE**	Propylene
C_4H_8 n=4	$H_3C\cdot CH_2\cdot CH=CH_2$	**bond**	BUT	*-ENE*	-	**1-BUTENE**	1-Butylene
	$H_3C\cdot CH=CH-CH_3$		BUT	*-ENE*	-	**2-BUTENE**	2-Butylene
ALKYNES	$C_n H_{2n-2}$						
n=1	-		-	-	-	-	-
C_2H_2 n=2	$HC\equiv CH$	$-C\equiv C-$	ETH	*-YNE*	-	**ETHYNE**	Acetylene
C_3H_4 n=3	$H_3C-C\equiv CH$	**Triple**	PROP	*-YNE*	-	**PROPYNE**	Methyl acetylene
C_4H_6 n=4	$H_3C-CH_2-C\equiv CH$	**bond**	BUT	*-YNE*	-	**1-BUTYNE**	Ethyl acetylene
	$H_3C-C\equiv C-CH_3$		BUT	*-YNE*	-	**2-BUTYNE**	Dimethyl acetylene
ALCOHOLS	$C_n H_{2n+1} OH$						*[Monohydric alcohols]*
CH_3OH n=1	H_3C-OH	**-OH**	METH	*-ANE*	-ol	**METHANOL**	Methyl alcohol
C_2H_5OH n=2	H_3C-CH_2-OH	**Hydroxyl**	ETH	*-ANE*	-ol	**ETHANOL**	Ethyl alcohol
C_3H_7OH n=3	$H_3C-CH_2-CH_2-OH$	[alcoholic]	PROP	*-ANE*	-ol	**1-PROPANOL**	n-Propyl alcohol
ALDEHYDES	$C_n H_{2n} O$	$-\overset{H}{\underset{\|}{C}}=O$					
HCHO n=1	H-CHO		METH	*-ANE*	-al	**METHANAL**	Formaldehyde
CH_3CHO n=2	H_3C-CHO	**Aldehydic**	ETH	*-ANE*	-al	**ETHANAL**	Acetaldehyde
C_2H_5CHO n=3	H_3C-CH_2-CHO		PROP	*-ANE*	-al	**PROPANAL**	Propionaldehyde
C_3H_7CHO n=4	$H_3C-CH_2-CH_2-CHO$		BUT	*-ANE*	-al	**BUTANAL**	Butraldehyde
CARBOXYLIC ACIDS	$C_n H_{2n} O_2$	$-\overset{OH}{\underset{\|}{C}}=O$					
HCOOH n=1	H-COOH		METH	*-ANE*	-oic acid	**METHANOIC ACID**	Formic acid
CH_3COOH n=2	$H_3C-COOH$	**Carboxylic** [carboxyl]	ETH	*-ANE*	-oic acid	**ETHANOIC ACID**	Acetic acid
C_2H_5COOH n=3	H_3C-CH_2-COOH		PROP	*-ANE*	-oic acid	**PROPANOIC ACID**	Propionic acid
ALKYL HALIDES	$C_n H_{2n+1} X$ [X=F, Cl, Br, I]	**Halo** [halides]					
CH_3Cl n=1	H_3C-Cl	**-F, -Cl,**	METH	*-ANE*	Chloro	CHLORO METHANE	Methyl chloride
C_2H_5Br n=2	H_3C-CH_2-Br	**-Br, -I,**	ETH	*-ANE*	Bromo	BROMO ETHANE	Ethyl bromide
KETONES	$C_n H_{2n} O$	**Ketonic** [keto]					
$CH_3-CO-CH_3$ n=3	$H_3C-CO-CH_3$	$-\overset{O}{\overset{\|\|}{C}}-$	PROP	*-ANE*	-one	**PROPANONE**	Dimethyl ketone [acetone]
$CH_3-CO-C_2H_5$ n=4	$H_3C-CO-CH_2-CH_3$		BUT	*-ANE*	-one	**2-BUTANONE**	Ethyl methyl ketone
$C_2H_5-CO-C_2H_5$ n=5	$H_3C-CH_2-CO-CH_2-CH_3$		PENT	*-ANE*	-one	**3-PENTANONE**	Diethyl ketone
ETHER	$C_n H_{2n+2} O$	**Alkoxy** [ether]					
CH_3-O-CH_3 n=2	$H_3C-O-CH_3$	$-\overset{\|}{C}-O-\overset{\|}{C}-$	METH	*-ANE*	-methoxy	METHOXY METHANE	Dimethyl ether
$CH_3-O-C_2H_5$ n=3	$H_3C-O-CH_2-CH_3$		METH	*-ANE*	-methoxy	METHOXY ETHANE	Ethyl methyl ether
$C_2H_5-O-C_2H_5$ n=4	$H_3C-CH_2-O-CH_2-CH_3$		ETH	*-ANE*	-ethoxy	ETHOXY ETHANE	Diethyl ether

REFER – PAGE 247-248 – FOR SUMMARY OF IUPAC NAMES OF ORGANIC COMPOUNDS & OF ISOMERS

F. HYDROCARBONS – General

- **TERM** – *Aliphatic, open-chain organic compounds containing* – ***carbon & hydrogen only.***
- **MOLECULAR FORMULA** – C_xH_y, where – x and y are whole numbers.
- **MAIN GROUPS** – Aliphatic hydrocarbons are divided into *two main groups:*
  - **Saturated hydrocarbons** eg. Homologous series of – ***Alkanes.***
  - **Unsaturated hydrocarbons** eg. Homologous series of – ***Alkenes & Alkynes.***

	ALKANES [paraffins]	ALKENES [olefins]	ALKYNES
NATURE	*Saturated* hydrocarbon	*Unsaturated* hydrocarbon	*Unsaturated* hydrocarbon
COVALENT BOND	Contains a ***single*** >C-C< covalent bond	Contains a ***double*** >C=C< covalent bond	Contains a ***triple*** >C≡C< covalent bond
GENERAL FORMULA	C_nH_{2n+2}	C_nH_{2n}	C_nH_{2n-2}
MOLECULAR FORMULA	CH_4 – Methane C_2H_6 – Ethane	no corresponding alkene C_2H_4 – Ethene	no corresponding alkyne C_2H_2 – Ethyne
STRUCTURAL FORMULA			
• Condensed	$H_3C - CH_3$ [ethane]	$H_2C = CH_2$ [ethene]	$HC \equiv CH$ [ethyne]
• Branched			$H-C \equiv C-H$
NOMENCLATURE	**I.U.P.A.C. name:** Ethane **Common name:** Ethane	**I.U.P.A.C. name:** Ethene **Common name:** Ethylene	**I.U.P.A.C. name:** Ethyne **Common name:** Acetylene

SATURATED ORGANIC COMPOUNDS

Methane [CH_4], ethane [C_2H_6]

SPECIAL STRUCTURAL FEATURES

- They contain carbon atoms joined by a–
  – ***single covalent bond*** >C-C< .
- All the 4 valencies of each carbon atom
  – ***are satisfied*** by hydrogen atoms
  – forming single covalent bonds.
- The **non-availability of electrons** –
  in the single covalent bond makes them
  – *less reactive* and therefore undergo
  – characteristic *substitution reactions* only.

CHARACTERISTIC REACTIONS

- **Substitution reactions** –
  Reactions involving –
  direct displacement or *substitution* of an atom or group of atoms by another atom or group. e.g. in ***alkanes*** –
  Replacement – of 'H' by 'Cl' or 'Br' atoms.

UNSATURATED ORGANIC COMPOUNDS

Ethene [C_2H_4], ethyne [C_2H_2]

SPECIAL STRUCTURAL FEATURES

- They contain carbon atoms joined by –
  – ***double covalent bonds*** >C = C< or
  – ***triple covalent bonds*** >C≡C< .
- The valencies of atleast 2 carbon atoms –
  are not fully satisfied by hydrogen atoms.
- The **availability of electrons** –
  in the double or triple bond makes them
  – *more reactive* and therefore undergo
  – characteristic *addition reactions* only.

CHARACTERISTIC REACTIONS

- **Addition reactions** –
  Reactions involving –
  addition of an attacking reagent eg. hydrogen, halogens etc. across the *double* or *triple* bond of an *unsaturated compound* to yield – a *saturated* product.

G. ALKANES - Methane & Ethane – Introduction, Sources, Nomenclature

1. INTRODUCTION - Alkanes

- **ALKANES** – *saturated aliphatic hydrocarbons* containing a *carbon-carbon single bond.*
  - They contain a [-C-C-] covalent bond & [-C-H-] covalent bonds in their molecule.
  - Since all the four valencies of carbon atoms are fully satisfied – by forming single covalent bonds these compounds are said to be – ***saturated.***
  - Alkanes are known as – ***paraffins*** [*latin*: parum=little; affinis=affinity]. They contain strong C– C & C– H bonds and hence are relatively chemically inert.
- **GENERAL FORMULA** – The *general formula* of alkanes is C_nH_{2n+2}.

2. SOURCES - Alkanes

- **DISTRIBUTION** – Alkanes are – widely distributed in *marshy lands, air & coal mines.*
- **MAIN SOURCES** – The main sources of alkanes are – *natural gas* and *petroleum.*

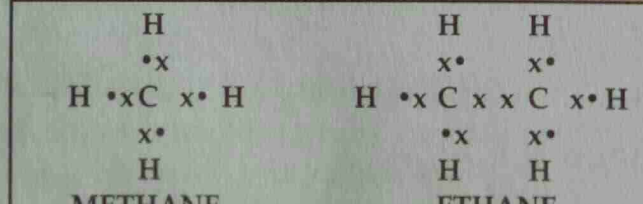
Natural gas – contains about 75% methane & is found associated with petroleum.
Marsh gas – produced by bacterial decay of *vegetable matter* contains *methane.*
Fire damp – coal pockets contains large amounts of *methane* & are called fire damp.
[*Methane* – is also one of the gases which contributes towards ***green house effect*** - whose blanketing effect over the earth's surface results in global warming.]

3. NOMENCLATURE - Alkanes – *There are two main ways of naming alkanes-*

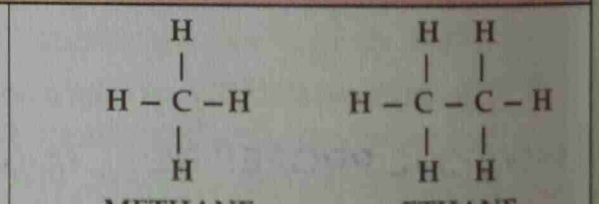
- **COMMON NAME SYSTEM :**
  The first four members of the series – are called by their common or trivial names i.e. methane, ethane, propane, butane etc. & refer to their source or characteristic property.
  From the fifth alkane onwards – alkanes are named by prefixing the Greek numerals- *pent* (5), *hex* (6), *hept* (7) to the terminal - **'ane'**. [indicating – no. of C atoms in the alkane]
- **I.U.P.A.C. SYSTEM :** This system retains the common names for the – First ten [C_1 to C_{10}] alkanes, but is used for naming higher branched chain alkanes.

Molecular formula - C_nH_{2n+2}	Common name	Molecular formula - C_nH_{2n+2}	Common name
add $-CH_2$ group ↓ CH_4	Methane	C_6H_{14}	Hexane
C_2H_6	Ethane	C_7H_{16}	Heptane
C_3H_8	Propane	C_8H_{18}	Octane
C_4H_{10}	Butane	C_9H_{20}	Nonane
C_5H_{12}	Pentane	$C_{10}H_{22}$	Decane

Structural formula – of Methane and Ethane



Electronic structure



Structural formula

Methane – Carbon has 4 electrons in the outermost shell which are shared with 4 electrons of – 4 hydrogen atoms i.e. *one carbon atom* joined to *four hydrogen atoms* by – *single covalent bonds.*

Ethane – There are two carbon & six hydrogen atoms in ethane. The *two carbons* are joined by – a *single covalent bond* & the *three remaining valencies* of each carbon atom are taken by – *three hydrogen atoms* forming – *single covalent bonds.*

4. PREPARATION – Methane & Ethane

a] LAB. PREPARATION FROM –

Sodium ethanoate [sodium acetate]

$CH_3\text{-}COONa + NaOH \xrightarrow[\Delta]{CaO} CH_4 + Na_2CO_3$

sodium acetate sodalime → methane

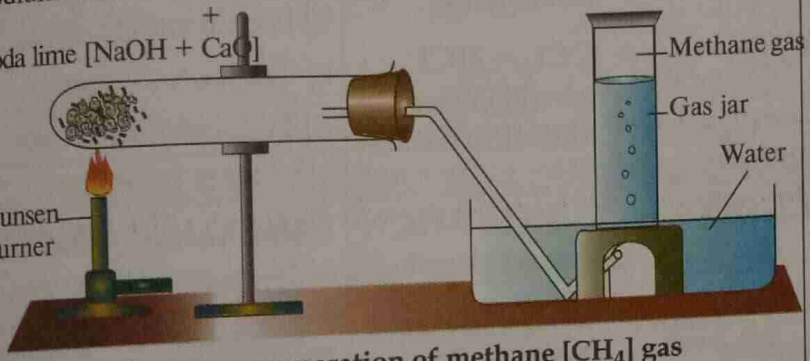
Sodium propanoate [sodium propionate]

$CH_3\text{-}CH_2\text{-}COONa + NaOH \xrightarrow[\Delta]{CaO} C_2H_6 + Na_2CO_3$

sodium propionate sodalime → ethane

[The above reactions are of **decarboxylation**]

Sodium ethanoate [sodium acetate] + Soda lime [NaOH + CaO]



Laboratory preparation of methane [CH_4] gas

REACTANTS:
Sodium acetate or *sodium propionate* and *sodalime* [sodalime – is a mixture of sodium hydroxide (NaOH) & calcium oxide (CaO)]

PROCEDURE:
The reactants are heated – in a hard glass test tube. [soda lime is used in preference to NaOH – since it is not deliquescent & does not attack glass.]

PRODUCT:
Methane or ethane respectively

COLLECTION:
CH_4 or C_2H_6 is collected by – downward displacement of water.

Decarboxylation – elimination of a molecule of CO_2 from – a carboxylic acid. [in the above reaction CO_2 is eliminated as a carbonate.]

b] GENERAL METHODS – from Alkyl halides

Iodomethane [methyl iodide]

$CH_3I + 2[H] \xrightarrow[\text{alcohol}]{\text{Zn/Cu couple}} CH_4 + HI$

methyl iodide, nascent hydrogen → methane

Bromoethane [ethyl bromide]

$C_2H_5Br + 2[H] \xrightarrow[\text{alcohol}]{\text{Zn/Cu couple}} C_2H_6 + HBr$

ethyl bromide, nascent hydrogen → ethane

$2CH_3I + 2Na \xrightarrow{\text{ether}} C_2H_6 + 2NaI$

methyl iodide, sodium → ethane

REACTANTS:
Methyl iodide or ethyl bromide & Zn/Cu couple in alcohol –which evolves nascent H.

PROCEDURE:
Alkyl halide & alcohol mixture is added to Zn/Cu couple kept in a conical flask. The alkyl halide is reduced with – nascent H.

COLLECTION:
The alkane is collected by – downward displacement of water.

WURTZ REACTION –
It is not suitable for prep. of alkanes with odd no. of C atoms e.g. CH_4

5. PHYSICAL PROPERTIES – Methane & Ethane

• Nature, colour and odour	Gas at ordinary temperatures. Colourless and odourless
• Solubility	Almost *insoluble* in water, *soluble* in organic solvents, eg. acetone
• Melting/boiling point	m.p. = –182.5°C [liquefaction]; b.p. = –161.5°C

VAPOUR DENSITIES OF - METHANE AND ETHANE				
Methane	CH_4	Mol. wt. = 16	$[12 + 1 \times 4]$	V.D. = 8 $[Mol.\ wt. = 2 \times V.D.]$
Ethane	C_2H_6	Mol. wt. = 30	$[12 \times 2 + 1 \times 6]$	V.D. = 15 $[Mol.\ wt. = 2 \times V.D.]$

6. CHEMICAL PROPERTIES – Methane & Ethane

A] SUBSTITUTION REACTIONS

a] METHANE			
CH_4 + **methane**	Cl_2 —Diffused sunlight, uv light, or Δ→	$CH_3Cl + HCl$ **monochloromethane** *[methyl chloride]*	***Chlorination*** - *Substitution of* hydrogen atoms – of *methane* by chlorine atoms.
CH_3Cl + monochloromethane	Cl_2 [excess] →	$CH_2Cl_2 + HCl$ **dichloromethane** *[methylene dichloride]*	***Conditions*** - Diffused sunlight, ultraviolet light or high temperatures [400°C].
CH_2Cl_2 + dichloromethane	Cl_2 →	$CHCl_3 + HCl$ **trichloromethane** *[chloroform]*	***Substitution Products*** - a] Monochloromethane b] Dichloromethane c] Trichloromethane d] Tetrachloromethane
$CHCl_3$ + trichloromethane *[$CH_4 + 4Cl_2$*	Cl_2 → *$CCl_4 + 4HCl$]*	$CCl_4 + HCl$ **tetrachloromethane** *[carbontetrachloride]*	
b] ETHANE			
C_2H_6 + **ethane**	Cl_2 —Diffused sunlight, uv light, or Δ→	$C_2H_5Cl + HCl$ **monochloroethane**	***Chlorination*** - *Substitution* of hydrogen atoms – of *ethane* by chlorine atoms. ***Conditions:*** same as above ***Substitution Products*** - a] Monochloroethane b] Dichloroethane c] Trichloroethane d] Tetrachloroethane e] Pentachloroethane f] Hexachloroethane [The products can be separated by fractional distillation due to difference in boiling points]
C_2H_5Cl + monochloroethane	Cl_2 [excess] →	$C_2H_4Cl_2 + HCl$ **dichloroethane**	
$C_2H_4Cl_2$ + dichloroethane	Cl_2 →	$C_2H_3Cl_3 + HCl$ **trichloroethane**	
$C_2H_3Cl_3$ + trichloroethane	Cl_2 →	$C_2H_2Cl_4 + HCl$ **tetrachloroethane**	
$C_2H_2Cl_4$ + tetrachloroethane	Cl_2 →	$C_2HCl_5 + HCl$ **pentachloroethane**	
C_2HCl_5 + pentachloroethane	Cl_2 →	$C_2Cl_6 + HCl$ **hexachloroethane**	

B] OXIDATION REACTIONS

- **Complete oxidation or combustion – in excess of air**

a] METHANE		
CH_4 +	$2O_2$[excess] →	$CO_2 + 2H_2O + \Delta$
b] ETHANE		
$2\,C_2H_6$ +	$7O_2$[excess] →	$4CO_2 + 6H_2O + \Delta$

Conditions: *IN EXCESS AIR OR OXYGEN* - Methane or ethane ***burns*** with a blue non-luminous flame. ***Products*** - a] CO_2 b] Water

- **Incomplete oxidation or combustion – in insufficient air**

a] METHANE		
$2CH_4$ +	$3O_2$[limited]→	$2CO + 4H_2O + \Delta$ [poisonous CO formed]
b] ETHANE		
$2\,C_2H_6$ +	$5O_2$ [limited]→	$4CO + 6H_2O + \Delta$
[$2\,C_2H_6$ +	$3O_2$[very limited]→	$4C + 6H_2O$]

Conditions: *IN LIMITED AIR OR OXYGEN* - ***Products*** - *In limited air or oxygen* - a] Carbon monoxide b] Water *In very limited air or oxygen* - a] Carbon black b] Water

CHEMICAL PROPERTIES – Methane & Ethane [contd.]

- **Catalytic oxidation** – gives – *alcohols, aldehydes & acids* – *depending on reaction conditions*

• $2CH_4$ methane	+	O_2	$\xrightarrow[200^oC]{\text{Cu tube}}$ $2\,CH_3OH$ methanol	CH_4 or C_2H_6 & air $[O_2]$ – passed in *ratio* : 9:1 [by vol.] *Catalyst* : **Copper [Cu] tube.** *Temp.* : 200°C [around 475 K] *Press* : 100 atmos.
$2C_2H_6$ ethane	+	O_2	$\xrightarrow[200^oC]{\text{Cu tube}}$ $2\,C_2H_5OH$ ethanol	

$2CH_3OH + O_2 \rightarrow 2HCHO + 2H_2O$ [Cu catalyst]
$2HCHO + O_2 \rightarrow 2H\text{-}COOH$ [Cu catalyst]
$2C_2H_5OH + O_2 \rightarrow 2CH_3CHO + 2H_2O$ [Cu catalyst]
$2CH_3CHO + O_2 \rightarrow 2CH_3COOH$ [Cu catalyst]

• CH_4 methane	+	O_2	$\xrightarrow[350\text{-}500^oC]{MoO}$ $HCHO + H_2O$ methanal	CH_4 or C_2H_6 & air $[O_2]$ – in presence of – *Catalyst* : **Molybdenum oxide.** *Temp.* : 350-500°C
C_2H_6 ethane	+	O_2	$\xrightarrow[350\text{-}500^oC]{MoO}$ $CH_3CHO + H_2O$ ethanal	

- **Controlled slow oxidation** – gives – *alcohols, aldehydes & acids*

ALKANES → ALCOHOL → ALDEHYDE → ACID

$CH_4 \xrightarrow[K_2Cr_2O_7]{[O]} CH_3OH \xrightarrow[K_2Cr_2O_7]{[O]} HCHO \xrightarrow[K_2Cr_2O_7]{[O]} HCOOH$

Methane — methanol [methyl alcohol] — methanal [formaldehyde] — methanoic acid [formic acid]

$C_2H_6 \xrightarrow[K_2Cr_2O_7]{[O]} C_2H_5OH \xrightarrow[K_2Cr_2O_7]{[O]} CH_3CHO \xrightarrow[K_2Cr_2O_7]{[O]} CH_3COOH$

Ethane — ethanol [ethyl alcohol] — ethanal [acetaldehyde] — ethanoic acid [acetic acid]

Alkanes on controlled oxidation with –
***Oxidising agent*: $K_2Cr_2O_7$.** [acidified with dil. H_2SO_4]
Press : High
Temp. : Low
Give –
a] The corresponding *alcohol* which on further oxidation give
b] The corresponding *aldehyde*
c] The corresponding *acid.*

In presence of oxidising agent – $K_2Cr_2O_7$ [acidified]

$CH_3OH + [O] \longrightarrow HCHO + H_2O$
$CH_3OH + 2[O] \longrightarrow HCOOH + H_2O$
$C_2H_5OH + [O] \longrightarrow CH_3CHO + H_2O$
$C_2H_5OH + 2[O] \longrightarrow CH_3COOH + H_2O$

C] PYROLYSIS

$2CH_4$ methane	$\xrightarrow{1500^oC}$	$HC \equiv CH + 3H_2$ ethyne	***Conditions: Thermal or catalytic decomposition*** – of alkanes in *absence of air* – at high temperatures is called – ***pyrolysis. Catalytic cracking is a dehydrogenation*** reaction.
$H_3C - CH_3$ ethane	$\xrightarrow[\text{catalyst } [Al_2O_3]]{500^oC}$	$H_2C = CH_2 + H_2$ ethene	

7. USES – Methane & Ethane

1. **Illuminant and domestic fuel.**	In the form of natural gas or gobar gas. [Hydrocarbons - have *high calorific value*. They are easily *combustible* & the reaction is *exothermic* - releasing heat energy. Hence they are *excellent fuels*]
2. **In manufacture of chemicals:** • **Chloroform** • **Carbon black** • **Formaldehyde** • **Methanol** • **Ethanol**	*Used as :-* Solvent for rubber, waxes. As an anaesthesia. A black pigment in shoe polishes, printers ink etc. An antiseptic, preservative for biological specimens. Solvent for varnishes, anti-freeze for automobiles. Solvent for resins, a low freezing liquid in thermometers.

H. ALKENES - Ethene – Introduction, Sources, Nomenclature

1. INTRODUCTION - Alkenes

- **ALKENES** – ***unsaturated aliphatic hydrocarbons*** containing a – ***carbon-carbon double bond*** [-C=C-] in their molecule.
  - Hydrocarbons in which valencies of atleast two carbon atoms – are *not fully satisfied by hydrogen atoms* and are deficient in hydrogen as compared to alkanes, are said to be – ***unsaturated***.
  - Alkenes are known as – ***olefins*** [*latin*: Oleum=oil; ficare=to make] They have tendency to form – oily products on treatment with halogens.
- **GENERAL FORMULA** – The ***general formula*** of alkenes is C_nH_{2n}. Alkenes have two hydrogen atoms less than the corresponding alkanes – which have general formula C_nH_{2n+2}.
  There is no alkene corresponding to methane [CH_4], hence the first member of the alkene series is ethene [ethylene] [C_2H_4 i.e. $CH_2=CH_2$] which corresponds to the alkane-ethane [C_2H_6 i.e. CH_3-CH_3].
- **REACTIVITY OF ALKENES** – Alkenes are – ***more reactive*** than alkanes – due to the presence of >C=C< carbon-carbon double bond called ***'olefenic bond'***.

2. SOURCES - Alkenes

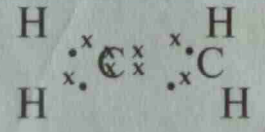
- **DISTRIBUTION** – Alkenes – seldom occur free in nature – though ethylene occurs naturally in small quantities in plants.
- **MAIN SOURCES** – Alkenes are however produced in large amounts during – thermal cracking of petroleum [hydrocarbons].

3. NOMENCLATURE - Alkenes – *There are two main ways of naming alkenes -*

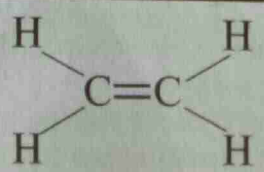
- **COMMON NAME SYSTEM** : The names of alkenes are derived from the – corresponding alkane by changing the suffix - ***'ane'*** into ***'ylene'***. eg. eth*ane* to eth*ylene*.
- **I.U.P.A.C. SYSTEM** : The names of alkenes are derived from the – corresponding alkane by changing the suffix ***'ane'*** into ***'ene'***. eg. ethane to ethene.

Structural formula - C_nH_{2n}	Common name	I.U.P.A.C. name	Corresponding alkane - C_nH_{2n+2}
$CH_2=CH_2$ C_2H_4	Ethylene	Ethene	CH_3-CH_3 ethane C_2H_6
$CH_3CH=CH_2$ C_3H_6	Propylene	Propene	$CH_3-CH_2-CH_3$ propane C_3H_8
$CH_3-CH_2-CH=CH_2$ C_4H_8	1-Butylene	1-Butene	$CH_3-CH_2-CH_2-CH_3$ butane C_4H_{10}
$CH_3-CH=CH-CH_3$	2-Butylene	2-Butene	
C_5H_{10}	1-Pentene $CH_3-CH_2-CH_2-CH=CH_2$	2-Pentene	$CH_3-CH_2-CH=CH-CH_3$

Structural formula of – Ethene [ethylene]



x = electrons of carbon
• = electrons of hydrogen
Electronic structure



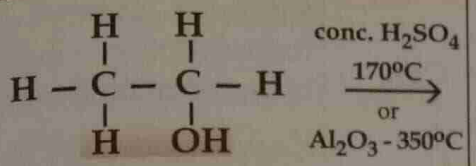
$CH_2 = CH_2$
Structural formula

- Two carbon atoms linked by a – *double covalent* bond.
- Double covalent bond formed by
  - sharing of two pairs of electrons
  - between the two carbon atoms.

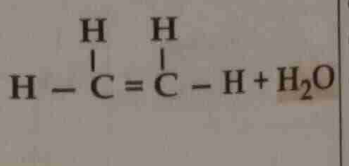
4. PREPARATION – Ethene *[ethylene]*

a] LAB. PREPARATION FROM –

Ethyl alcohol – by *dehydration*



$[CH_3.CH_2.OH]$
Ethanol [ethyl alcohol]

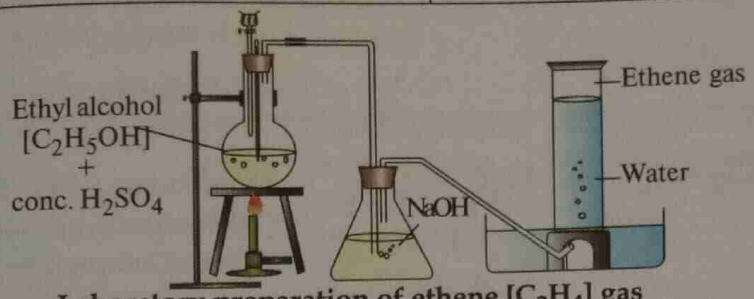


$[H_2C = CH_2]$
ethene [ethylene]

REACTANTS :
Ethyl alcohol [1 vol.] with **conc. H_2SO_4** [2 vol.] at 170°C or **ethyl alcohol** vapours with **alumina** $[Al_2O_3]$ at 350°C.
[*Dehydration* – involves elimination of elements of water from alcohol. Conc. H_2SO_4 and Al_2O_3 act as *dehydrating agents*.]

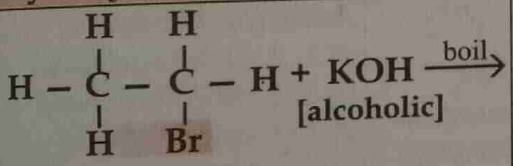
PURIFICATION:
Passage of ethene through NaOH soln. – removes CO_2 & SO_2 impurities formed by – oxidation of the hot acid.

PRODUCT:
Ethene is collected by downward displacement of water.

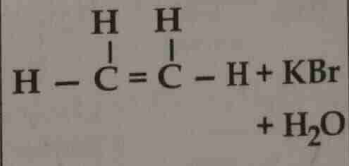


Laboratory preparation of ethene $[C_2H_4]$ gas

Bromo ethane – [ethyl bromide] by *dehydrohalogenation*



$[C_2H_5Br]$
Bromo ethane [Ethyl bromide]
[Chloro ethane [ethyl chloride - C_2H_5Cl] reacts similarly with - alcoholic KOH]



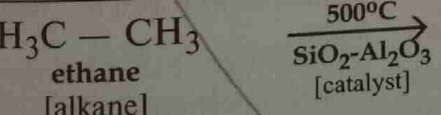
$[H_2C = CH_2]$
ethene [ethylene]

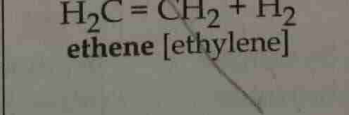
REACTANTS :
Alkyl halide – *Ethyl bromide* $[C_2H_5Br]$ & **hot, conc. alcoholic KOH soln.**
[*Dehydrohalogenation* – involves *elimination* of hydrogen halide.]

PRODUCT:
Ethene is collected by downward displacement of water.

b] GENERAL METHOD

Cracking or *dehydrogenation*





Ethane on thermal decomposition at high pressure & temp. in presence of catalyst silica alumina $[SiO_2\text{-}Al_2O_3]$ gives ethene. The reaction is a – ***pyrolysis*** reaction.

5. PHYSICAL PROPERTIES – Ethene *[ethylene]*

• **Nature, colour, odour**	Gas [at ordinary temp.]; Colourless gas; Pleasant odour.
• **Solubility**	Slightly soluble in water, soluble in organic solvents, eg. acetone, benzene.
• **Density**	Slightly less dense than air.
• **Melting & boiling point**	M.P. –169°C [liquefaction]; B.P. –104°C

6. CHEMICAL PROPERTIES – Ethene [ethylene]

• ADDITION REACTIONS

a] CATALYTIC HYDROGENATION

$H_2C = CH_2$ + H_2 —Nickel, 300°C→ $H_2C - CH_2$ (H, H)

Ethene [ethylene] → ethane

Catalytic hydrogenation: Saturated addition product formed due to – addition of hydrogen at the double bond.

Conditions : Vapours of ethene mixed with hydrogen are passed over a **catalyst** eg. nickel, [Pd or Pt] at – high temperatures.

Addition Product : Ethane

b] HALOGENATION

$H_2C = CH_2$ + Cl_2 —CCl_4 [inert solvent]→ $H_2C - CH_2$ (Cl, Cl)

Ethene [ethylene] → **1,2,dichloroethane** [ethylene dichloride]

$H_2C = CH_2$ + Br_2 —CCl_4 [inert solvent]→ $H_2C - CH_2$ (Br, Br)

Ethene [ethylene] → **1,2,dibromoethane** [ethylene dibromide]

C_2H_4 + I_2 —CCl_4→ $C_2H_4I_2$

Ethene [ethylene] → **1,2, di iodoethane**

Conditions : The halogen – ***Chlorine gas*** [one mole] or ***Bromine*** is passed into a solution of ethene [one mole] in an inert solvent [CCl_4] at room temperature. ***Iodine*** reaction is very difficult.

Addition Products :
a] 1, 2, dichloroethane
b] 1, 2, dibromoethane
c] 1, 2, diiodoethane

CHEMICAL TEST : Brown colour of bromine discharged-serves as a ***test for unsaturation.***

c] HALOGEN ACIDS

$H_2C = CH_2$ + **HBr** → $H_2C - CH_2$ (H, Br)

Ethene [ethylene] → **hydrogen bromide** → **bromoethane** [ethyl bromide]

$H_2C = CH_2$ + **HCl** → CH_3CH_2Cl

[CH_3CH_2Cl + **KOH** → C_2H_5OH + KCl]

Conditions : Halogen acids [i.e. HCl, HBr, HI] adds on to ethene at room temperature.

Product : Ethyl halide – Bromoethane [with HBr]

Chlorooethane [with HCl]

[Chloroethane with KOH soln. – gives ethanol]

d] SULPHURIC ACID

$H_2C = CH_2$ + $H{\cdot}HSO_4$ [H_2SO_4] conc. → $H_2C - CH_2$ (H, HSO_4)

Ethene [ethylene] → **ethyl hydrogen sulphate**

Conditions :
Ethene reacts with conc. H_2SO_4 at room temperature.

Product :
Ethyl hydrogen sulphate [on hydrolysis gives ethyl alcohol]

CHEMICAL PROPERTIES – Ethene [Contd.]

e] OZONE			
$H_2C = CH_2$ +	O_3 ether →	$H_2C-O-CH_2$ O — O	*Conditions :* Stream of ozone passed through a – soln. of ethene in an inert solvent ether. *Product :* Ethylene ozonide
Ethene [ethylene]	ozone	ethylene ozonide	
f] OXIDATION			
– With cold dil. $KMnO_4$			
$H_2C = CH_2$ +	HOH + [O] → [H_2O]	$H_2C - CH_2$ OH OH	*Conditions :* Ethene passed through cold dil. $KMnO_4$ soln. at room temp.
Ethene [ethylene]	cold dil. alkaline $KMnO_4$ soln. [oxidising agent] *[BAEYER'S REAGENT]*	ethane-1,2 diol [ethylene glycol]	*Product :* Ethylene glycol *CHEMICAL TEST : Purple* $KMnO_4$ is first converted into green K_2MnO_4 which is unstable in an alkaline medium & gets converted to brown MnO_2, the supernatant liquid being ***decolourised***.
– Combustion C_2H_4 +	$3O_2$ →	$2CO_2 + 2H_2O + \Delta$	Ethene burns in air with a sooty flame. In excess air it burns with a pale blue flame
g] POLYMERIZATION			
$n\ H_2C = CH_2$	high temperature high pressure catalyst →	$[H_2C - CH_2]_n$	*Conditions :* Polymerization – a process by which simple molecules join to form – large molecules at high – temp. & press. in the presence of – catalyst HF, H_2SO_4, peroxides. *Product :* Polyethylene [an important polymer – plastic]
Ethene [ethylene]	polymerization	polyethylene	

7. USES – Ethene [ethylene]

• Production of oxy-ethylene torch	For welding purposes and cutting metals.
• Ripening of green fruits	Artificial ripening and preservation of fruits.
• Catalytic hydrogenation	Used in hardening of oils. [unsaturated carbon chains]
• Manufacture of : a] Synthetic chemicals	Ethylene glycol [anti-freeze], di-ethyl ether [solvent], ethylene oxide [fumigant], mustard gas [chemical warfare]
b] Polymers	Polyethylene, polyvinyl chloride [P.V.C.] - used in packaging, insulators, containers, rain coats etc.

I. ALKYNE - Ethyne – Introduction, Sources, Nomenclature

1. INTRODUCTION – Alkynes

- **ALKYNES** – ***unsaturated aliphatic hydrocarbons*** containing a – ***carbon-carbon triple bond*** [$-C \equiv C-$] in their molecule.
- **GENERAL FORMULA** – The ***general formula*** of alkynes is $\mathbf{C_nH_{2n-2}}$.

  Alkynes have four hydrogen atoms less than the corresponding alkanes which have general formula C_nH_{2n+2}. The first member of the alkyne series is ethyne (acetylene) C_2H_2 i.e. $CH \equiv CH$ which corresponds to the alkane - ethane [C_2H_6 i.e. CH_3-CH_3].
- **REACTIVITY** – Alkynes are *more reactive* than alkenes – due to the presence of $>C \equiv C<$ carbon-carbon triple bond often referred to as *'acetylenic linkage'*. The first and most important member of this series of hydrocarbons is – acetylene and hence the series is also referred as – ***'acetylene series'***.

2. SOURCES – Alkynes

- **DISTRIBUTION** – Naturally occurring alkynes are encountered less frequently – than even alkenes.
- **MAIN SOURCES** – The most important and useful alkyne - acetylene is nowadays produced primarily from *natural gas* and from higher alkanes obtained from *petroleum*. [acetylene is manufactured on a large scale by action of water on calcium carbide].

3. NOMENCLATURE – Alkynes – *There are two main ways of naming alkynes -*

- **COMMON NAME SYSTEM** : Acetylene is the common name for the – first member of the series. The system is now obsolete and further the – *derived name system* is now applicable where the members are considered as – alkyl derivatives of acetylene eg. methyl acetylene.
- **I.U.P.A.C. SYSTEM** : The names of the members are derived from the – corresponding alkanes by changing the suffix - ***'ane'*** to ***'yne'*** eg. ethane to ethyne.

Structural Formula - C_nH_{2n-2}	Derived [common] name	I.U.P.A.C. name	Corresponding alkane C_nH_{2n+2}
$CH \equiv CH$ C_2H_2	Acetylene	Ethyne	CH_3-CH_3 ethane C_2H_6
$CH_3-C \equiv CH$ C_3H_4	Methyl acetylene	Propyne	$CH_3-CH_2-CH_3$ propane C_3H_8
$CH_3-CH_2-C \equiv CH$ C_4H_6	Ethyl acetylene	1-Butyne	$CH_3-CH_2-CH_2-CH_3$ C_4H_{10} butane
$CH_3-C \equiv C-CH_3$	Dimethyl acetylene	2-Butyne	
C_5H_8	1-Pentyne $CH_3-CH_2-CH_2-C \equiv CH$	2-Pentyne $CH_3-CH_2-C \equiv C-CH_3$	

Structural formula - of Ethyne [acetylene]

H ·x C x x x x C x· H x = electrons of carbon · = electrons of hydrogen **Electronic structure**	H–C ≡ C–H CH ≡ CH **Structural formula**	• Two carbon atoms linked by a – *triple covalent* bond. • Triple covalent bond formed by – sharing three pairs of electrons – between the two carbon atoms.

4. PREPARATION – Ethyne [acetylene]

a] LAB. PREPARATION FROM –		**REACTANTS :**
Calcium carbide		**Calcium carbide & cold water**
$Ca\begin{matrix}C\\ \vdots\\ C\end{matrix}$ + $\begin{matrix}H-OH\\ H-OH\end{matrix}$ ⟶ $\begin{matrix}CH\\ \vdots\\ CH\end{matrix}$ + $Ca(OH)_2$ $[CaC_2]$ calcium carbide $[2H_2O]$ water $[C_2H_2]$ ethyne [acetylene] Preparation of calcium carbide $[CaO + 3C \xrightarrow{2000^oC} CaC_2 + CO]$		**PROCEDURE:** Cold water is added dropwise through a thistle funnel into conical flask containing calcium carbide at room temp. **PURIFICATION:** Impurities i.e. phosphine, H_2S, NH_3 and arsine are formed. Passage of ethyne through water absorbs – all impurities except phosphine which is absorbed in – acidified $K_2Cr_2O_7$. **COLLECTION:** By downward displacement of water.
1,2 dibromoethane **[ethylene dibromide]**		**REACTANTS :** **1,2 dibromo ethane & hot conc. alcoholic potassium hydroxide**
$\begin{matrix}CH_2Br\\ \vert\\ CH_2Br\end{matrix}$ + 2KOH [alcoholic] $\xrightarrow{\text{boil}}$ $\begin{matrix}CH\\ \vdots\\ CH\end{matrix}$ + 2KBr + $2H_2O$ **1,2,dibromo ethane** [ethylene dibromide] $[C_2H_2]$ **ethyne** [acetylene] **Dehydrohalogenation reaction**		**PROCEDURE:** 1,2 dibromo ethane is boiled with conc. alcoholic KOH soln. – in a round bottom flask. **COLLECTION:** By downward displacement of water.
b] GENERAL METHOD		
Methane or Natural gas		
$2CH_4$ **methane** [by pyrolysis] $\xrightarrow[\text{electric arc}]{1500^oC}$ $CH \equiv CH + 3H_2$ **ethyne** [acetylene]		**Methane** on thermal decomposition at around 1500°C in an electric arc gives ethyne.

5. PHYSICAL PROPERTIES – Ethyne *[acetylene]*

• **Nature**	Gas at ordinary temperatures, slightly lighter than air.
• **Colour and odour**	Colourless, faint garlic odour
• **Solubility**	Very slightly soluble in water, soluble in organic solvents, eg. acetone
• **Melting point**	–82°C [liquefies at -84°C under ordinary pressure]
• **Boiling point**	–75°C

6. CHEMICAL PROPERTIES – Ethyne [acetylene]

• ADDITION REACTIONS

a] CATALYTIC HYDROGENATION

$H\text{-}C \equiv C\text{-}H + H_2 \xrightarrow[300^oC]{Ni}$ $H\text{-}C=C\text{-}H \xrightarrow[300^oC]{+H_2, Ni}$ $H_3C\text{-}CH_3$

Ethyne [acetylene] → **ALKYNE** → **ethene** → **ALKENE** → **ethane** → **ALKANE**

Catalytic hydrogenation: Saturated addition product formed due to addition of hydrogen in – *two stages.*

Conditions: Vapours of ethyne mixed with hydrogen are passed over a catalyst eg. nickel [Pd or Pt] at high temperatures.

Addition Products :

a] Ethene [alkene] – 1st stage

b] Ethane [alkane] – 2nd stage

b] HALOGENATION

$H\text{-}C \equiv C\text{-}H + Cl_2 \xrightarrow{CCl_4}$ $H\text{-}C=C\text{-}H \xrightarrow{+Cl_2}$ $H_2C(Cl)\text{-}C(Cl)H_2$

Ethyne [acetylene] → **1,2,dichloro-ethene** [acetylene dichloride] → **1,1,2,2, tetra-chloroethane** [acetylene tetrachloride]

$H\text{-}C \equiv C\text{-}H + Br_2 \xrightarrow{CCl_4}$ $H\text{-}C=C\text{-}H \xrightarrow{+Br_2}$ $H_2C(Br)\text{-}C(Br)H_2$

Ethyne [acetylene] → **1,2,dibromo-ethene** [acetylene dibromide] → **1,1,2,2, tetra-bromoethane** [acetylene tetrabromide]

$C_2H_2 + I_2 \xrightarrow{alcohol} C_2H_2I_2$

Ethyne [acetylene] → [acetylene di iodide]

Conditions : The halogen – ***Chlorine gas*** or ***Bromine*** is passed into a solution of ethyne in an inert solvent [CCl_4] – at room temperatures.

Addition Products :

a] 1,2, dichloroethene – 1st stage

1,1,2,2, tetrachloroethane – Finally

b] 1,2, dibromoethene – 1st stage

1,1,2,2, tetrabromoethane–Finally

CHEMICAL TEST : Brown colour of bromine discharged – serves as a ***test for unsaturation.***

[The reddish brown liquid – bromine dissolved in water, turns colourless when ethyne is passed through it.]

Acetylene reacts with iodine with difficulty giving acetylene di iodide ***[ICH = CHI]*** as the only end product.

c] HALOGEN ACIDS

$H\text{-}C \equiv C\text{-}H + HBr \xrightarrow{+HBr}$ $H_2C=C(H)Br$ $\xrightarrow{+HBr}$ $H_3C\text{-}CHBr_2$

Ethyne [acetylene] → [H_2C=CHBr] **Bromoethene** → [$H_3C\text{-}CHBr_2$] **1,1-Dibromoethane**

$H\text{-}C \equiv C\text{-}H + HCl \rightarrow$ [H_2C=CHCl] → **Chloroethene** → [$H_3C\text{-}CHCl_2$] **1,1-Dichloroethane**

Conditions: Halogen acids i.e. [HCl, HBr, HI] add on to acetylene – at room temps.

Addition Products :

Bromoethene – 1st stage

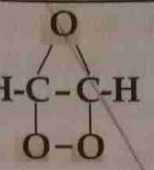
1,1-Dibromoethane – Finally

Chloroethene – 1st stage

1,1-Dichloroethane – Finally

[In presence of peroxides, 1,2,dibromo or 1,2dichloroethane obtained.

CHEMICAL PROPERTIES – Ethyne [contd.]

d] OZONE			
$H\text{-}C \equiv C\text{-}H$ + Ethyne [acetylene]	O_3 → ozone	 acetylene ozonide	*Conditions :* Acetylene reacts with ozone at ordinary temps. *Addition Product :* Acetylene ozonide [which on decomposition with water in presence of Zn yields glyoxal (CHO–CHO)].
e] OXIDATION			
- With dil. alk. $KMnO_4$ $HC \equiv CH$ + ethyne [acetylene]	4[O] → dil. alk. $KMnO_4$ [oxidising agent] [BAEYERS REAGENT]	COOH | COOH Ethane dioic acid [oxalic acid]	*CHEMICAL TEST :* Purple colour of $KMnO_4$ discharged or turns green– serves as a *test for unsaturation.*
- Combustion $2C_2H_2$ +	$5O_2$ →	$4CO_2 + 2H_2O + \Delta$	Ethyne burns in air with a sooty flame. In excess air it burns with a brilliant white flame evolving heat.
f] AMMONIACAL CUPROUS CHLORIDE			
$H\text{-}C \equiv C\text{-}H$ + Ethyne [acetylene]	$2CuCl + 2NH_4OH$ →	$Cu\text{-}C \equiv C\text{-}Cu$ + copper acetylide $2NH_4Cl + 2H_2O$	*Conditions:* Acetylene reacts with ammoniacal cuprous chloride or silver nitrate solutions at – room temp. *Addition Product :* Respective acetylide *Copper* or *Silver acetylide*
AMMONIACAL SILVER NITRATE			
$H\text{-}C \equiv C\text{-}H$ + Ethyne [acetylene]	$2AgNO_3 + 2NH_4OH$ →	$Ag\text{-}C \equiv C\text{-}Ag$ + silver acetylide $2NH_4NO_3 + 2H_2O$	*CHEMICAL TEST:* Formation of coloured precipitates – a] *Red ppt.* of copper acetylide b] *White ppt.* of silver acetylide Serves as *test for – Ethyne only*

7. USES – Ethyne [acetylene]

• Production of oxy-acetylene torch	For welding and cutting metals [flame temp. 3500°C] $2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O + \Delta$ [exothermic reaction] [Hence acetylene is commonly used for *welding purposes*]
• Ripening of green fruits	Artificial ripening and preservation of fruits.
• Manufacture of organic compounds	Acetic acid [manufacture of polyvinyl acetate, vinegar], Acetaldehyde [manufacture of dyes, acetic anhydride], Acetylene dichloride [solvent], Ethyl alcohol [drugs, antiseptic], oxalic acid [for removing ink stains].
• Manufacture of synthetic products	Polymers [polyvinylacetate], synthetic rubbers and fibres.

J. ALCOHOLS - Ethanol – Introduction, Sources, Nomenclature

1. INTRODUCTION - Alcohols

- **ALCOHOLS - are *'hydroxy' derivatives of alkanes,*** obtained by replacement of – one, two or three hydrogen atoms of alkanes by – the corresponding number of hydroxyl [-OH] groups.
  e.g. Alkane – ***Ethane*** [C_2H_6], Corresponding alcohol – ***Ethanol*** [C_2H_5·OH]
- **FUNCTIONAL GROUP - OF ALCOHOLS –**
  The ***hydroxyl group*** is the – *functional group* of alcohols.
  Alcohols are classified according to the number of hydroxyl groups – attached to a saturated carbon atom
  i.e. **Monohydric alcohols** – One OH group; **Dihydric alcohols** – Two OH groups.
- **FORMULA – OF ALCOHOLS -** Monohydric alcohols –
  i.e. *General formula* **R-OH;** *General molecular formula* $C_nH_{2n+1}OH$.
  [They are further classified as ***primary, secondary*** or ***tertiary monohydric alcohols*** – depending on the attachment of the -OH group to the specified carbon atom.]

2. SOURCES - Alcohols

- **DISTRIBUTION** - Alcohols are not – generally found in nature.
- **MAIN SOURCES** - Ethanol was obtained by – fermentation of *sugars.*
  Ethanol is also produced from ethene which is abundantly available as a by-product of the – *cracking of petroleum.*

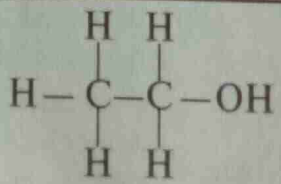
3. NOMENCLATURE - Alcohols

There are two main ways of naming alcohols -

- **COMMON NAME SYSTEM :** In this system alcohols [R-OH] are named as *alkyl alcohols.* The alkyl group attached to the -OH group is named & 'alcohol' is added – as a separate word i.e. *alkane* - ethane; *alkyl group* - ethyl; *alcohol* - ethyl alcohol.
- **I.U.P.A.C. SYSTEM :** In this system alcohols are named as – *alkanols* where the longest continuous carbon chain containing the -OH group is selected and the name of the alkane corresponding to this chain is changed by dropping the – ending **'-e'** and adding suffix - **'ol'** i.e. ***alkane*** - ethane; ***alcohol*** - ethanol.

Condensed Structural Formula	Trivial or Common name	I.U.P.A.C. name	Corresponding alkane C_nH_{2n+2}
$CH_3.OH$	Methyl alcohol	Methanol	CH_4 - methane
$CH_3.CH_2.OH$	Ethyl alcohol	Ethanol	CH_3-CH_3 - ethane
$CH_3.CH_2.CH_2.OH$	n-Propyl alcohol	Propan-1-ol	CH_3-CH_2-CH_3-propane
$CH_3.CHOH.CH_3$	iso-Propyl alcohol	Propan-2-ol	

Branched structural formula – of Ethanol



Ethyl alcohol - CH_3-CH_2-OH

4. PREPARATION – Ethanol

a] LAB. PREPARATION BY –		
• HYDROLYSIS OF ALKYL HALIDES		
Alkyl halide + Alkali soln. $\xrightarrow{\text{boil}}$	Alcohol	**Ethyl alcohol can be prepared by hydrolysis of alkyl halide with aqueous alkali solns.** **Conditions :** Ethyl halide [C_2H_5-X, X = Cl, Br, I] is boiled with aq. alkalis
C_2H_5-Cl + NaOH [aq] $\xrightarrow{\text{boil}}$ **Chloroethane** [ethyl chloride] [or monochloro ethane & aq. KOH]	C_2H_5-OH + NaCl **Ethanol [ethyl alcohol]**	
C_2H_5-Br + KOH [aq] $\xrightarrow{\text{boil}}$ **Bromoethane** [ethyl bromide] [or bromoethane & aq. NaOH]	C_2H_5OH + KBr **Ethanol [ethyl alcohol]**	
b] INDUSTRIAL METHOD		
• HYDRATION OF ETHENE		
C_2H_4 + H_2SO_4 [conc.] $\xrightarrow[30\text{ atmos.}]{80^oC}$ **Ethene**	C_2H_5-HSO_4 **Ethyl hydrogen sulphate**	**Conditions:** ***Ethene*** is absorbed in conc. H_2SO_4 at 80°C. under 30 atmospheric pressure to give ***ethyl hydrogen sulphate,*** which on *hydrolysis with – steam* gives **– *ethanol.***
C_2H_5-HSO_4 + H_2O [steam] $\longrightarrow$ **Ethyl hydrogen sulphate**	C_2H_5-OH+H_2SO_4 **Ethanol [ethyl alcohol]**	
[C_2H_4 + H_2O $\xrightarrow[\text{[acid]}]{H^+}$ C_2H_5-OH] ethene, water [steam], ethanol		*[Hence ethene reacts with water (steam) in presence of an acid eg. phosphoric or sulphuric acid, to give ethanol]*
• By fermentation of carbohydrates – sucrose		
$C_{12}H_{22}O_{11}$ + H_2O $\xrightarrow[\text{[yeast]}]{\text{invertase}}$ **Cane sugar [molasses]**	$C_6H_{12}O_6$ + $C_6H_{12}O_6$ **Glucose** **Fructose**	**Conditions:** ***Yeast*** which contains enzyme ***invertase*** is added to ferment the sucrose soln. The enzyme ***zymase*** also in yeast further ferments ***glucose*** – to – ***ethanol.***
$C_6H_{12}O_6$ **Glucose** $\xrightarrow[\text{fermentation}]{\text{zymase [yeast]}}$	$2C_2H_5OH$ + $2CO_2$ **Ethanol**	

5. PHYSICAL PROPERTIES – Ethanol

• Nature	Inflammable volatile liquid. Toxic in nature. Small doses of methanol can cause blindness or death.
• Colour and odour	Colourless liquid with characteristic pleasant odour.
• Solubility	*Soluble* in water and *soluble* in almost all organic solvents. It is a good solvent for oils, fats and resins and dissolves inorganic substances like sulphur and phosphorus.
• Density	Specific gravity 0.789 at 20°C.
• Boiling point	Ethyl alcohol : 78.1°C.

ALCOHOLS - Ethanol – Chemical properties, Uses [Contd.]

6. CHEMICAL PROPERTIES – Ethanol

a] COMBUSTION -			
C_2H_5OH + **ethanol**	$3O_2$	$\longrightarrow 2CO_2 + 3H_2O$	**Conditions:** Burns in air or oxygen with a blue flame forming carbon dioxide and water.
b] OXIDATION - $K_2Cr_2O_7$			
C_2H_5OH **ethyl alcohol [ethanol]** ALCOHOL	$\xrightarrow[K_2Cr_2O_7\ \text{[acidified]}]{[O]}$	CH_3CHO **acetaldehyde** ALDEHYDE	$\xrightarrow[K_2Cr_2O_7\ \text{[acidified]}]{[O]}$ CH_3COOH **acetic acid** ACID	**Conditions:** Reaction with oxidising agents – *Acidified* $K_2Cr_2O_7$ or aq. $KMnO_4$ which supply nascent [O] for oxidation. Reaction at high pressure & low temp.
c] SODIUM			
$2C_2H_5OH$ + **ethanol**	$2Na$	$\longrightarrow 2C_2H_5ONa + H_2$ **sodium ethoxide**	**Condition:** Reaction with sodium metal ***at room temp.*** **Chemical Test:** Effervescence of H_2 serves as a ***–Test for alcohols.***
d] ACETIC ACID			
C_2H_5OH + **ethanol [ethyl alcohol]**	$\xrightarrow{\text{conc. } H_2SO_4}$ CH_3COOH **ethanoic acid [acetic acid]**	$CH_3\text{-}COO\text{-}C_2H_5 + H_2O$ **ethyl acetate [ethyl ethanoate]**	**Conditions:** Reaction with carboxylic acid [acetic acid] in presence of conc H_2SO_4 at high temps. give – **esters** which have a fruity smell - **Test for alcohols.** ***ESTERIFICATION REACTION.*** ***[A distinctive reaction that takes place when — ethanol is treated with acetic acid.]***
e] SULPHURIC ACID [Conc.]			
C_2H_5OH **ethyl alcohol**	$\xrightarrow[\text{[excess]}\ 170^oC]{\text{conc. } H_2SO_4}$	$CH_2 = CH_2 + H_2O$ **ethene**	**Conditions:** Reaction with ***excess conc.*** H_2SO_4 at 170°C causes *dehydration* of ethyl alcohol to give – ethene. With ***excess ethyl alcohol*** - at 140°C diethyl ether is formed.
$2C_2H_5OH$ [excess]	$\xrightarrow[140^oC]{\text{conc. } H_2SO_4}$	$C_2H_5\text{-}O\text{-}C_2H_5 + H_2O$ **diethyl ether**	
• $3C_2H_5OH$ +	PCl_3	$\longrightarrow 3C_2H_5Cl + H_3PO_3$ **chloroethane**	

7. USES – Ethanol

- **As a solvent** – For gums and resins
- **In thermometers and spirit levels** – Low freezing mobile liquid. [freezing point - 114.1°C]
- **In manufacture of chemicals** – Acetaldehyde [dyes], acetic acid [manufacture of vinegar], chloroform [antiseptic] diethyl ether [anaesthetic].

Spurious alcohol - Alcohol is used in the *distilled form* for human consumption. *Undistilled alcohol* contains large amounts of – *methanol* in the mixture & is called *spurious* or *illicit alcohol*. It is fatal for human consumption. Spurious alcohol may be used as a – solvent for paints, varnishes etc.
Methylated spirit or alcohol – Ethyl alcohol containing about 5% *methyl alcohol* is termed – *methylated spirit*.
Denaturated alcohol – Ethyl alcohol containing *pyridine* or *copper sulphate* is termed – *denaturated alcohol*.
[Methylated spirit and denaturated alcohol are used for – industrial applications only & hence made undrinkable.]

4. CARBOXYLIC ACIDS - Acetic acid – Introduction, Sources, Nomenclature

1. INTRODUCTION - Carboxylic acids

- **CARBOXYLIC ACIDS** – *are organic compounds containing carboxylic group* i.e. $-\overset{\overset{O}{\|}}{C}-OH$ [a *carboxyl group* (>C=O) and a *hydroxyl group* (OH)] – *attached to an – alkyl group [e.g. CH_3 – methyl] or to a – hydrogen atom.*

e.g. $H-\overset{\overset{O}{\|}}{C}-OH$ *[formic acid]* or $H-\overset{\overset{H}{|}}{\underset{\underset{H}{|}}{C}}-\overset{\overset{O}{\|}}{C}-OH$ *[acetic acid].*

- *Representation of – carboxylic acids* : **R–COOH** [R is either – H or alkyl]
- *Functional group of – carboxylic acids* : **–COOH** [carboxylic]
  [The acidic character in carboxylic acids is due to the presence of – the replaceable hydrogen atom in the – carboxylic group.]
- **CLASSIFICATION** – *Carboxylic acids are classified as* – monocarboxylic acid, di, tri... – carboxylic acid depending on the – number of – COOH groups present in the molecule.
  e.g. acetic acid [CH_3–COOH] is a *monocarboxylic acid* and is a *monobasic acid.*
  [Monocarboxylic acids of aliphatic series are commonly called – fatty acids as many of them e.g. palmitic acid are constituents of – fats & oils].

2. SOURCES - Acetic acid – *ethanoic acid*

- Acetic acid is a – fatty acid and the chief constituent of *vinegar* [latin - acetum]
- It occurs in the *free state* – in fruit juices which on fermentation have gone sour.
  It is present in the *combined state* – in 'plant extracts'.

3. NOMENCLATURE - Carboxylic acids –

There are two main ways of naming carboxylic acids -

- **COMMON [TRIVIAL] NAME SYSTEM** : In this system the carboxylic acids [R–COOH] have names of lower members derived from Latin or Greek word – indicating the source of the acid. The common names have ending *–ic acid.*
  e.g. *Formic acid* [HCOOH]; *Source:* red ant [*Latin* : ant = formica] hence *formic acid.*
  Acetic acid [CH_3COOH]; *Source:* vinegar [*Latin* : vinegar = acetum] hence *acetic acid.*
- **I.U.P.A.C. SYSTEM** : In this system the acids are named as – ***alkanoic acids*** – *'e'* of corresponding alkane replaced by – ***'oic acid'***.
  e.g. *Acetic acid* – alkane – ethan*'e'* + oic acid: Hence ethan*oic acid.*

Condensed Structural formula	Trivial or Common name	I.U.P.A.C. name	Corresponding alkane
H – COOH	Formic acid	Methanoic acid	Methane
CH_3 – COOH	Acetic acid	Ethanoic acid	Ethane
$CH_3 - CH_2$ – COOH	Propionic acid	Propanoic acid	Propane
$CH_3 - CH_2 - CH_2$ – COOH	Butyric acid	Butanoic acid	Butane
$CH_3-\underset{\underset{CH_3}{|}}{CH}$ – COOH	Iso butyric acid	2-methyl propanoic acid	Butane

In case of substituted carboxylic acids, the longest chain including – COOH group is selected – and numbering is done from the side of the carboxyl group for its I.U.P.A.C. name.

4. PREPARATION – Acetic acid – *ethanoic acid*

• **BY OXIDATION OF** *Ethyl alcohol*		
C_2H_5OH + [O] $\xrightarrow[\text{acidified}]{K_2Cr_2O_7}$ CH_3CHO + H_2O **Ethyl alcohol** **Acetaldehyde** CH_3CHO + [O] $\xrightarrow[\text{acidified}]{K_2Cr_2O_7}$ CH_3COOH **Acetaldehyde** **Acetic acid**		Oxidation of primary alcohols with acidified $K_2Cr_2O_7$ give aldehydes which on further oxidation give – *carboxylic acids.*
• **By Hydrolysis of –** *Ethyl acetate*		
$CH_3COOC_2H_5$ + H_2O $\xrightarrow[\text{conc. } H_2SO_4]{\text{hydrolysis}}$ CH_3COOH + C_2H_5OH **Ethyl acetate** **Acetic acid** **Ethyl alcohol**		Hydrolysis of *ethyl acetate* results in formation of – *acetic acid.*

5. PHYSICAL PROPERTIES – Acetic acid

• **Physical state**	At ordinary temperatures, acetic acid is a colourless liquid.
• **Odour, solubility**	Pungent odour of ***vinegar.*** Miscible with water, alcohol & ether.
• **Boiling point**	It boils at 118°C [there is strong hydrogen bonding between the acid molecules and hence acetic acid has a high boiling point].
• **Liquefaction**	***Pure acetic acid forms an ice like solid on cooling [glacial acetic acid]*** Anhydrous acetic acid on cooling below 16.5°C crystallizes out in the pure form, forming a crystalline mass resembling ice [m.p. around 17°C]. Hence pure acetic acid is called ***'glacial acetic acid'.***

6. CHEMICAL PROPERTIES – Acetic acid

1. ACIDIC NATURE	Product/s
a] *Litmus*	Aqueous solution of acid, turns - ***blue litmus red.***
b] *Alkalis*	
CH_3COOH + $NaOH$ →	CH_3COONa + H_2O **Sodium acetate**
$2CH_3COOH$ + $Ca(OH)_2$ →	$(CH_3COO)_2Ca$ + $2H_2O$ **Calcium acetate**
CH_3COOH + NH_4OH →	CH_3COONH_4 + H_2O **Ammonium acetate**
	Acetic acid is ***neutralized*** by ***alkalis*** – forming the corresponding ***salt*** *[acetate]* & ***water.*** [$CH_3COONa + HCl \rightarrow CH_3COOH + NaCl$]

CHEMICAL PROPERTIES – Acetic acid [contd.]

ACIDIC NATURE – [Contd.]

c) *Sodium carbonate/bicarbonate*

$2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COONa + H_2O + CO_2$

$CH_3COOH + NaHCO_3 \rightarrow CH_3COONa + H_2O + CO_2$

sodium acetate; water; carbon dioxide

Effervescence is seen due to evolution of carbon dioxide

d) *Active metals – Na, Mg*

$2CH_3COOH + 2Na \rightarrow 2CH_3COONa + H_2$

sodium; sodium acetate; hydrogen

$2CH_3COOH + Mg \rightarrow (CH_3COO)_2Mg + H_2$

magnesium; magnesium acetate; hydrogen

Acetic acid reacts with *strong electropositive metals* to give the corresponding – salts with liberation of hydrogen.

2. REACTION WITH – ALCOHOLS

$CH_3COOH + C_2H_5OH \xrightleftharpoons{\text{Conc } H_2SO_4 \text{ or dry HCl gas}} CH_3COOC_2H_5 + H_2O$

Acetic acid [Ethanoic acid]; Ethyl alcohol [Ethanol]; Ethyl acetate [ester] – *IUPAC name - Ethyl ethanoate*

Esterification: Condensation of an alcohol with an acid.

Acetic acid on heating with an alcohol & a dehydrating agent [conc. H_2SO_4] gives an **ester** – ethyl acetate.

[Reversible reaction may be prevented by using conc. H_2SO_4 when the reaction is carried to completion by removal of H_2O].

The above reaction is the conversion of –

Ethanoic acid *[CH_3COOH] to* ***Ethyl ethanoate*** *[$CH_3COOC_2H_5$].*

Tests for acetic acid:

Esters have a *fruity smell* - *serves as a test for acetic acid.*

Acetic acid also reacts with neutral $FeCl_3$ soln. - to give a wine red colour - *also serves as a test for acetic acid.*

$3CH_3COOH + PCl_3 \rightarrow 3CH_3COCl + H_3PO_3$

$CH_3COOH + PCl_5 \rightarrow CH_3COCl + POCl_3 + HCl$

acetyl chloride

On reacting with phosphorus trichloride & phosphorus pentachloride – gives acetyl chloride

$2CH_3COOH \xrightarrow{P_2O_5} (CH_3CO)_2O + H_2O$

acetic anhydride

On heating with P_2O_5 a dehydrating agent – gives acetic anhydride

$CH_3COOH + 4[H] \xrightarrow{LiAlH_4} C_2H_5OH + H_2O$

ethanol

On reacting with $LiAlH_4$ a reducing agent – gives ethanol

USES – Acetic acid

- In manufacture of important organic compounds
- In the food industry
- As a solvent
- As a laboratory reagent
- As a coagulant

Acetic acid is used in the preparation of – Vinyl acetate [used in resins], acetic anhydride [used in aspirin], cellulose acetate [used in synthetic fibres], various dyes, perfumes and medicines.

It is used in the food industry as – vinegar for preserving and flavouring food.

It dissolves – phosphorus, sulphur and iodine.

It is used for preparing – acetone, esters etc.

For coagulating rubber.