IGCSE CHEMISTRY 0620 · CHAPTER 11 NOTES · ~14 MIN READ

Organic chemistry

The chemistry of carbon compounds made clear: how to name and draw them, crude oil and cracking, alkanes and alkenes, alcohols, acids, esters and polymers.

Homologous series | Alkanes | Alkenes | Isomers | Alcohols | Carboxylic acids | Esters | Polymers

RS by Riyaz Sir
mentorriyaz.in

No tag = **Core** (everyone) EXTENDED Extended only highlight = comes up again and again

Test yourself at the end

IN 30 SECONDS

- Organic compounds are built on **carbon chains**. A **homologous series** is a family with the **same functional group** and similar reactions.
- **Alkanes** (C–C single bonds) are **saturated** and burn. **Alkenes** (C=C double bond) are **unsaturated** and react by **addition**. Bromine water turns colourless with alkenes.
- **Crude oil** is separated by **fractional distillation**. **Cracking** turns long alkanes into short alkanes and alkenes.
- **Alcohols** end in **-ol**, **carboxylic acids** in **-oic acid**. **Polymers** are made from many monomers.

BY THE END YOU CAN

- Draw and name the first four members of the alkane, alkene, alcohol and carboxylic acid series.
- Describe fractional distillation of crude oil and the uses of the fractions.
- Describe cracking, and the reactions and tests of alkanes and alkenes.
- Describe how ethanol is made and its uses, and the reactions of ethanoic acid.
- Describe polymerisation and the environmental problems of plastics.
- Draw structural isomers, name esters and describe condensation polymers. EXT

1 Naming and drawing carbon compounds

The key words

Hydrocarbon — a compound containing only **hydrogen and carbon**.

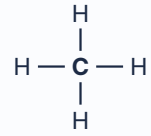
Homologous series — a family of compounds with the **same functional group**, the same general formula and similar chemical properties. Each member differs from the next by CH_2. Physical properties change gradually (e.g. boiling point rises).

Functional group — the atom or group of atoms that gives a compound its characteristic reactions.

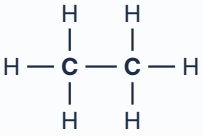
Saturated — contains only **single** C–C bonds. **Unsaturated**

The four families

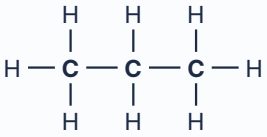
alkanes: single bonds only (saturated), general formula C_nH_{2n+2}



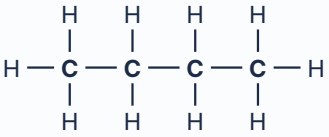
methane CH_4



ethane C_2H_6



propane C_3H_8

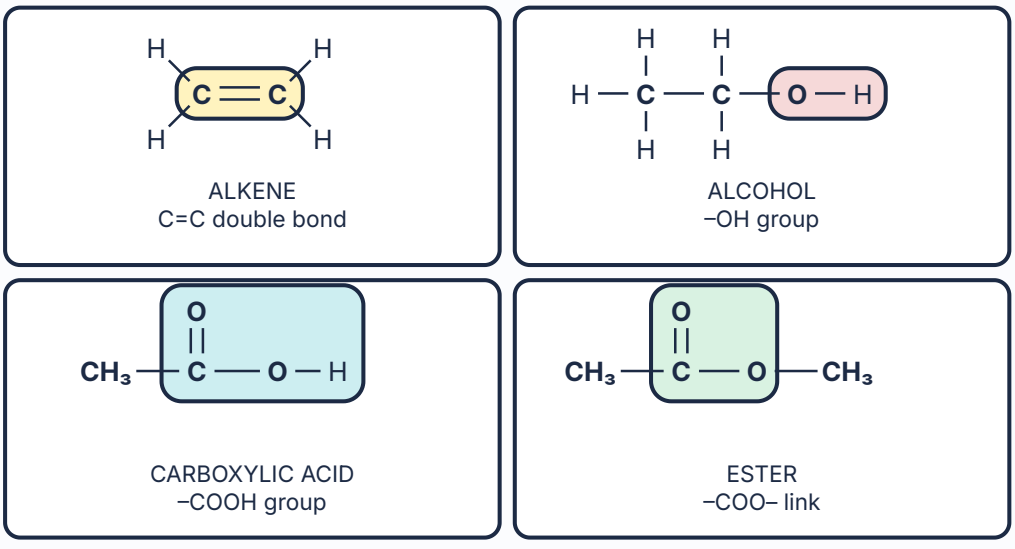


butane C_4H_{10}

each carbon forms 4 bonds · each hydrogen forms 1 bond

The first four alkanes. Each carbon forms four bonds and each hydrogen forms one. These are displayed formulae — every atom and bond is drawn.

Series	Functional group	General formula	First member
alkanes	C–C single bonds only	C_nH_{2n+2}	methane CH_4
alkenes	C=C double bond	C_nH_{2n}	ethene C_2H_4
alcohols	–OH	$C_nH_{2n+1}OH$	methanol CH_3OH
carboxylic acids	–COOH	$C_nH_{2n+1}COOH$	methanoic acid HCOOH



The functional groups on a displayed formula: the C=C of an alkene, the –OH of an alcohol, the –COOH of a carboxylic acid and the –COO– link of an ester.

- A **displayed formula** shows **every atom and every bond**. A **structural formula** groups the atoms: ethanol is CH_3CH_2OH. A **molecular formula** just gives the totals: C_2H_6O.

WORKED EXAMPLE

What is the formula of the alkane with 6 carbon atoms, and the alkene with 5 carbon atoms?

1. alkane C_nH_{2n+2} with n = 6: C_6H_{14}
2. **alkene C_nH_{2n} with n = 5: C_5H_{10}**

WORKED EXAMPLE

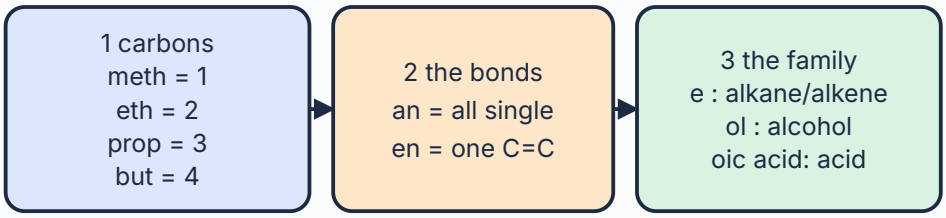
What type of compound is each: C_3H_8, C_3H_6, C_2H_5OH?

1. C_3H_8 fits C_nH_{2n+2} → **alkane** (propane)
2. C_3H_6 fits C_nH_{2n} → **alkene** (propene)
3. **C_2H_5OH contains –OH → alcohol (ethanol)**

Naming organic compounds

EXTENDED

how organic names are built



eth + an + e = ethane
prop + en + e = propene
but + an + ol = butanol
eth + an + oic acid = ethanoic acid

esters: alcohol part first, then acid part:
ethyl ethanoate = made from ethanol + ethanoic acid

Building a name: carbon count + bond type + family. Esters are named alcohol part first, then acid part.

- **Stem** (number of carbons): meth = 1, eth = 2, prop = 3, but = 4.
- **Ending:** **-ane** (alkane), **-ene** (alkene), **-ol** (alcohol), **-oic acid** (carboxylic acid).
- Examples: eth + an + e = **ethane**; prop + en + e = **propene**; but + an + ol = **butanol**; eth + an + oic acid = **ethanoic acid**.
- **Esters** are named alcohol part first, then the acid: ethanol + ethanoic acid → **ethyl ethanoate**.

COMMON MISTAKE

Calling CH_3COOH "ethanol". The –COOH group makes it an **acid**: ethanoic acid. Ethanol is C_2H_5OH.

Structural isomers

EXTENDED

two different molecules with the same formula, C_4H_{10}



butane
(straight chain)

2-methylpropane
(branched chain)

isomers: same molecular formula, different structural formula
they have different physical properties (e.g. boiling point)

molecular formula: how many atoms · structural formula: how they are joined

Two isomers of C_4H_{10}: butane (a straight chain) and 2-methylpropane (a branched chain). Same molecular formula, different structure.

Structural isomers — compounds with the **same molecular formula** but **different structural formulae**.

- Isomers have **different physical properties**, such as boiling points. Branched isomers usually boil at a lower temperature.

EXAM TIP

Draw isomers by changing the **carbon skeleton**. First draw the longest chain, then move carbons into branches. Check that each carbon still has **four bonds**.

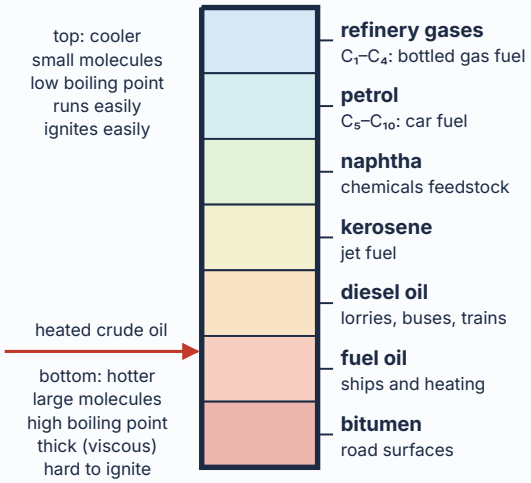
2 Fuels and crude oil

Fossil fuels

- **Fossil fuels** are coal, oil (petroleum) and natural gas. They formed over millions of years from the remains of dead organisms. They are **non-renewable**.
- **Natural gas** is mostly **methane (CH_4)**. **Petroleum (crude oil)** is a **mixture of hydrocarbons**.
- When a hydrocarbon burns completely: hydrocarbon + oxygen → carbon dioxide + water. **$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$**. See incomplete combustion for what happens if oxygen is limited.

Riyaz Sir

Fractional distillation



the fractions are separated because their boiling points are different

The fractionating column. Crude oil is heated and the vapours rise. Each fraction condenses at a different height, where the temperature falls below its boiling point.

- Crude oil is heated and the vapour enters a tall column that is **hot at the bottom and cool at the top**.
- Each fraction is a mixture of hydrocarbons with **similar boiling points**. Each one condenses and is collected where the temperature is just below its boiling point.

Fraction	Use
refinery gases (smallest molecules)	bottled gas for heating and cooking
petrol (gasoline)	fuel for cars
naphtha	chemicals feedstock (making plastics)
kerosene (paraffin)	jet fuel
diesel oil	lorries, buses and trains
fuel oil	ships and heating
bitumen (largest molecules)	road surfaces and roofing

- **Going down the column:** molecules get **bigger**, the **boiling point rises**, the liquid is **more viscous** (thicker), **less flammable** (harder to ignite) and darker.

PICTURE IT

Short-chain molecules are like marbles — they roll easily and escape as a gas. Long chains are like tangled spaghetti — thick, slow, and sticking together.

COMMON MISTAKE

Saying that crude oil is "boiled" in a chemical reaction. Fractional distillation is a **physical** separation. No new substances are made.

Riyaz Sir

3 Alkanes

Saturated and unreactive

- Alkanes have **only single bonds** — they are **saturated**. They are generally **unreactive**, apart from **combustion** and **reaction with chlorine**.
- **Combustion:** they burn well, so they are used as fuels.
- EXT **Substitution with chlorine:** in **UV light**, a hydrogen atom is replaced by a chlorine atom. **$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$** (chloromethane and hydrogen chloride).
- UV light supplies the energy to start the reaction — it is called a **photochemical** reaction.

WORKED EXAMPLE

EXT **Write the equation for the substitution of ethane by chlorine, making one product with a single chlorine.**

1. replace one H by Cl
2. **$C_2H_6 + Cl_2 \rightarrow C_2H_5Cl + HCl$ (chloroethane and hydrogen chloride)**

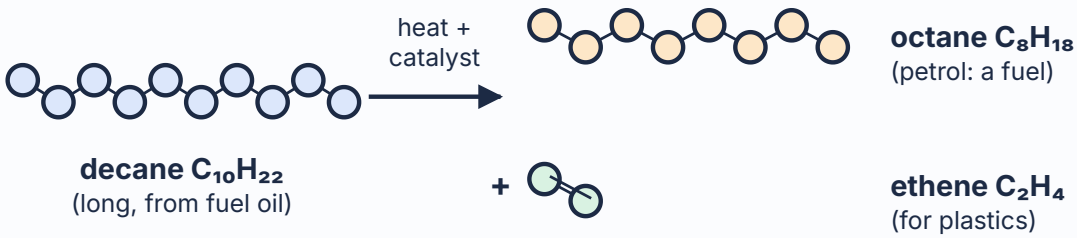
COMMON MISTAKE

Describing the chlorine reaction as "addition". It is **substitution** — two products are formed.

4 Alkenes

Cracking

cracking: breaking long alkane molecules into shorter ones



cracking needs a high temperature (about 600–700 °C) and a catalyst (such as aluminium oxide). Why? There is more demand for petrol and alkenes than for large alkanes.

$$C_{10}H_{22} \rightarrow C_8H_{18} + C_2H_4$$

Cracking breaks long alkane molecules into shorter ones. Decane is cracked into octane (for petrol) and ethene (for plastics).

Cracking — breaking down long-chain alkanes into shorter alkanes and alkenes using **heat and a catalyst**.

- **Conditions:** high temperature (about 600–700 °C) and a catalyst (aluminium oxide or silica).

- **Why:** there is **more demand for petrol** (shorter chains) than the crude oil can supply, and **alkenes** are needed to make **plastics** (polymers) and other chemicals.

$$C_{10}H_{22} \rightarrow C_8H_{18} + C_2H_4$$

decane → octane + ethene

WORKED EXAMPLE

Complete the cracking equation: $C_{15}H_{32}$ → C_8H_{18} + ?

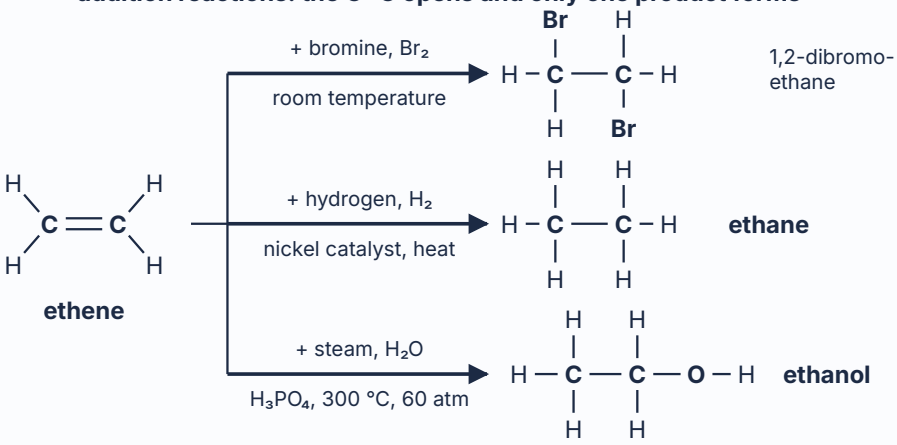
1. carbon atoms: 15 − 8 = 7
2. hydrogen atoms: 32 − 18 = 14
3. **the other product is C_7H_{14}, which fits C_nH_{2n}, so it is an alkene (heptene)**

- Every cracking reaction makes **at least one alkene**.

The alkene test and reactions

- **Alkenes** have a **C=C double bond** — they are **unsaturated**. This makes them much more reactive than alkanes.
- **Test for an alkene:** shake with **bromine water**. An alkene turns it from **orange-brown to colourless**. An alkane has no effect.

addition reactions: the C=C opens and only one product forms



test: alkenes turn orange-brown bromine water colourless; alkanes do not

Addition reactions of ethene. The double bond opens and the other molecule joins on, so only one product forms.

- EXT **Addition reaction:** the double bond opens and atoms add on. **Only one product** forms.

Reagent	Conditions	Product
bromine, Br_2	room temperature	1,2-dibromoethane
hydrogen, H_2	nickel catalyst, heat	ethane
steam, H_2O	phosphoric acid catalyst, 300 °C, 60–70 atm	ethanol

- EXT **$C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$; $C_2H_4 + H_2 \rightarrow C_2H_6$; $C_2H_4 + H_2O \rightarrow C_2H_5OH$.**

EXAM TIP

Alkene tests: "turns **orange-brown bromine water colourless**" — never "clear" and never "decolourises" without saying what it was before. The reason is the C=C double bond.

COMMON MISTAKE

Saying "the bromine water turns clear". Say **colourless**: it was coloured before.

Making ethanol

two ways to make ethanol

FERMENTATION	STEAM HYDRATION
glucose → ethanol + carbon dioxide	ethene + steam ⇌ ethanol
$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$	$C_2H_4 + H_2O \rightleftharpoons C_2H_5OH$
yeast, 25–35 °C, no oxygen	300 °C, 60–70 atm,
+ renewable (sugar crops)	phosphoric acid catalyst
+ low temperature, cheap equipment	+ fast, continuous, pure
– slow batch process	– uses non-renewable crude oil
– impure: needs distilling	– high temperature and pressure

uses: a solvent and a fuel (ethanol burns: $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$)

the fermentation mixture is about 15% ethanol; fractional distillation makes it purer

Two ways to make ethanol. Fermentation uses yeast and glucose. Steam hydration uses ethene from crude oil.

- **Fermentation:** glucose is broken down by **yeast** in **warm (25–35 °C), oxygen-free** conditions. **$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$**.
- **Hydration of ethene:** ethene reacts with steam, with a **phosphoric acid catalyst**, at 300 °C and 60–70 atm. **$C_2H_4 + H_2O \rightleftharpoons C_2H_5OH$**.

	Fermentation	Steam hydration
raw material	sugar (renewable)	ethene from crude oil (non-renewable)
conditions	low temperature	high temperature and pressure
speed	slow batch process	fast, continuous
purity	impure, needs distilling	pure

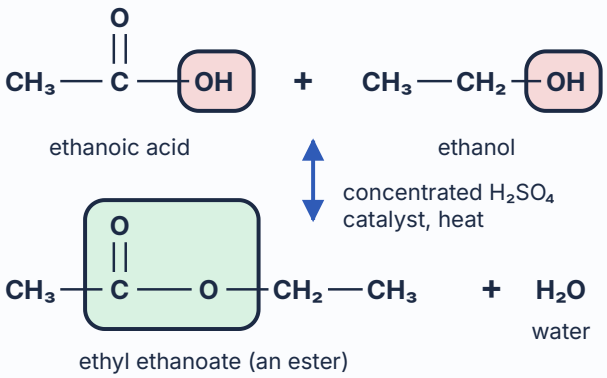
- **Uses of ethanol:** a **solvent** (perfumes, paints) and a **fuel**. $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$.

Ethanoic acid

- **Ethanoic acid (CH_3COOH)** is a **weak acid**. It reacts like other acids:
- with **metals**: $2CH_3COOH + Mg \rightarrow (CH_3COO)_2Mg + H_2$
- with **bases**: $CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$
- with **carbonates**: $2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COONa + H_2O + CO_2$
- The salts are called **ethanoates** (magnesium ethanoate, sodium ethanoate).
- EXT **Making it:** ethanol is **oxidised** to ethanoic acid by acidified potassium manganate(VII) (purple → colourless), or by **bacteria** in air (wine goes sour to make vinegar). $C_2H_5OH + O_2 \rightarrow CH_3COOH + H_2O$.

Esters

EXTENDED



–OH of the acid and –H of the alcohol leave as water

ethanoic acid + ethanol ⇌ ethyl ethanoate + water

esters smell sweet and fruity: used in flavourings and perfumes

Ethanoic acid + ethanol ⇌ ethyl ethanoate + water. The –OH of the acid and the –H of the alcohol leave as water.

- **Esterification:** carboxylic acid + alcohol ⇌ **ester + water**, using **concentrated sulfuric acid** as catalyst and heat.
- Esters smell **sweet and fruity**. They are used in **flavourings and perfumes**.

WORKED EXAMPLE

EXT **Name the ester made from propanol and ethanoic acid, and give the other product.**

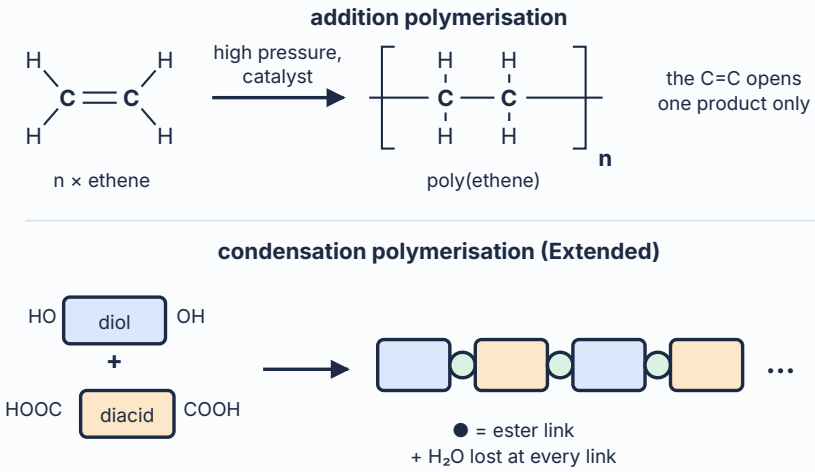
1. alcohol part first: propyl
2. acid part second: ethanoate
3. **propyl ethanoate**
4. **the other product is water**

6 Polymers

Long molecules from small ones

Polymer — a very large molecule made of many repeating units joined together. The small molecules that join are **monomers**.

Riyaz Sir



Top: addition polymerisation. Many ethene molecules join to make poly(ethene); the C=C opens. Bottom: condensation polymerisation (Extended). A small molecule, water, is lost at every link.

- **Addition polymerisation:** many **unsaturated** monomers (alkenes) join by opening their C=C bonds. **Only a polymer forms.**
- Example: n C_2H_4 → $-(CH_2-CH_2)_n-$ **poly(ethene)**. The repeat unit is $-CH_2-CH_2-$.
- EXT To find the repeat unit from a monomer: open the double bond and show a **bond going out of each end** (propene → $-CH_2-CH(CH_3)-$). To find the monomer from a polymer: take one repeat unit and **put the double bond back** between the two carbons in the chain.
- EXT **Condensation polymerisation:** monomers with **two functional groups** join and a small molecule (usually **water**) is lost at each link.

Polymer	Monomers	Link
polyester (PET)	a diol + a dicarboxylic acid	ester
nylon (a polyamide)	a diamine + a dicarboxylic acid	amide
protein (natural polyamide)	amino acids	amide

- EXT **PET can be recycled** by melting and reshaping, or by breaking it down chemically into monomers to make new PET.

Plastics and the environment

- Most plastics are **non-biodegradable** — they do not rot, so they stay in the environment for hundreds of years.
- **Landfill** fills up. **Litter** harms wildlife: animals get tangled or swallow plastic. Plastic in the sea breaks into **microplastics**.
- **Burning** plastics releases CO_2 (global warming), and some release toxic gases (for example HCl from PVC).
- **Solutions: reduce** use, **reuse**, **recycle** (sorting is needed), and develop **biodegradable** plastics.

COMMON MISTAKE

Writing that all plastics are made by addition polymerisation. Many (PET, nylon) are condensation polymers.

7 Test yourself

Test yourself — cover the answers first

QUICK CHECK

1. What is a homologous series?
2. What is the general formula of the alkanes?
3. What is the functional group of the alcohols?
4. What is the test for an alkene?
5. Name two uses of ethanol.
6. What is the repeat unit of poly(ethene)?
7. What does the fractional distillation of crude oil separate it into?
8. EXT What are structural isomers?

EXAM-STYLE

9. Describe how petrol is obtained from crude oil. Include fractional distillation. [4]
10. Explain why cracking is carried out in an oil refinery. [3]
11. Compare the two methods of making ethanol. [4]
12. EXT Draw the structures of the two isomers of C_4H_{10} and name them. [4]
13. EXT A student mixes ethanoic acid and ethanol with a few drops of concentrated sulfuric acid and warms them. Name the product and the smell. [2]

Show answers

1. a family of compounds with the same functional group and similar chemical properties, differing by CH_2
2. C_nH_{2n+2}
3. –OH
4. bromine water goes from orange-brown to colourless
5. solvent, fuel
6. $–CH_2–CH_2–$
7. fractions with different boiling points
8. same molecular formula, different structural formula
9. crude oil is heated and the vapour enters a fractionating column
   the column is hotter at the bottom and cooler at the top
   petrol condenses at its boiling point range, near the top
   it is collected as a liquid
10. there is a higher demand for shorter alkanes (petrol) than the supply
    large alkanes are cracked into shorter alkanes
    and alkenes, which are used to make plastics
11. fermentation: sugar, yeast, 25–35 °C, slow, impure, renewable
    steam hydration: ethene and steam, 300 °C and 60–70 atm, fast, pure, non-renewable
12. $CH_3CH_2CH_2CH_3$ (butane)
    $CH_3CH(CH_3)CH_3$ (2-methylpropane)
    each carbon has four bonds
    different structural formulae with the same molecular formula
13. ethyl ethanoate
    sweet fruity smell

Stuck on a question?

Send it to me on WhatsApp. I read every message.

Share with a friend

Ask Riyaz Sir

Want regular help? Send this to your parent →