# Chapter 15: Fuels and Crude Oil

## 15.1 - Importance of natural gas and crude oil in our lives

Methane and crude oil are non-renewable sources of energy

## 15.2 - Separation of crude oil/petroleum

Crude oil
Crude oil contains a mixture of hydrocarbons
Hydrocarbons are compounds containing carbon and hydrogen only

Separation of crude oil

| Name<br>(in order of fractions) | No. of carbon atoms | Boiling point/ °C | Uses |
|---|---|---|---|
| Liquefied petroleum gas (LPG) | 1-4 | 40< | Fuel for cooking |
| Petrol (gasoline) | 5-10 | 40-75 | Fuel in cars |
| Naphtha | 7-14 | 75-150 | Feedstock for the petrochemical industry |
| Kerosene (paraffin) | 11-16 | 160-250 | Fuel for heating and cooking<br>Fuel for aircraft engines |
| Diesel | 16-20 | 250-300 | Fuel for diesel engine |
| Lubricating oils | 20-50 | 300-350 | Lubricants<br>For polishes and waxes |
| Bitumen | >50 | >350 | Making road surfaces |

Mnemonic
**Love Pushing Naughty Kids Down Oversized Bags**

Process of separation
Fractional distillation:

- Crude oil is heated and turns into vapour, then enters the fractionating column
- As hot vapour rises up the column, it **cools and condenses at different temperatures**
- The fractions with the **lowest boiling point** condense at the **top**, then removed
- The fractions with the **highest boiling points** condense at the **bottom**

## 15.3 - Changes in properties for different fractions

As the size and mass of the hydrocarbons increase **down the fractions from LPG to Bitumen**:

Boiling point increase

When the size of molecules increases, intermolecular forces of attraction increase, and more energy is needed to overcome these forces

Viscosity increase

When the size of molecules increases, intermolecular forces of attraction increase, the forces are harder to overcome, and the larger hydrocarbons do not flow easily

Flammability decreases

When the size of the hydrocarbon increases, the *percentage* of mass of hydrogen in the molecule decreases, and hydrogen is flammable

**Competing uses of crude oil**

- It is non-renewable
- To meet the competing uses of crude oil, there is a growing need for its conservation
- Thus, use alternatives like solar energy, biofuels

## Biofuels

Bioethanol is obtained by fermentation of sugar in sugarcane to ethanol
(seen in 17.1)

*Ethanol* + *Oxygen* → $CO_2$ + *Water*

Better for the environment because it offsets the carbon dioxide emission during burning by absorbing carbon dioxide during plant growth

# Chapter 16/17: Alkanes and Alkenes, Alcohols and Carboxylic Acids

## 16.1 - Organic chemistry

Organic compounds are a class of chemical compounds in which one or more atoms are covalently bonded to atoms of other elements

Homologous series

- A general formula
- Similar chemical properties due to the same functional group
- A gradual change in physical properties as a result of the increase in size/mass of the molecules
- Successive members differ by – $CH_2$

A functional group is a combination of atoms which gives organic compounds their distinctive properties

As the size and mass of the organic molecule increase:
- Melting and boiling point increases
- Viscosity increase
- Flammability decrease

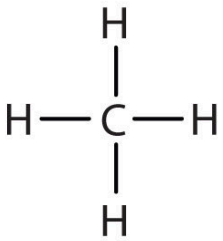
Prefixes and suffixes

| Prefix | No. of carbon atoms | Suffix | Homologous series |
|---|---|---|---|
| Meth- | 1 | -ane | Alkane |
| Eth- | 2 | -ene | Alkene |
| Pro- | 3 | -anol | Alcohol |
| But- | 4 | -anoic acid | Carboxylic acid |

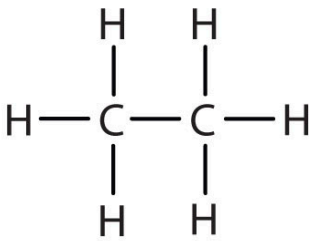
## 16.2 - Alkanes

Alkanes
- A homologous series
- Functional group: Has saturated hydrocarbons (carbon-carbon single bonds only)
- General formula: $C_n H_{2n+2}$

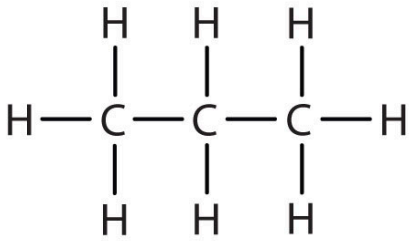
**Physical Properties**
- Gas at RTP



Methane



Ethane



Propane

**Chemical properties**
Alkanes are generally unreactive
Alkane undergo 2 reactions
- Combustion
- Substitution by chlorine

Combustion

- Complete combustion

Alkanes burn in excess/sufficient air with a blue (non-luminous) flame

The products are **carbon dioxide and water**

Methane + oxygen → carbon dioxide + water
$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O$**(g)**

- Incomplete combustion

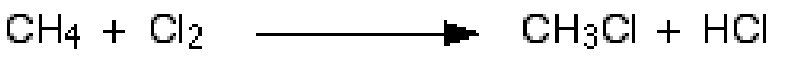
Alkanes burn in limited amount of air with a yellow smoky (luminous) flame
Possible products are **carbon (soot), carbon monoxide and water**

Methane + oxygen → carbon monoxide + water
$2CH_4(g) + 3O_2(g) \rightarrow 2CO(g) + 4H_2O(g)$

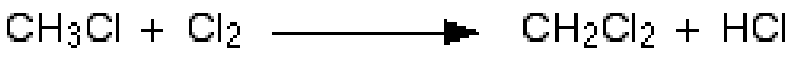
Methane + oxygen → carbon + water
$CH_4(g) + O_2(g) \rightarrow C(g) + 2H_2O(g)$

Substitution by chlorine

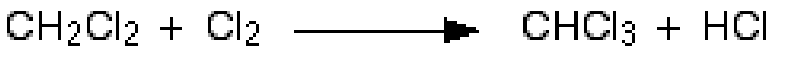
The reaction takes place in the **presence of sunlight (UV light) as the catalyst.**
Each hydrogen in the alkane is replaced one at a time by one molecule of chlorine to form **chloroalkanes**
Substitution is a random process where any hydrogen has an equal chance of being replaced by chlorine
Example:



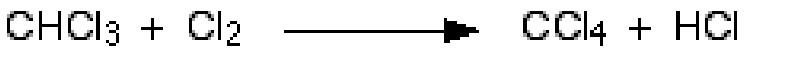

chloromethane




dichloromethane




trichloromethane




tetrachloromethane

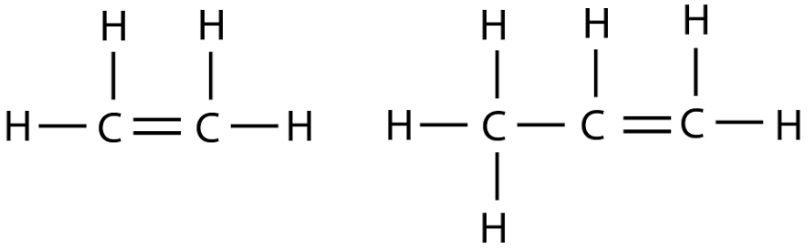
During a substitution reaction, the mixture will contain all the above substances – $CH_4$, $CH_3Cl$, $CH_2Cl_2$, $CHCl_3$, $CCl_4$, and $Cl_2$, HCl at the same time

**Preparation**
Alkanes are obtained directly from the fractional distillation of crude oil

## 16.3 - Alkenes

Alkenes
- A homologous series
- Functional group: Has unsaturated hydrocarbons (contain carbon-carbon double bonds)
- General formula: $C_n H_{2n}$

**Physical Properties**
- Gas at RTP



Ethene Propene

**Chemical properties**
In a carbon-carbon double bond, each carbon atom is only covalently bonded to 3 atoms
Meaning a new atom can be added to it
Thus, alkenes are reactive since they are unsaturated

Alkenes undergo 3 reactions
- Combustion
- Hydrogenation
- Bromination
- Addition polymerisation

Combustion

- Complete combustion

Alkenes burn in excess oxygen

Methane + oxygen → carbon dioxide + water

$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(g)$

- Incomplete combustion

Alkanes burn in limited amount of oxygen

Possible products are carbon (soot), carbon monoxide and water

ethene + oxygen → carbon monoxide + water

$2C_2H_4(g) + 3O_2(g) \rightarrow 2CO(g) + 4H_2O(g)$

Methane + oxygen → carbon + water

$CH_4(g) + O_2(g) \rightarrow C(g) + 2H_2O(g)$

Hydrogenation

Alkene + Hydrogen → Alkane

Conditions: 200°C, nickel catalyst

Bromination

Alkene + Bromine

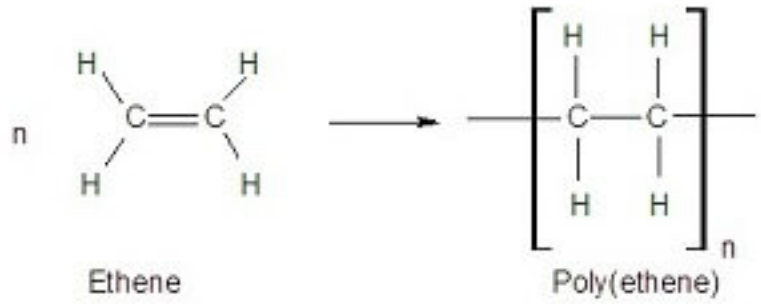
$C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$

Test for unsaturated hydrocarbons

Addition polymerisation

Monomers react with one another to form long molecules called polymers

Conditions: High temperature and pressure, catalyst




**Preparation of alkene through Cracking**

Large alkane → smaller alkane + alkene

Or

Large alkane → alkene + Hydrogen

Used to produce alkene, hydrogen, small alkane molecules which are essential to **match the demand for fractions containing smaller molecules**
Conditions: High temperature (600°C), solid catalyst (aluminium oxide, silicon (IV) oxide)

### 16.4 - Fats and oils

Polyunsaturated fats contain a lot of carbon-carbon double bonds
Such as vegetable oil

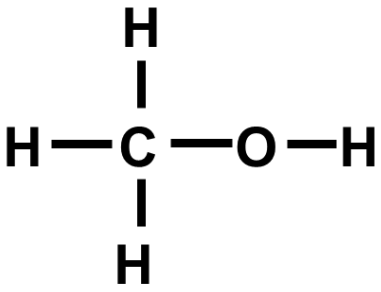
Hydrogenating polyunsaturated fats **causes it to be solid, which is easier to store**

Vegetable oil + $H_2$ → Margarine

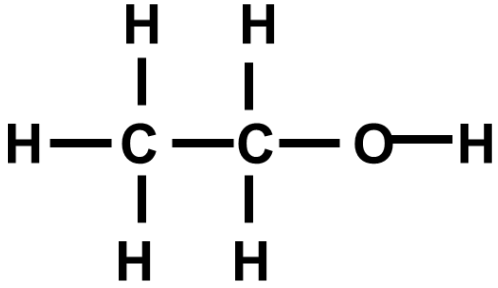
## 17.1 - Alcohols

Not a hydrocarbon
Alcohols

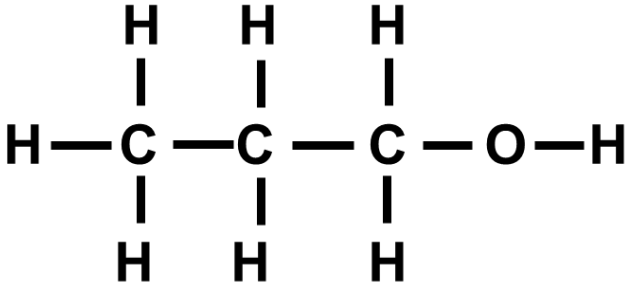
- A homologous series
- Functional group called hydroxyl, -O-H
- General formula: $C_n H_{2n+1}OH$



**Methanol ($CH_3OH$)**



**ETHANOL ($C_2H_5OH$)**



**PROPANOL ($C_3H_7OH$)**

**Physical Properties**

- Soluble in water
- Liquid at RTP

As size and mass of alcohol molecule increase:

- Solubility in water decreases

**Chemical properties**

Undergoes 2 reactions

- Combustion
- Oxidation of alcohol to carboxylic acid

Combustion

- (refer to the top, the reaction is the same as other combustion processes)

Oxidation

Alcohol + oxygen from oxidising agent → carboxylic acid + water

$C_2H_5OH + 2[O] \rightarrow CH_3COOH + H_2O$

Alcohol loses 2 hydrogen atoms and gains 1 oxygen atom

Oxygen can come from:

- atmospheric oxygen
- acidified potassium manganate(VII)

**Preparation of alcohol**

Fermentation of glucose

Glucose → ethanol + $CO_2$

$C_6H_{12}O_6 \rightarrow C_2H_5OH + CO_2$

Conditions: yeast, 37°C(room temp.), airtight environment

Oxygen can oxidise the alcohol into an carboxylic acid

Temperature too high will cause enzyme in the yeast to denature
Temperature too low will cause enzyme in the yeast to be inactive

Fermentation process produces low concentration of ethanol
When the concentration is too high, it will kill the yeast

Fractional distillation is then used to separate the alcohol

Addition of steam
Alkene + water (g) → alcohol

Conditions: 300°C, phosphoric acid, 60 atm

## 17.2 - Carboxylic acid

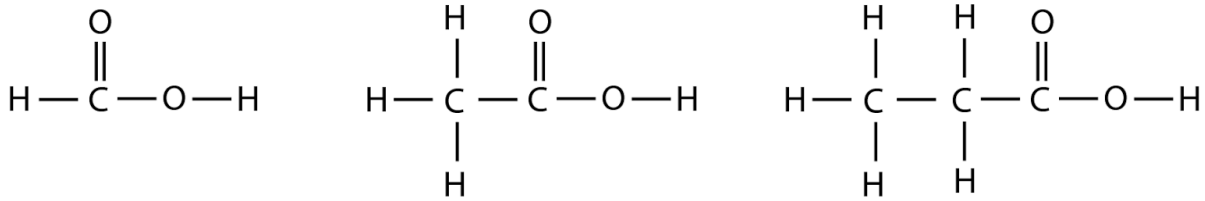
Not hydrocarbons
Carboxylic acid

- Homologous series
- Functional group called carboxyl, -COOH
- General formula: $C_nH_{2n+1}COOH$

**Physical Properties**

- Dissociates in water into $C_nH_{2n+1}COO^-$ and $H^+$ ions
- Liquid at RTP

They are acids so they share the same properties as acids



Methanoic acid | Ethanoic acid | Propanoic acid

## Summary

Alkane undergoes:

- Combustion
- **Substitution by chlorine**

presence of sunlight (UV light) as the catalyst.

- Preparation of alkene through **Cracking**

Conditions: High temperature (600°C), solid catalyst (aluminium oxide, silicon (IV) oxide)

Alkene undergoes:

- Combustion
- **Hydrogenation**

Conditions: High temperature (200°C), nickel catalyst

- **Bromination**
- **Addition polymerisation**

Conditions: High temperature and pressure, catalyst

Alcohol undergoes:

- Combustion
- **Oxidation of alcohol** to carboxylic acid

Conditions: Oxygen from the atmosphere or through $KMnO_4$

Prepared through:

- **Fermentation of glucose**

Conditions: yeast, Room temperature (37°C), airtight environment

- **Addition of steam**

Conditions: High temperature (300°C) and pressure (60 atm), phosphoric acid

****The specific temperatures and pressure values are not required according to syllabus**

# Chapter 18: Polymers

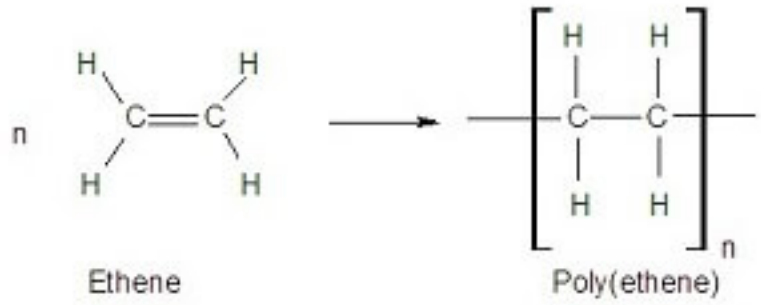
Polymers are many monomers covalently bonded together

## Addition polymerisation

Monomers react with one another

Conditions: High temperature and pressure, catalyst

Drawing monomers from polymers




Application of Polyethene as a typical plastic

- Make plastic bags, bottles
- Make Plastic wrap

## Effects of plastic disposal on the environment

Air pollution
- Produces poisonous gas when burnt, like carbon monoxide

Land pollution
- **Non-biodegradable**, so **more landfills** are required to store them

Water pollution
- Endangers marine animals who mistake them as food

## Recycling plastics (mostly general knowledge)

<u>Pre-treatment:</u>

- Sorted
- Washed
- Shredded

<u>Physical method:</u>
After pre-treatment, small pieces of polyethylene are melted, cooled, and pulled into long thin strands and cut into pellets, and made into new products

<u>Chemical method:</u>
- Plastic waste can undergo cracking to form short chains alkanes and alkenes

<u>Issues to recycling plastics</u>
Environmental
- Waste water generated must be tested before released into water bodies

Economic,
- It is expensive, so it is unprofitable to recycle plastics

Social
- Recyclable plastics disposed cannot be recycled as they may be contaminated with leftover food
- Non-recyclable materials gets thrown into the recycling bin
- Communities are unwilling to adopt recycling