Organic Chemistry

Organic compounds:

The branch of chemistry which deals with the study of carbon compounds is called organic chemistry.

Catenation:

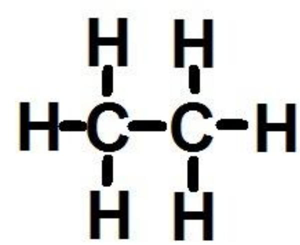
The carbon atom has a property to undergo self linking by covalent bonds to form long chains, branching rings and networks of carbon atoms.

Hydrocarbons:

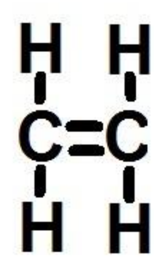
They are organic compounds in which the carbon atoms are covalently bounded to hydrogen atoms only. There are three types of hydrocarbons:

- Alkanes
- Alkenes
- Alkynes

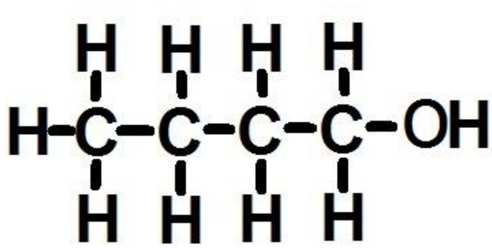
Alkanes are hydrocarbons in which the carbon atoms are joined by single covalent bonds.



Alkenes are hydrocarbons in which the carbon atoms are joined by double covalent bonds.

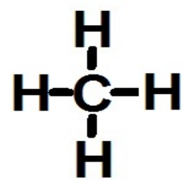
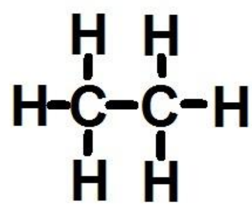
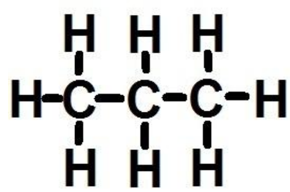
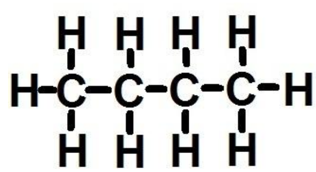
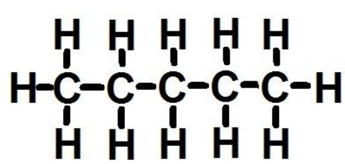


Alcohols are hydrocarbons with the functional group –OH.



Alkanes

Alkanes have a general formula of C_nH_{2n+2}

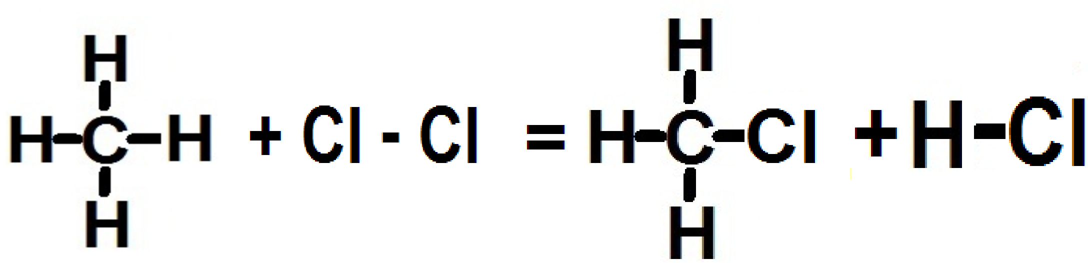
General Formula	Molecular Formula	Structural Formula	Name	State
n=1	CH_4		Methane	Gas
n=2	C_2H_6		Ethane	Gas
n=3	C_3H_8		Propane	Gas
n=4	C_4H_{10}		Butane	Gas
n=5	C_5H_{12}		Pentane	Liquid

Most alkanes are obtained from the fractional distillation of crude oil. The first members are used as fuel.

As the molecular mass of alkanes increases their boiling points also increase. They are less volatile, harder to ignite, denser and thicker than the upper members of the alkane group.

Reactions of the Alkane group:

- Combustion (used as fuels)
  - Complete combustion:
    Burning in the presence of sufficient supply of oxygen is called complete combustion. Hydrocarbons on complete combustion produce carbon dioxide and water.
    E.g. Methane + Oxygen = Carbon Dioxide + Water
    $CH_{4(g)} + 2O_{2(g)} = 2CO_{2(g)} + 2H_2O_{(g)}$
  - Incomplete combustion:
    Burning in the presence of insufficient supply of oxygen gas is called in complete combustion. Hydrocarbons on incomplete combustion produce Carbon Monoxide and Water.
    E.g. Methane + Oxygen = Carbon Monoxide + Water
    $2CH_{4(g)} + 3O_{2(g)} = 2CO_{(g)} + 4H_2O_{(g)}$
- Substitution
  Alkanes undergo substitution reactions with halogens, with diffused light.
  e.g. Methane + Chlorine = Chloromethane + Hydrochloric acid



This reaction can keep on happening until all the hydrogen atoms in the hydrocarbons have been replaced by a halogen (group 7 elements).

The products of substitution reactions involving alkanes and halogens are called halogenoalkanes.

Alkanes functional group (the part of the molecule in which reactions happen) is the C-H bond.

Branched alkanes:

When the alkane is not just a simple straight chain of carbon atoms joined together the names become a little more complex.

The longest connected chain of carbon atoms must be found as before and the alkane name generated as usual.

Then the name for the pendent group is found, again by counting the number of carbon atoms present, and used as a prefix.

CH_3- group : *methyl*___

CH_3CH_2- group : *ethyl*___

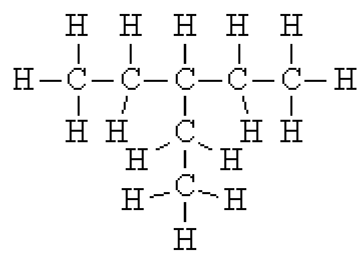
$CH_3CH_2CH_2$- group : *propyl*___

$CH_3CH_2CH_2CH_2$- group : *butyl*___

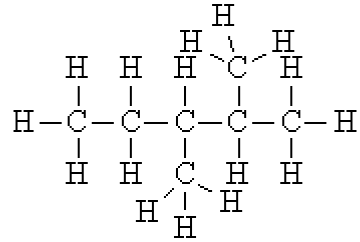
The numbers used to indicate the positions of the pendent groups must be the lowest numbers possible, so always check them from both ends of the molecule.

Example -

3-ethylpentane :

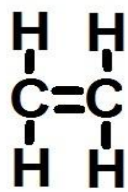
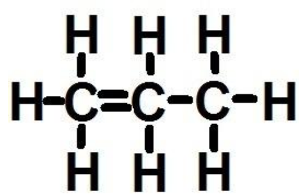
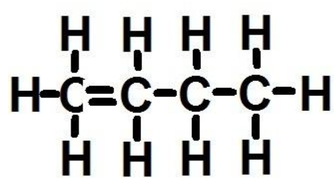
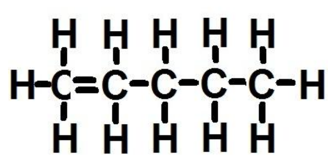


2,3- methyl pentane :



Alkenes

These are unsaturated hydrocarbons (having the C=C double bond), with the functional group C=C.

General Formula	Molecular Formula	Structural Formula	Name	State
n=2	C_2H_4		Ethene	Gas
n=3	C_3H_6		Prop-1-ene	Gas
n=4	C_4H_8		But-1-ene	Gas
n=5	C_5H_{10}		Pent-1-ene	Liquid

Alkenes have the general formula = C_nH_{2n}

In the alkene group methene does not exist because a C double bond C can't exist.

<u>Reactions of alkenes:</u>

a) Combustion

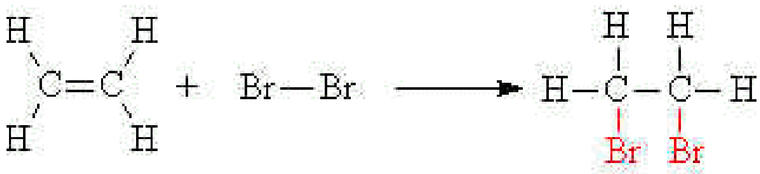
They form CO_2 and water in an excess oxygen supply, and CO and water in a limited supply of oxygen. These show greater tendency to undergo incomplete combustion to form CO and water. They are not used as fuels because the double bond makes them chemically reactive and can therefore, are used to make plastics and solvents. They burn with a yellow smoky flame.

b) Addition reactions of alkenes:

(*i*) Addition of bromine -

The double bond of an alkene will undergo an ***addition reaction*** with aqueous bromine to give a di-bromo compound. The **orange** bromine water is **decolourised** in the process.

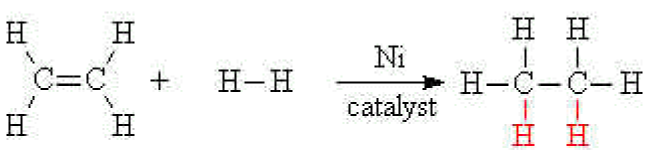
e.g. ethene reacts with bromine water to give 1,2-dibromoethane,



(*ii*) Addition of hydrogen -

Alkenes may be turned into alkanes by reacting the alkene with hydrogen gas at a high temperature and high pressure. A nickel catalyst is also needed to accomplish this addition reaction.

e.g. ethene reacts with hydrogen to give ethane,

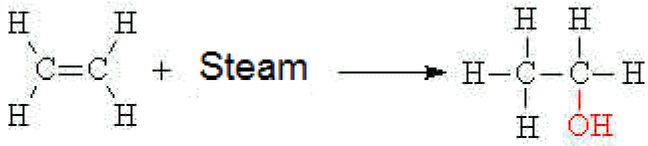


This reaction is also called ***saturation*** of the double bond. In ethene the carbon atoms are said to be ***unsaturated***. In ethane the carbon atoms have the maximum number of hydrogen atoms bonded to them, and are said to be ***saturated***.

(*iii*) Addition of steam -

Water adds to alkenes across the double bond to form alcohols with the same number of carbon atoms.

e.g. ethene reacts with steam to give ethanol

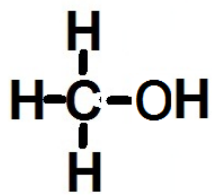
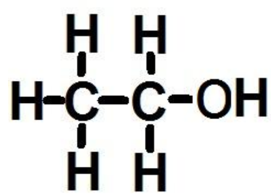
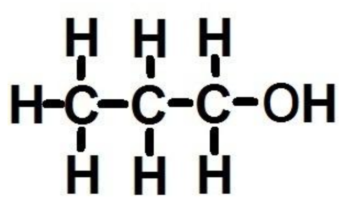
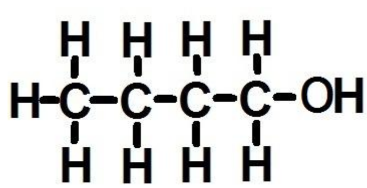


Alcohols:

They are alkanes in which one H atom has been replaced by a –OH group.

They have the –OH functional group (hydroxyl).

General formula - $C_nH_{2n+1}OH$

General Formula	Molecular Formula	Structural Formula	Name	State
n=1	CH_3OH		Methanol	Liquid
n=2	C_2H_5OH		Ethanol	Liquid
n=3	C_3H_7OH		Propanol	Liquid
n=4	C_4H_9OH		Butanol	Liquid

Reactions of alcohols:

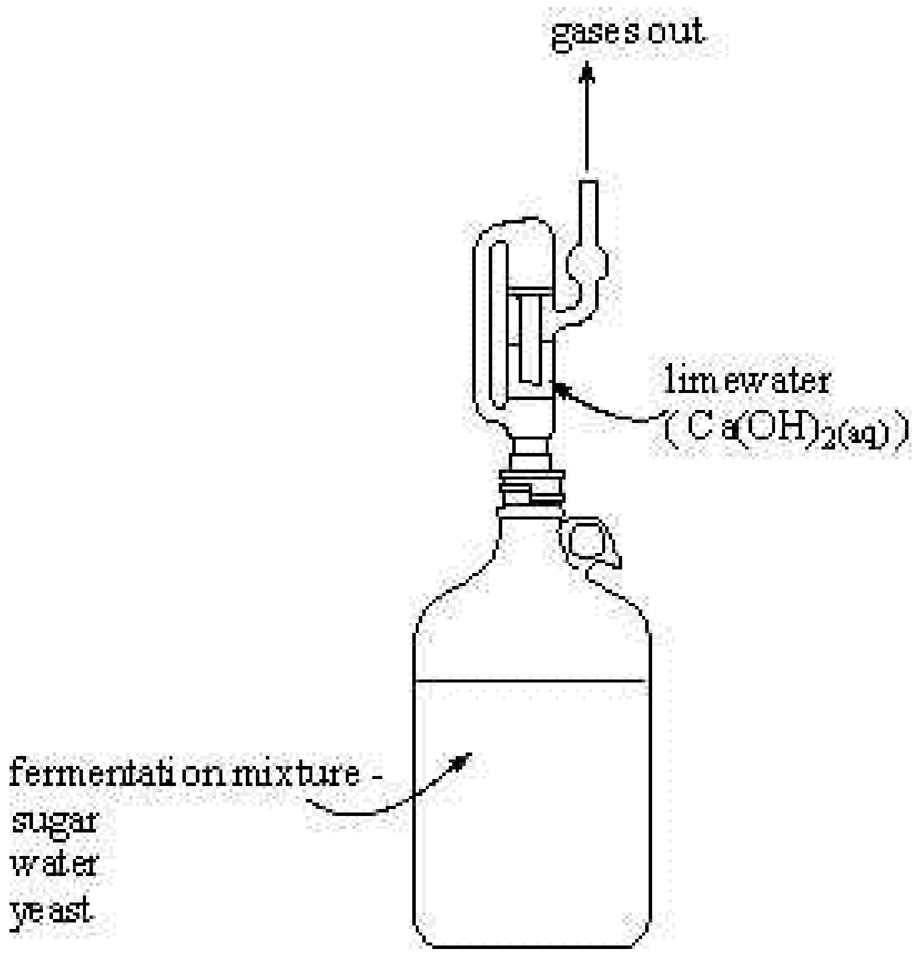
(i) Preparation of ethanol by fermentation -

Ethanol is prepared in the laboratory and in the alcoholic drinks industry, by the process of ***fermentation***. This involves the use of an ***enzyme*** (***yeast***) that changes a ***carbohydrate***, ***e.g.*** sucrose, into ethanol and carbon dioxide gas,

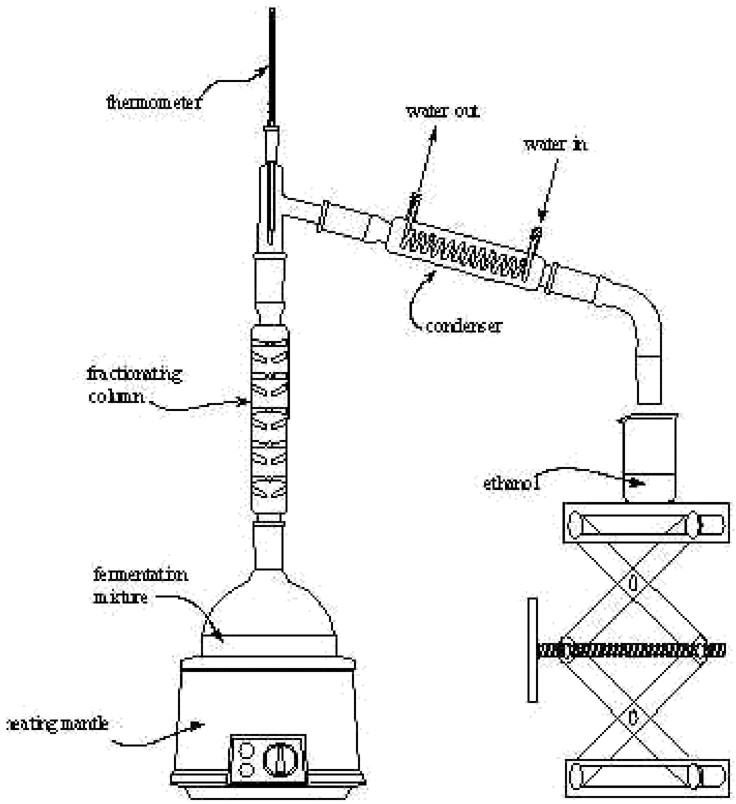
$$C_6H_{12}O_{6(aq)} \longrightarrow 2CH_3CH_2OH_{(aq)} + 2CO_{2(g)}$$

The yeast used requires a certain temperature to be active - somewhere between 15 and 37 °C. Too high a temperature and the yeast "dies" and too low a temperature causes the yeast to become dormant.

The production of carbon dioxide gas can be monitored by bubbling any gases produced during the reaction through limewater (calcium hydroxide$_{(aq)}$). The formation of a white precipitate (calcium carbonate) in the limewater shows that carbon dioxide has been given off.



To obtain pure ethanol from the fermentation mixture, the process of fractional distillation must be carried out on the resulting solution. The equipment is shown below,



In a process similar to that of crude oil, the ethanol/water mixture can be separated by fractional distillation because of the difference in boiling points.

Ethanol boils at 79 °C and water boils at 100 °C, so that ethanol boils first and therefore comes over through the condenser first. The fractionating column allows the vapours to condense and drop back down into the round-bottom flask, stopping water vapour from passing through into the condenser

(ii) Dehydration of ethanol -

All alcohols contain hydrogen and oxygen (as well as carbon) and these atoms can be removed from an alcohol as a molecule of water (H_2O). This type of reaction is called ***dehydration***. It can be accomplished by passing alcohol vapour over a heated ***aluminium oxide*** catalyst.

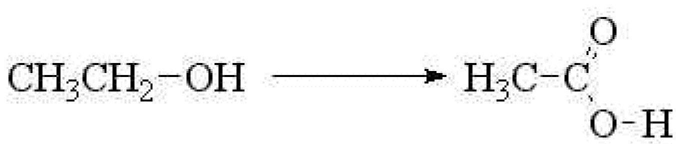
e.g. ethanol can be turned into ethene,

$CH_3CH_2OH_{(g)} \longrightarrow CH_2{=}CH_{2(g)} + H_2O_{(g)}$

(iii) Oxidation of ethanol –

Oxidation can be defined as the ***addition of oxygen*** to a substance. This can be accomplished with alcohols by the use of acidified potassium dichromate (VI) $_{(aq)}$. This turns the alcohol into a carboxylic acid.

e.g. ethanol can be turned into ethanoic acid,

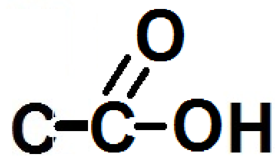
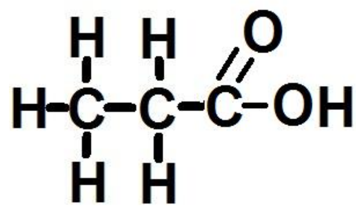
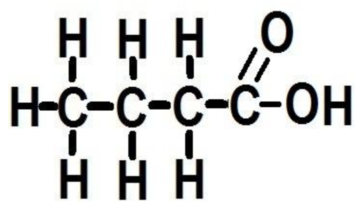
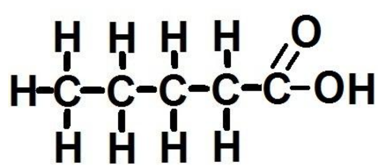


Uses of Ethanol:

- Used as a solvent
- Used as a fuel in some cars
- Used to make alcoholic drinks
- Camping stoves
- To make organic chemicals such as esters

Carboxylic Acids

These have the functional group –COOH and the general formula $C_nH_{2n+1}COOH$

General Formula	Molecular Formula	Structural Formula	Name	State
n=1	HCOOH		Methanoic Acid	Liquid
n=2	CH_3COOH		Ethanoic Acid	Liquid
n=3	C_2H_5COOH		Propanoic Acid	Liquid
n=4	C_4H_9OH		Butanoic Acid	Liquid

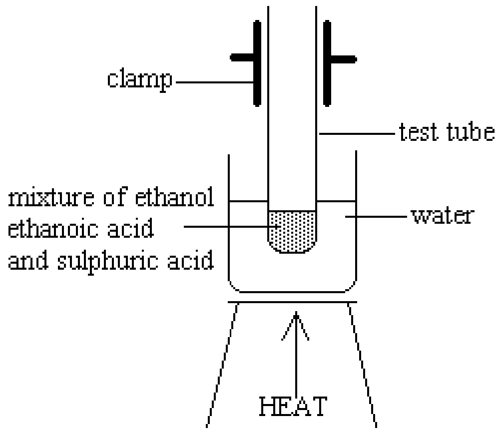
Carboxylic Acids reactions:

1) Esterification

The Esterification of Ethanol to Ethyl Ethanoate

Apart from the normal reactions of acids, such as reactions with metals and bases, ethanoic acid (along with all the carboxylic acids) will react with ethanol (or other alcohols) to give ethyl ethanoate (an ***ester***) in a simple process.

Diagram -



Method

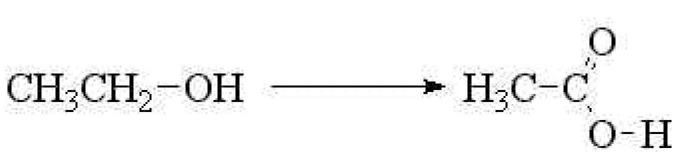
Set up a boiling tube in a beaker of cold water as in the diagram above. Add about a few cm's depth of ethanol followed by another cm of ethanoic acid from a bottle. Then ***carefully*** add a few drops of concentrated sulphuric acid (***CARE: very dangerous***) to the boiling tube. Add an anti-bumping granule or two, and heat up the water bath until the reaction mixture in the boiling tube starts to boil gently. Keep the reaction boiling gently for about 15 minute. Then raise the boiling tube out of the water bath and leave to cool.

Carefully add some sodium or calcium carbonate to the boiling tube until no more fizzing is produced. Filter the solution and carefully smell the clear liquid remaining.

Note down all your observations during this reaction.

Carboxylic acids will react with alcohols to produce organic compounds called ***esters***.

e.g. ethanoic acid and ethanol will produce ethyl ethanoate,



Some ***concentrated sulphuric acid*** is added to act as a catalyst for the reaction. It removes the water produced in the reaction, thus helping the reaction to produce more products.

Esters are used as flavourings and perfumes in all sorts of materials.

Preparation of ethanoic acid:

1) By the oxidation of ethanol in fermented solution with atmospheric oxygen in the presence of certain bacteria.
   This is why wine smells like vinegar when it's exposed to air. The ethanol is oxidized into ethanoic acid.
2) By heating ethanol with an oxidation agent such as acidified potassium dichromate (VI) $K_2Cr_2O_7$.
   In the reaction, potassium dichromate which is orange is reduced, so the colour changes from orange to green.
   $C_2H_5OH + K_2Cr_2O_7 = CH_3\text{-}COOH + H_2O$

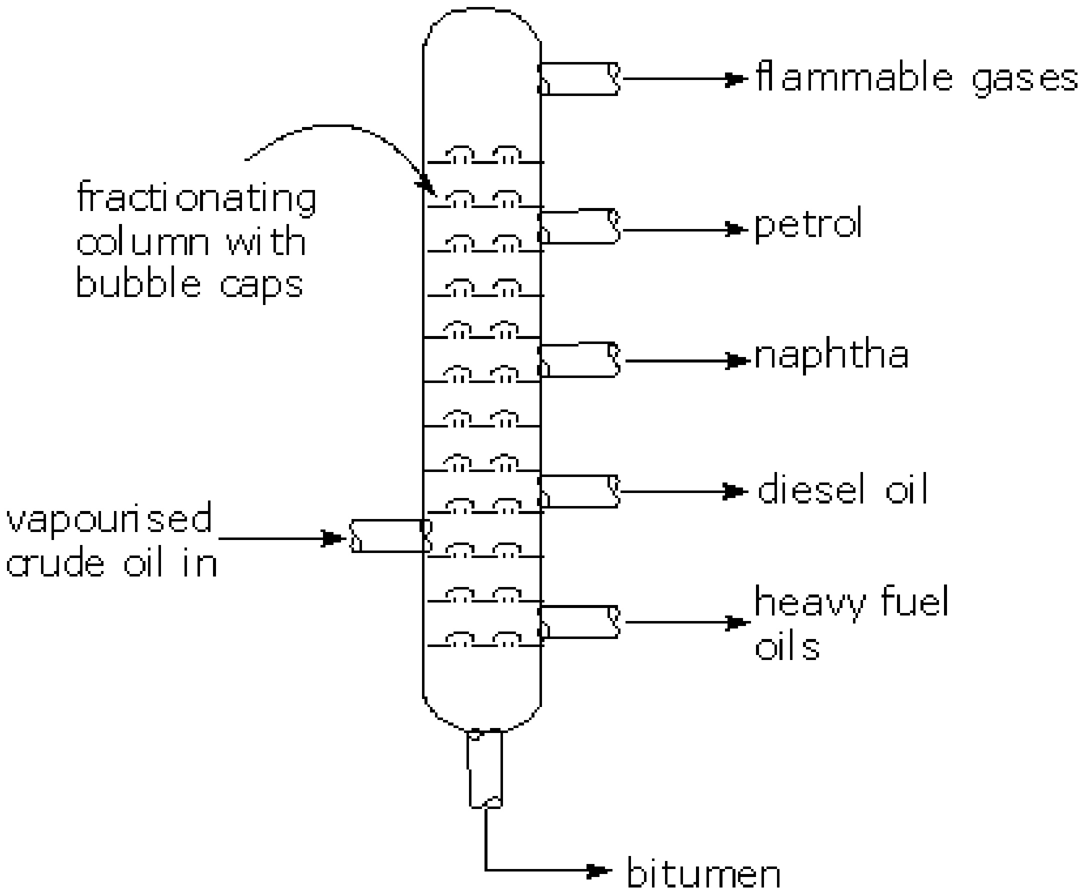
Properties of ethanoic acid:

1) It is a weak acid, as only one percent of the ethanoic acid is ionized.
2) Does all the reactions just like other mineral acids but more slowly.
3) Reaction with alcohols to form sweet smelling liquids called esters and water.

Crude oil:

Fractional distillation -

Crude oil is a mixture of many different hydrocarbon compounds, some of them liquid and some of them gases. These compounds can be separated because the different length of alkanes will have different boiling points. The crude oil is heated up to about 350 ^{o}C and is fed into a fractionating column, as in the diagram below,



The vapours with the lowest boiling points pass all the way up the column and come off as ***gases***, ***e.g.*** methane, ethane and propane. The temperature of the column gradually decreases the higher up the vapours go, and so various fractions will condense to liquids at different heights.
The fractions with the highest boiling points do not vaporize and are collected at the bottom of the fractionating column, e.g. bitumen

Here is a table with some boiling points for the commonest fractions:

Fraction name	***Boiling point (^oC)***
Refinery gases	-5 to 2
Gasoline	40
Naphtha	110
Kerosene	180

Diesel oil	260
Fuel oil	300
Bitumen	340

Cracking:

Alkenes are made by cracking of large alkanes. Larger alkane molecules which are obtained by fractional distillation of crude oil are passed over heated catalyst of Silicone (VI) Oxide, and aluminium oxide. This gives more useful fractions that can be used for other reactions or used as fuels.

The products are a shorter alkane and an alkene

$C_{10}H_{22} \longrightarrow C_8H_{18} + C_2H_4$ (Dectane = Octane + Ethene)

OR

Two alkene molecules and hydrogen

$C_{10}H_{22} \longrightarrow C_7H_{14} + C_3H_6 + H_2$ (Alkane = Alkene + Alkene + Hydrogen)

Uses of Cracking:

- To make alkenes
- To obtain hydrogen
- Gasoline from higher fractions since there are higher demands for gasoline than that for kerosene.